
**Thermal spraying — Qualification
testing of thermal sprayers**

*Projection thermique — Qualification des agents en projection
thermique*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

This second edition cancels and replaces the first edition (ISO 14918:1998), which has been technically revised.

Introduction

This document examines the principles of qualification testing of sprayer performance for thermal spraying.

The quality of work involved in thermal spraying depends on the skill, operation of the spray equipment and job knowledge of the thermal sprayer.

The ability of the thermal sprayer to follow verbal and written instructions and the testing of his/her skill and operation of the spray equipment are therefore important factors in ensuring the quality of the thermally sprayed product.

This document is intended to provide the basis for mutual recognition by examining bodies for qualification relating to thermal sprayer's competence in the various fields of application. Tests can be carried out in accordance with this document, unless more severe tests are specified by the relevant application standards in which case these can be applied.

The thermal sprayer's skill and job knowledge continues to be classified as qualified as long as the thermal sprayer works with reasonable continuity on thermal spraying work within the extent of qualification.

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Thermal spraying — Qualification testing of thermal sprayers

1 Scope

This document specifies procedural instructions for qualification testing of thermal sprayers. It defines requirements, ranges of qualification, test conditions, acceptance requirements and certification for qualification testing of thermal spray performance.

This document is applicable when the thermal sprayer's qualification is required by this document, the purchaser, by inspection authorities or by other organizations.

The thermal spraying processes referred to in this document include those spraying processes which are designated as manual or mechanized.

The test for mechanised application includes the use of automatically controlled thermal spraying, e.g. robotics, scan units.

2 Normative references

The following documents are referred to in the 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 14916, *Thermal spraying — Determination of tensile adhesive strength*

ISO 14917, *Thermal spraying — Terminology, classification*

ISO 2063-2, *Thermal spraying — Zinc, aluminium and their alloys — Part 2: Execution of corrosion protection systems*

EN 15340, *Thermal spraying — Determination of shear load resistance of thermally sprayed coatings*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14917 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 <https://www.iso.org/obp>

3.1

thermal sprayer

person who performs thermal spraying with a manual or mechanized system

3.2

manual thermal spraying

process in which the spraying gun or torch is manipulated by hand

3.3

mechanized thermal spraying

process in which some aspects are mechanized, i.e. with the gun/torch not manipulated by hand

3.4

automatic thermal spraying

process in which all operations typical of the spraying process are fully mechanized including all handling, e.g. workpiece loading and unloading, and which are integrated in a programmed system

Note 1 to entry: For examination, it is equal to *mechanized thermal spraying* (3.3).

3.5

examiner

person who verifies compliance with the application standard

3.6

examining body

organization who verifies compliance with the application standard

3.7

specific acceptance criteria

document providing in detail the criteria by which a *thermal sprayer* (3.1) can be tested to be qualified for a particular spraying technique or application area

3.8

test piece

thermal spray workpiece used for the qualification *test* (3.10)

3.9

test specimen

portion cut from the *test piece* (3.8) in order to perform a specified analytical *test* (3.10)

3.10

test

series of operations which include the making of a thermally sprayed *test piece* (3.8), subsequent non-destructive and/or destructive testing and reporting of results

4 Essential requirements for qualification testing

4.1 General

The criteria specified in this clause shall be examined in order to identify the ability of the thermal sprayer in these areas.

The thermal sprayer's qualification test shall be carried out on test pieces of comparable geometry.

The thermal sprayer shall be tested on both basic job knowledge and specific knowledge related to the process for all thermal spraying processes and operations, see [Annex A](#).

4.2 Equipment operation

The thermal sprayer shall be tested to determine his/her knowledge of the equipment, as described in [A.4.3](#).

4.3 Masking procedure

The thermal sprayer shall be tested to determine his/her knowledge of proper masking procedures for both surface preparation and spraying.

4.4 Surface preparation

The thermal sprayer shall verify that the surface of the thermal spray test piece which is used for qualification is acceptable. S/he should also maintain a properly prepared surface during the qualification testing.

4.5 Environmental conditions

The thermal sprayer shall verify the acceptability of environmental conditions, such as temperature, humidity and dew point, as being suitable for spraying the test pieces if called up by the specific coating process and method of application being evaluated.

4.6 Application equipment

The test results used for the qualification testing shall come from work or test pieces sprayed with production equipment or equipment similar to it. The certifying examining body shall agree that equal equipment used to perform the testing is representative of the said equipment's quality.

5 Range of qualification

5.1 General

Thermal sprayers shall be qualified for thermal spraying to a specific coating process and method of application. The qualification shall only be valid for that specific coating process and method of application. The thermal spraying processes and methods of application covered by this document are identified in [5.2](#).

5.2 Thermal spraying processes

5.2.1 Grouping of thermal spraying processes

This document covers the following thermal spraying processes according to ISO 14917:

- arc spraying;
- plasma spraying;
- high velocity oxy fuel flame spraying, cold spraying, detonation spraying;
- powder flame spraying, plastic flame spraying;
- wire/rods/cords flame spraying;
- powder flame spraying with fusing, laser spraying, plasma transferred arc spraying (PTA).

5.2.2 Application methods

This document covers the following application methods:

- manual;
- mechanized.

5.2.3 Spray materials

5.2.3.1 General

The spray materials that shall be used in the qualification test are split into material groups.

The materials listed in [5.2.3.2](#) to [5.2.3.5](#) are given for information only to show which material is generally appropriate for each process.

5.2.3.2 Flame spraying (powder, wire, cords or rods)/arc spraying

- Metals and alloys (for engineering purposes).
- Zinc, aluminium and their alloys and plastic (for corrosion protection).

5.2.3.3 Flame spraying (powder, wire, cords or rods, PTA, laser spraying and flame sprayed and fused)

- Self-fluxing alloys, cobalt based alloys, hard-facing.

5.2.3.4 Plasma spraying, plasma spraying in a chamber under vacuum

- Metals and alloys.
- Metal based hard material.
- Ceramics, hydroxyl-apatite.

5.2.3.5 High velocity flame spraying

- Metals and alloys.
- Metal based hard material.

5.3 Qualification scope

The requirements for initial thermal sprayer qualification are different for each of the classifications in [5.2](#). Qualification in one category (process and application method) does not imply any ability or experience in practising the specific thermal spraying technique in any other category.

The thermal sprayer qualification level shall be indicated by the thermal spray process, followed by the application method. For example, manual operation of arc spraying equipment can be written as "Arc spraying – Manual". In addition, information on the spray material (material group) sprayed for qualification shall be available upon request to the certifying examining body.

5.4 Supervision

The thermal spraying and testing of the test pieces shall be witnessed by the licensed examiner, or by the responsible thermal spraying coordinator.

5.5 Shapes and dimensions of test pieces

Shapes and dimensions of test pieces and test specimens are defined in [Annex B](#).

5.6 Test methods

The test methods are specified in [Annex B](#).

5.7 Acceptance requirements for test pieces

The acceptance requirements for test pieces are specified in [Annex B](#).

5.8 Spray consumables for the test

For any process group mentioned in [5.2.1](#) there are various material groups possible, see [5.2.3](#). The sprayer can choose the material according to the group to use for the test. The coating properties of the materials used should be in accordance with [Annex C](#). [Tables C.1](#) and [C.2](#) include basic points for the testing of materials (e.g. tensile bond test values).

A plasma sprayer can choose a ceramic material for the test, e.g. $\text{Al}_2\text{O}_3/\text{TiO}_2$, Cr_2O_3 , ZrO_2 or an equivalent metallic material, e.g. WCCo.

6 Examination and testing

6.1 General

The thermal sprayer shall be tested in two ways:

- s/he shall complete a job knowledge test to determine his/her knowledge of the process;
- s/he shall undergo a practical test to demonstrate his/her skill and ability to operate the equipment in the appropriate area.

6.2 Job knowledge test

The thermal sprayer shall satisfactorily complete a test covering the appropriate coating process, application method and material. The test shall be prepared by the certification body. For the particular aspects to be tested see [Annex A](#).

6.3 Practical test

The practical test serves the purpose of determining if the thermal sprayer has the necessary practical skills, as detailed in the specific acceptance criteria (according to [Annex A](#) and [Annex B](#)).

When practically testing more than one sprayer (mechanized) using the same equipment, the same spray material and the same parameter, the assessment of the material in question can be reduced to a 20 % sample random test provided no unacceptable coatings are produced. In the case of imperfection all specimens shall be tested.

7 Re-tests

7.1 General

In the event of the thermal sprayer's failure to meet the requirements of this document, a re-test may be scheduled at the discretion of the examiner, but not without additional training and not usually within three months of the initial test.

7.2 Additional tests

If during spraying the thermal sprayer can show that there is some extraneous fault preventing spraying a good test piece, a new attempt may be made when the fault has been corrected.

8 Period of validity

8.1 Initial qualification

The validity of the thermal sprayer's qualification begins from the date when all the required tests are satisfactorily completed. This date may be different to the date of issue marked on the certificate.

A thermal sprayer's qualification shall remain valid for a period of three years providing that the sprayer has provably sprayed in his/her relevant production field and this activity had not been interrupted for more than six months or a re-qualification has been carried out showing a satisfactory test piece. The relevant certificate shall be signed at six months intervals by the employer/coordinator and shall show that the following conditions are fulfilled.

8.2 Prolongation

8.2.1 Period

A re-qualification is required for the thermal sprayer every three years.

8.2.2 Thermal sprayer and production spraying

The thermal sprayer shall carry out production spraying without lapses of six months or more.

8.2.3 Interruption periods in thermal spray works

A thermal sprayer who has not carried out production spraying for a period of six months shall follow the procedure for a repetition or re-qualification to regain a qualified status.

8.3 Requirements

The qualified status shall be deemed to be fulfilled by acceptable thermal spraying of test specimens. No job knowledge test should be required, providing said results have been obtained within a six month-period of the requested re-qualification.

8.4 Scheduling

The scheduling for re-qualification shall be agreed between the thermal sprayer and his/her employer.

8.5 Expired or cancelled qualification status

Thermal sprayers with an expired or cancelled qualification shall not be permitted to perform thermal spray operations on parts covered by this document.

9 Records

Copies of qualification records and test results should be maintained for a period of three years.

10 Designation

The thermal sprayer's qualification test shall be designated by the following information:

- number of this document, i.e. ISO 14918;
- thermal spray process;
- application method;
- spray material.

EXAMPLE Thermal sprayer qualification test ISO 14918 Wire flame spraying – manual.

An example of a qualification test certificate for a thermal sprayer is provided in [Annex D](#).

Annex A **(normative)**

Job knowledge

A.1 General

A test of job knowledge is required for the initial qualification of thermal sprayers.

This annex outlines the job knowledge that a thermal sprayer shall have to ensure compliance with procedures and common practices.

The tests of a thermal sprayer's job knowledge can be given by any of the following methods or combinations of these methods:

- written tests;
- oral examination, following a series of written questions;
- computer testing;
- demonstration/observation testing, following a series of written criteria.

The test of job knowledge shall be specific to the relevant thermal spraying process.

A.2 Requirements

A.2.1 General

The job knowledge of the thermal sprayer shall be specifically tested for the relevant process in the areas described in [A.2.2](#) to [A.2.6](#).

A.2.2 Thermal spraying equipment

Basic knowledge should include gas/electrical energy supply devices, essential components and cooling systems.

A.2.3 Thermal spraying process

Basic knowledge should include preparation of the work piece, geometrical aspects, masking, measuring methods during spraying, control of parameters, work piece storage and post treatments.

A.2.4 Substrate materials and consumables

Basic knowledge should include identification, storage and handling.

A.2.5 Safety and accident prevention

Basic knowledge should include safe assembly, setting up and closing down procedures, personal protection, fire hazards, dust explosions, electrical hazard, flash backs, leak detection, radiation and noise.

A.2.6 Methods of testing thermal sprayed coatings

Basic knowledge should include visual inspection, metallographic investigations, adhesion testing, coating structure and imperfections of the coating.

A.3 Surface preparation during the qualification test

The thermal sprayer shall demonstrate an understanding of the interactions of cleaning, degreasing, different mechanical surface roughening methods, preheating and storage so that s/he is able to assess the quality of prepared substrate surfaces.

The thermal sprayer shall be able to recognize the suitability, or otherwise, of a surface to accept the proposed coating system.

The thermal sprayer shall demonstrate an awareness of the effects of blast cleanliness and profile, and also what level of preparation is required for different types of coating.

For examination purposes, inadequate, adequate and good test piece surfaces shall be presented to the thermal sprayer as follows:

- a) surface blasted with ball shot to provide clean surface but without a sharp profile;
- b) surface blasted for too short a time, leaving excessive contamination;
- c) surface blasted too much, leading to polishing as the profile is reduced;
- d) surface contaminated with oil or dust;
- e) surface blasted correctly, giving a clean metal surface with a good sharp profile appropriate to the coating type. The surface as prepared shall be free of dust arising from other spraying operations, broken down blast media, etc.

The thermal sprayer shall be questioned on which of the test pieces is acceptable and why. S/he should also be questioned on the reasons behind the acceptability, e.g. effect of contamination etc. The thermal sprayer shall also be aware of other factors which may reduce the receptiveness of the surface for spraying.

A.4 Other factors to be tested during the qualification test

A.4.1 Material storage

The thermal sprayer shall demonstrate his/her knowledge concerning conditions of storage and handling of spray materials (consumables) and their influence on coating quality.

A.4.2 Masking procedure

The thermal sprayer shall be tested to determine his/her knowledge of proper masking procedures for both surface preparation and spray process. Where certain areas of a workpiece are not to be sprayed, these shall be masked off. This can be done using a variety of techniques; whichever is appropriate depending upon the geometry of the piece and the type of coating being applied may be used. For example, paper tape can be used to mask off zinc spray only but cannot be used for high melting point materials or as protection against blasting material.

The thermal sprayer shall show an awareness of the correct method for the work in hand.

A.4.3 Equipment operation

The thermal sprayer shall be tested to determine his/her knowledge of operating the equipment. S/he shall put into operation thermal spray equipment according to the procedure and operating manual provided by the equipment manufacturer. The thermal sprayer's knowledge should not be limited to normal operation; rather, s/he should be sufficiently skilled to recognize when the equipment is not functioning normally.

A.4.4 Application of the coating

The thermal sprayer shall show that s/he is capable of assessing the preparation of the part to be sprayed. Consideration should be given to geometrical factors such as holes and fasteners as well as the operation of the equipment, i.e. by setting it up, spraying the coating, monitoring the process (e.g. temperature control, parameter control) and assessing the result.

A.4.5 Safety aspects concerning personal health, safe handling of the entire equipment and environmental safety requirements

The thermal sprayer shall show his/her knowledge about safety aspects during the practical testing. Particular attention should be paid to the proper handling of all connections whether electrical, gas or air, as historically most accidents involving metal spraying equipment derive from these connections.

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Annex B (normative)

Specific acceptance criteria

B.1 Zinc, aluminium and their alloys for corrosion protection/plastics

B.1.1 Instructions

The equipment, of whatever type, shall always be set up by the thermal sprayer and used in accordance with the manufacturer's instructions.

B.1.2 Practical test

B.1.2.1 General

Particular points to note are that the spray gun is used at a range according to manufacturer's recommendations and that the coating produced is free from lumps, dust inclusions and coarse textured areas and is of a uniform thickness.

B.1.2.2 Test piece production

The test piece to be sprayed shall be a plate of, for example, alloyed steel or carbon steel according to [Figure B.1](#) or a work piece (e.g. a production part) which is comparable in degree of difficulty. Before the spraying begins, the thermal sprayer shall accept the quality of the prepared surface and the suitability of the environment. The coating shall be sprayed evenly onto the plate.

B.1.3 Testing of the sprayed coating

B.1.3.1 Thickness test

The thermal sprayer shall be provided with a thickness gauge by which s/he may assess the thickness of the coating on no more than three occasions during the test. Using the same gauge the assessor shall then test the plate as described in ISO 2063-2 for general thickness and uniformity of thickness. If the coating thickness lies between 0,15 mm and 0,25 mm at all tested points the thermal sprayer shall be deemed to have passed this test.

B.1.3.2 Coating quality

Using the same sprayed plate the examiner shall visually inspect the coating for texture and freedom from lumps, dust inclusions and blisters. If no such imperfections are present the thermal sprayer shall be deemed to have passed this test.

B.1.3.3 Adhesion test

An adhesion test shall be performed in accordance with ISO 2063-2.

B.2 Metal and alloys, metal based hard material (e.g. carbides), ceramics

B.2.1 Instructions

The equipment, of whatever type, shall always be set up by the thermal sprayer and used in accordance with the manufacturer's instructions.

B.2.2 Test piece production

The test piece to be sprayed shall be a tube of, for example, alloyed steel or carbon steel according to [Figure B.2](#) or a work piece (e.g. a production part) which is comparable in degree of difficulty. The area of the test piece to be coated (about 150 mm) shall be undercut to a depth of 0,2 to 0,5 mm. The thermal sprayer shall spray an adequate quantity of spray material (typical coating thickness of the material used shall be sprayed) so that the original diameter can be reached again after a subsequent machining.

The torch shall be maintained at a distance and relative speed to the work piece according to the supplier's instructions (respective to internal parameter guidelines).

B.2.3 Testing of the sprayed coating

B.2.3.1 Thickness test

It shall be the thermal sprayer's responsibility to determine what this thickness should be, but it should not exceed 1,0 mm in any case and 0,80 mm if a mechanical traverse is used. The coating thickness shall be tested in at least four places along the bar or tube.

B.2.3.2 Coating quality

Using the same test piece the examiner shall visually inspect the coating for texture and freedom from lumps, dust inclusions, cracks and blisters. Delamination and spalling-off are not accepted. If no such imperfections are present the thermal sprayer shall be deemed to have passed this test.

B.2.3.3 Machining test

After visual inspection the test specimen shall be machined to diameter 75 mm or the diameter agreed to confirm an adequate coating thickness. Provided that the original thickness was not excessive, and that the coating cleans up over the entire surface upon machining, the thermal sprayer shall be deemed to have passed the thickness test. The machined surface shall be inspected for over-heating, excessive porosity, cracks and detachment, bearing in mind the difference between spraying and machining effects.

B.2.3.4 Adhesion/shear load resistance test

An adhesion test in accordance with ISO 14916 or a shear load resistance test according to EN 15340 shall be performed. The mean value in both tests shall reach the agreed rated value at least.

The rated value shall represent a value usually used for manufacturing. Internal guidelines, requirements of the client, guidelines by other standards or regulations shall be considered. Determining the rating value also depends upon the required coating thickness, porosity, etc.

Alternative to the tensile adhesive test the shear load resistance according to EN 15340 can be determined. [Tables C.1](#) and [C.2](#) show technological properties as reference values.

B.2.3.5 Metallographic examination

A test piece or a work piece specimen, an additional tensile adhesive test piece or a coated cross-section specimen can be used for the metallographic investigation. The metallographic investigation

shall not show any transverse cracks, delamination or substrate to coating interface voids, porosity or unacceptable blasting material residues.

B.3 Self fluxing alloys, cobalt based alloys, hard facings

B.3.1 Instructions

The equipment, of whatever type, shall always be set up by the thermal sprayer and used in accordance with the manufacturer's instructions.

B.3.2 Test piece production

The test piece to be sprayed shall be a tube of, for example, alloyed steel according to [Figure B.2](#) or a work piece (e.g. a production part) which is comparable in degree of difficulty. The area of the test piece to be coated (about 100 mm to 200 mm) shall be undercut to a depth of 0,5 mm. The thermal sprayer shall spray an adequate quantity of spray material so that the original diameter can be reached again after fusing and a subsequent machining.

The torch shall be maintained at a distance and relative speed to the work piece according to the supplier's instruction (respective to internal parameter guidelines).

B.3.3 Testing of the sprayed and fused coating

B.3.3.1 Coating quality

Using the same sprayed and fused test piece the examiner shall visually inspect the coating for texture and freedom from lumps, cracks and blisters. Delamination and spalling-off are not accepted. If no such imperfections are present the thermal sprayer shall be deemed to have passed this test.

The metallographic investigation shall not show any transverse cracks, delamination or substrate to coating interface voids, porosity or unacceptable blasting material residues. Overheating is not acceptable.

B.3.3.2 Machining test

After visual inspection the bar or tube shall be machined to 75 mm diameter to confirm an adequate coating thickness. Provided that the original thickness was not excessive, and that the coating cleans up over the entire surface upon machining, the thermal sprayer shall be deemed to have passed the thickness test. The machined surface shall be inspected for over-heating, excessive porosity, cracks and detachment, bearing in mind the difference between spraying and machining effects.

B.3.3.3 Metallographic examination

A test piece or a work piece specimen, an additional tensile adhesive test piece or a coated cross-section specimen can be used for the metallographic investigation. The metallographic examination shall not show any transverse cracks, delamination or substrate to coating interface voids, porosity or unacceptable blasting material residues.

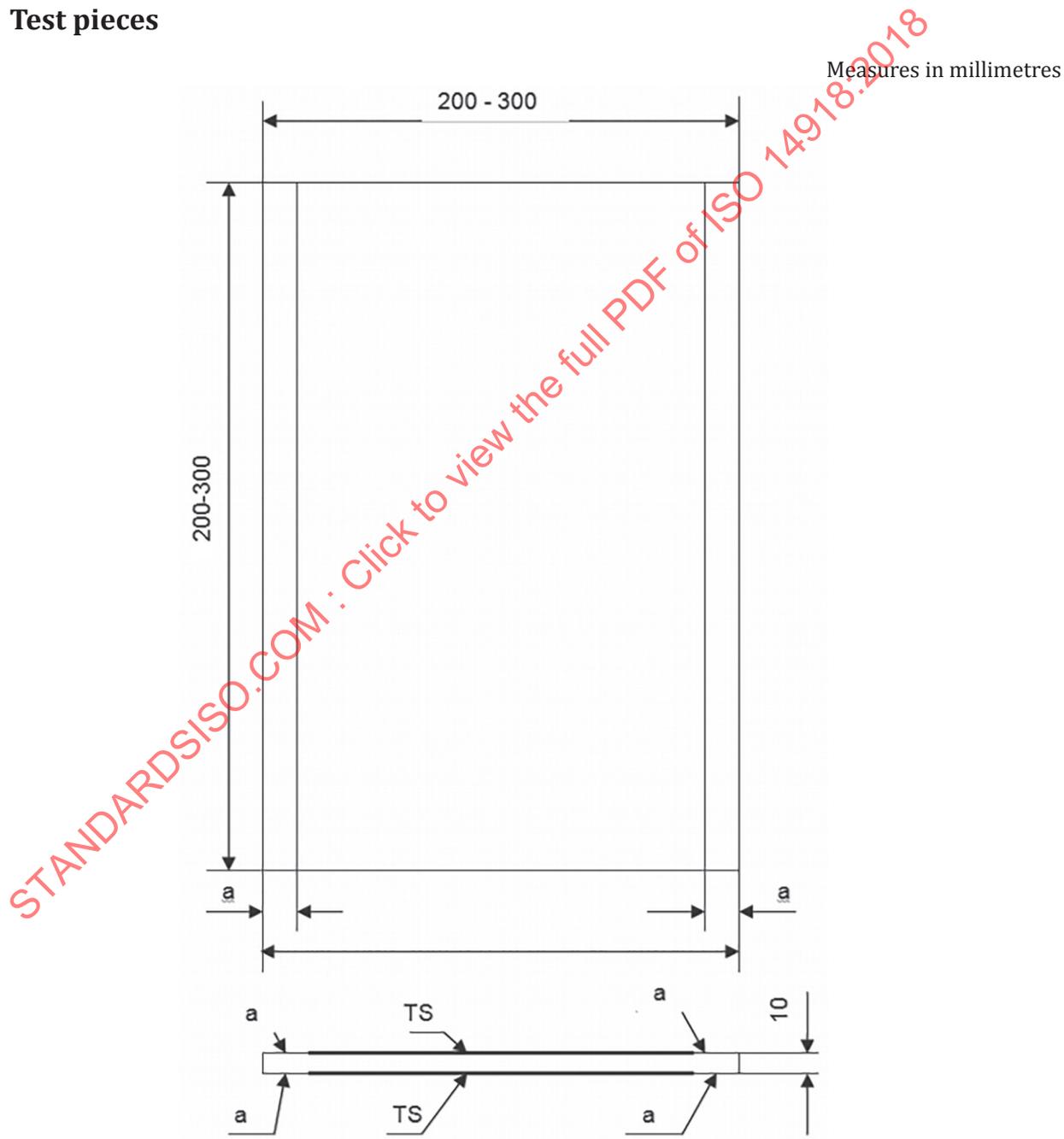
B.4 Summary of specific acceptance criteria

Specific acceptance criteria is give in [Table B.1](#).

Table B.1 — Specific acceptance criteria

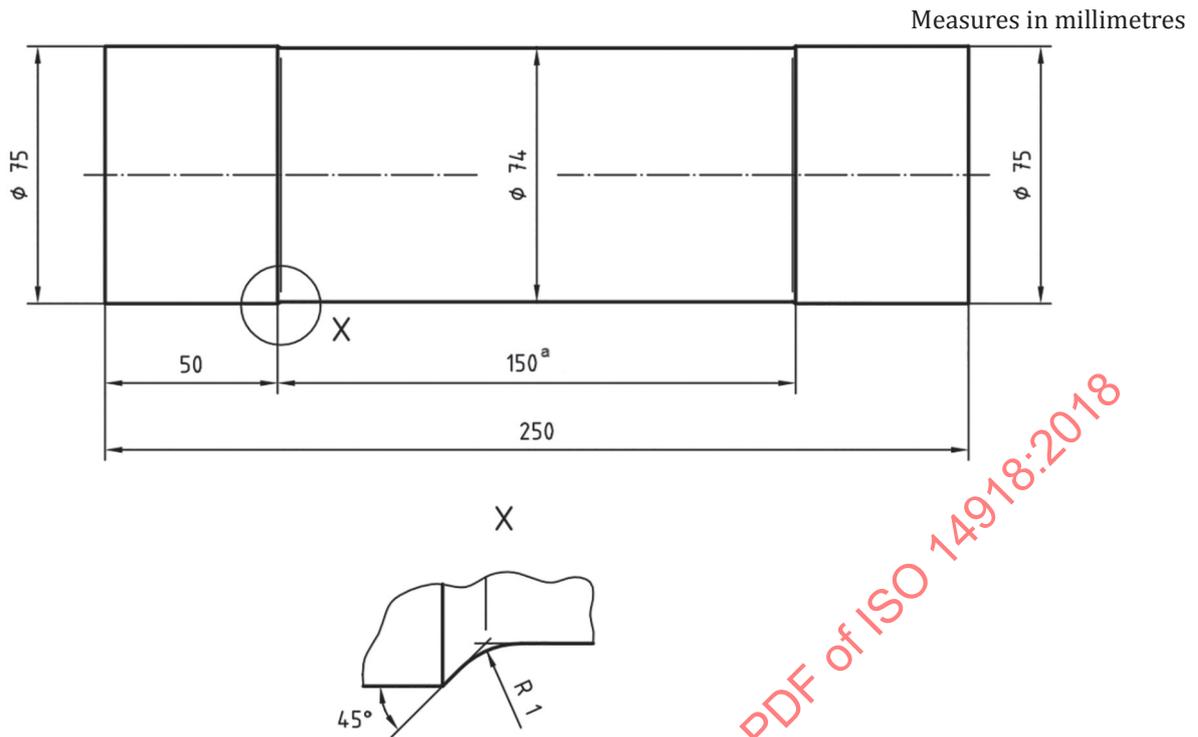
Testing	Cold spray	HVOF, D-gun	APS, VPS	PFS, WFS, RFS (rod), CFS (cord), AS	PFS (SF), PTA, LS
ISO 14916	X	X	X	X	
EN 15340	X	X	X	X	
ISO 2063-2 (corrosion protection)				X	
Micro cross-section	X	X	X	X	X

B.5 Test pieces



a Masked.

Figure B.1 — Example test piece for manual coating



^a Spray over this area.

Figure B.2 — Example test piece for mechanized coating (bar or tube)

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