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Full document details: 25/30462473 DC

Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

English Version

Test methods for determining the contribution to the fire
resistance of structural members - Part 11: Applied
protection to solid steel bars in tension based on
mechanically loaded fire tests

Prüfverfahren zur Bestimmung des Beitrages zum
Feuerwiderstand von tragenden Bauteilen - Teil 11:
Angewandter Schutz für massive Stahlträger unter
Spannung auf der Grundlage mechanisch belasteter
Brandprüfungen

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 127.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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European foreword

This document (prEN 13381-11:2024) has been prepared by Working Group 1 'Structural and separating elements' under Technical Committee CEN/TC 127 "Fire safety in buildings", the secretariat of which is held by BSI.

This document is currently submitted to the CEN Enquiry.

This document has been prepared under a standardization request addressed to CEN by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

This document is one of a series of standards for evaluating the contribution to the fire resistance of structural members by applied fire protection materials. Other parts of this series are:

Part 1: Horizontal protective members.

Part 2: Vertical protective members.

Part 3: Applied protection to concrete members.

Part 4: Applied passive protection to steel members.

Part 5: Applied protection to concrete/profile sheet steel and composite members.

Part 6: Applied protection to concrete filled hollow steel columns.

Part 7: Applied protection to timber members.

Part 8: Applied reactive protection to steel members.

Part 9: Applied fire protection systems to steel beams with web openings.

Part 10: Applied protection to solid steel bar in tension.

Introduction

The evaluation of a system's capability to provide fire protection performance to beams and/or columns with I- or H-section as well as hollow section is undertaken by test and assessment procedures detailed in EN 13381-8 for reactive (intumescent) fire protection systems. The scope of the above standard excludes the assessment of solid steel bars used as tension members.

In general, it is not possible to use the results of fire protection systems tested according to EN 13381-8 on beams or columns with open or closed profile to steel tension bars with solid section. This has several reasons:

- a) the profiles used for steel bars are usually much slenderer than the profiles used for beams or columns. Consequently, to achieve the same fire resistance usually higher thicknesses of the reactive fire protection system are required;
- b) due to the different profile shape, there is an altered foaming and cracking behaviour of reactive fire protection systems. On the predominantly flat surfaces of a beam with open profile, reactive fire protection systems behave differently than on highly convex curved surface of steel bars with circular solid section;
- c) because the tensile stresses in a steel bar are equal along the entire bar length and within the cross-section, the failure occurs at the position, where the highest steel temperature is present. Therefore, tensile bars are vulnerable to local defects, e.g. cracks or ununiform foam thicknesses of reactive fire protection systems. Furthermore, beams have the possibility of cross-sectional plasticisation. Due to the resulting stress redistribution and the activation of additional load capacity reserves, in fire tests beams suffer lower strains compared to a bar in pure tension. This is also clear from the fact that the tests of a steel bar usually end with the breakage. In mechanically loaded beam tests such a high strain is usually not achieved;
- d) columns are not suitable for a comparison with steel bars, because the cross-sections are much bigger as well as the thermal and mechanical strains are acting in opposite direction;
- e) in contrast to beams, which are generally used in a horizontal position, steel bars are used in different orientations. This may influence the thermal protection performance of the reactive fire protection system.

For reactive fire protection systems that have already been successfully tested and assessed according to EN 13381-8, the test standard EN 13381-10 offers under certain conditions the possibility to extend the scope of application to steel tension bars with solid sections. The fire tests in EN 13381-10 are based upon unloaded specimens. Because this approach contradicts to the German national safety level, where the fire resistance of structural members must be tested under mechanical load, an A-Deviation was granted, meaning that it is not possible to apply EN 13381-10 in Germany. In addition, recent research and testing on loaded and unloaded steel bars protected with reactive fire protection coatings has shown the need for mechanically loaded fire testing.

The following standard provides a test and assessment procedure to cover a reactive fire protection system's scope of application to solid circular or rectangular steel bars used as tension members based on mechanically loaded fire tests. The standard is a stand-alone test standard and does not require a successful completion of the test procedure according to EN 13381-8. The standard has been created to cover a testing and assessment procedure based primarily upon mechanically loaded fire tests. Across a range of solid circular and/or rectangular bars fire tests on mechanically loaded specimens are carried out. Unloaded specimens may be used to assess additional aspects, such as the influence of the bar orientation as well as smouldering fire behaviour. The assessment procedure described in this document aims to determine the reactive fire protection system's thermal protection performance.

The document does not apply to passive fire protection systems.

1 Scope

This document describes the test and assessment procedure for determining the contribution of reactive fire protection systems to the fire resistance of solid steel bars used as tension members, when exposed to the standard temperature/time curve specified in EN 1363-1. In special circumstances, where specified in National Building Regulations, there can be a need to subject reactive fire protection systems to a slow heating curve (smouldering fire) as defined in EN 1363-2. The corresponding test and assessment procedure are described in Annex E. The fire protection performance is determined by testing mechanically loaded steel bars in horizontal orientation. Information regarding the testing of additional unloaded specimens is given to assess the influence of the bar orientation and smouldering fire behaviour.

The principles of the testing and assessment procedure can also be applied for other section shapes such as angles, channels and flats. This document does not include steel bars used as reinforcement in concrete construction.

The document is applicable to steel bars up to a maximum diameter of 130 mm. In the case of rectangular bars, the maximum edge length is limited to 130 mm with a maximum aspect ratio of 2:1 against the shorter edge length.

The test programme and the assessment are designed to cover:

- a range of valid fire protection classification periods;
- a range of thickness of the applied reactive fire protection system;
- a range of steel bar dimensions and profiles;
- a range of specified design temperatures;
- a range of load utilization factors in case of fire;
- a range of bar orientation.

This document also provides the assessment procedure, which prescribes how the analysis of the test data is made and gives guidance on the procedures by which interpolation is undertaken. The assessment procedure is used to establish:

- a) on the basis of data derived from mechanically loaded testing steel bar, any practical constraints on the use of the reactive fire protection system under fire test conditions (the physical performance);
- b) on the basis of the temperature data derived from testing steel bar the thermal properties of the reactive fire protection system (the thermal performance).

The limits of applicability of the results of the assessment arising from the fire test are defined together with permitted direct application of the results to different steel types and sizes over the range of thicknesses of the applied reactive fire protection system tested.

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.

EAD 350402-00-1106, *Reactive coatings for fire protection of steel elements*

EN 1363-1:2020, *Fire resistance tests — Part 1: General requirements*

EN 1363-2, *Fire resistance tests — Part 2: Alternative and additional procedures*

EN 10025-1, *Hot rolled products of structural steels — Part 1: General technical delivery conditions*

EN ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1)*

EN 10204, *Metallic products — Types of inspection documents*

EN ISO 13943, *Fire safety — Vocabulary*

EN ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system (ISO 7500-1)*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1363-1, EN ISO 13943 and ISO 8421-2, and the following apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1.1

steel bar

element of building construction, which is loadbearing and fabricated from steel. It has a solid circular or rectangular (including square) cross-section composed entirely of steel with a consistent cross-sectional size throughout its length

3.1.2

reactive fire protection material

reactive materials which are specifically formulated to provide a chemical reaction upon heating such that their physical form changes and in doing so provide fire protection by thermal insulative and cooling effects

3.1.3

fire protection system

fire protection material together with any supporting system including mesh reinforcement and a specified primer and top coat if applicable

3.1.4

fire protection

protection afforded to the steel member by the reactive fire protection system such that the temperature of the steel member is limited throughout the period of exposure to fire

3.1.5

test specimen

steel bar plus the reactive fire protection system under test

3.1.6

fire protection thickness

mean dry film thickness of the reactive fire protection material excluding primer and top coat

3.1.7

stickability

ability of a reactive fire protection system to remain sufficiently coherent and in position for a well-defined range of deformations, furnace and steel temperatures, such that its ability to provide fire protection is not significantly impaired

3.1.8

maximum steel temperature

the highest average temperature recorded at two measuring stations nearest the rupture point

3.1.9

section factor

ratio of the fire exposed outer perimeter area of the steel bar per unit length, to its cross-sectional volume per unit length

3.1.10

mechanical load

axial tensile force applied to the mechanically loaded specimen during the fire test (see 6.4)

3.1.11

load utilisation in case of fire

ratio of mechanical load to the tensile load carrying capacity of steel bar in case of fire (see 6.4)

3.1.12

test programme

describes the intended scope of application (see Clause 5)

3.1.13

test set

part of the test programme and consists of a group of mechanically loaded specimens (template see 5.6)

3.1.14

design steel bar temperature

temperature of a steel bar, which shall be used for the assessment of the physical and thermal performance

3.1.15

deformation steel bar temperature

temperature of a steel bar, which shall be used by the structural engineer to check the total deformation of the steel bar and the entire steel construction at elevated temperature

3.2 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

Symbol	Unit	Description
α	K ⁻¹	thermal expansion coefficient
A_m/V	m ⁻¹	Section factor of the unprotected steel section
A_{section}	mm ²	Cross-sectional area of the steel section
b	mm	Width of the rectangular solid steel section
D	mm	Diameter of the circular solid steel section
d_p	mm	Thickness of reactive fire protection system
d_{min}	mm	minimum protection thickness of the loaded or tall section (according to EN 13381-8)
d_{max}	mm	maximum protection thickness of the loaded or tall section (according to EN 13381-8)
D_{small}	mm	Diameter of the smaller tested steel bar from the fire test
D_{large}	mm	Diameter of the larger tested steel bar from the fire test
D_{select}	mm	Diameter of steel bar for which appropriate dry film thickness is calculated
DFT_{mean}	mm	Mean value of all thickness measurements of the fire protection material
DFT_{small}	mm	Dry film thickness of the smaller tested steel bar from the fire test
DFT_{large}	mm	Dry film thickness of the larger tested steel bar from the fire test
DFT_{ref}	Mm	Dry film thickness of the unloaded steel bar used as reference specimen
DFT_K	mm	DFT_{mean} of the unloaded steel bar for which the correction time ($t_{\text{corection},k,i}$) is calculated
$\dot{\epsilon}$	min ⁻¹	Strain rate of steel
F_{load}	kN	The mechanical tensile load applied to the specimen
$f_{y,20^\circ\text{C}}$	N/mm ²	Yield strength at room temperature
$f_{p0.2,20^\circ\text{C}}$	N/mm ²	0,2 % proof stress at room temperature
h	mm	Height of the rectangular steel section
L_F	mm	Fire exposed length of the mechanically loaded specimen
L_G	mm	Total length of the mechanically loaded specimen
L_U	mm	Total length of unloaded steel bar
r	mm	Radius of the circular solid steel section

s	mm	Cross-sectional dimension of the specimen
θ_i	°C	Design steel temperature for the thermal and physical assessment
θ_{def}	°C	Steel deformation temperature for the check of the total deformation of the steel bar and the entire steel construction at elevated temperature
θ_s	°C	Maximum steel temperature at time t_i
θ_{rupture}	°C	Steel temperature when the rupture occurred
θ_{select}	°C	Selected design temperature value for which the dry film thickness will be calculated
$\theta_{\text{average,unload},i}$	°C	Average temperature of unloaded steel bar for different orientation
$\theta_{\text{SH,average,unload},i}$	°C	Average temperature of unloaded specimen in different orientation for bars exposed to slow heating (SH) temperature/time curve
$\Delta\theta_k$	°C	Temperature difference between steel bars with different orientation
t	min	Fire performance period
t_F	min	Fire resistance time
t_C	min	The time when the load-bearing capacity (t_C) is reached
$t_{C,i}$	min	Time for which the load utilisation factor in case of fire is calculated for interpolation purposes
$t_{\text{correction},k,i}$	min	Corrected time, when unloaded steel bar reached design temperature θ_i
$t_{k,i}$	min	Time for the reference section to reach the design temperature
t_{rupture}	min	Time when the steel bar rupture occurred
$\Delta T_{\text{unload},i}$	°C	Temperature difference between unloaded steel bars with different orientations
$\Delta T_{\text{load},k}$	°C	Temperature difference between loaded steel bars with different orientations
U	mm	Deformation of the steel bar including longitudinal elongation
dU/dt	mm/min	Rate of deformation
$\Delta dU/dt_{\text{limit}}$	mm/min	Limit value of the rate of deformation of the mechanically loaded specimen
μ_0	–	Load utilisation factor at ambient temperature
μ_{fi}	–	Load utilisation factor in case of fire
$\mu_{fi,\text{max}}$	–	Upper limit of load utilisation factor in case of fire
$\mu_{fi,\text{min}}$	–	Lower limit of load utilisation factor in case of fire

$\mu_{fi,select}$	–	Load utilisation factor in case of fire, which is selected based on the applied load utilisation in case of fire of tension steel bar
$\mu_{fi,reduce}$	–	Load utilisation factor in case of fire, which is reduced based on the real load utilisation of tension steel bars
Abbreviation		Description
DFT		Dry film thickness of the reactive fire protection system
MS		Measuring station
MP		Measuring point
TC		Thermocouple
ULS		Ultimate limit state

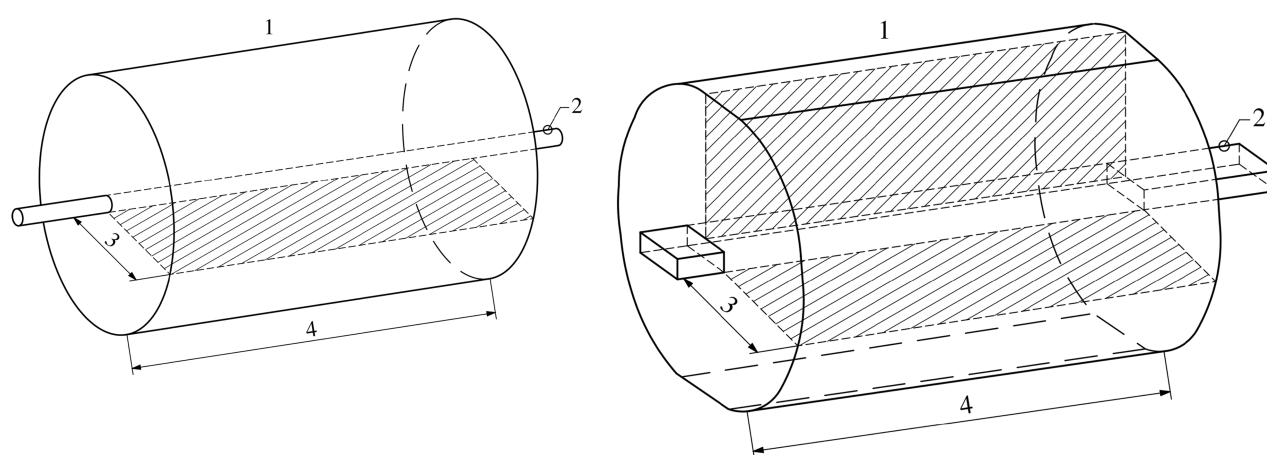
4 Test equipment

4.1 General

The furnace and test equipment shall conform to that specified in EN 1363-1. A number of steel bars, protected by the reactive fire protection system, are mechanically loaded by a constant tension load and then heated in a furnace according to the protocol given in EN 1363-1. It is recommended that the tests be continued until the specimen reaches the maximum steel temperature specified in the scope of testing or rupture of the specimen occurs. The description in this document refers to a fire test in horizontal position of the bar. However, it is also possible to conduct the fire test in vertical position. The load device and the furnace shall be changed accordingly. The procedures given in EN 1363-1 shall be followed in the performance of this test unless specific contrary instructions are given in this document. The specimens shall be chosen to suit the scope of testing.

4.2 Furnace

The furnace shall permit the dimensions of the test specimens to be exposed to heating, as specified in Clause 5 and their installation within the test furnace to be as specified in Clause 6. A minimum distance of 300 mm shall be kept between the specimen and the edge of the burner outlet, the burner flame, other obstacles (except furnace plate thermocouples and specimen thermocouples) and furnace walls, floor and ceiling (see 6.1 and Figure 1). In addition, a direct impingement shall be avoided. In General, the furnace shall be able to create a uniform temperature distribution around the specimen. Furthermore, the required furnace temperature shall be reached at the specimen and the associated plate thermocouples.



Key

- 1 undisturbed and obstacle free zone
- 2 specimen (tension bar)
- 3 = 300 mm
- 4 fire exposed length of the specimen ($L_F = 1\,000\text{ mm}$)

**Figure 1 — Undisturbed and obstacle free zone around the specimen in the furnace
(the geometric limitations also apply to other bar orientations)**

4.3 Load frame and hydraulic actuator

The loading equipment shall be capable of subjecting the test specimens to the level of tensile load specified in the scope of testing (see 5.1). Furthermore, the loading equipment shall be able to simulate conditions of uniform loading, which can maintain the test load at a constant value ($\pm 2\%$ of the required value, according to EN ISO 7500-1) without changing its distribution and following the maximum deformation as well as rate of deformation of the test specimen until failure (maximum temperature or rupture of the bar) occurs.

The load frame shall have room temperature over the entire duration of the fire test (a locally higher temperature of the load frame of not more than 50 K is allowed; it is recommended to locate the load frame outside of the furnace). The effect of deformation of the load frame shall be considered to determine the steel rods deformation. A computer-based controlling of the loading system and deformation measurement is recommended.

5 Test programme

5.1 General

The manufacturer of the reactive fire protection system specifies the intended scope of application by defining the test programme. To develop the test programme the testing institute can be consulted. Based on the selected test programme the different test sets can be defined. The test programme contains at least one test set. If the general parameters selected in the test programme have more than one entry per line, several test sets shall be created. A subdivision into different test sets is required, because in the assessment only specimens with comparable parameters, i.e. identical entries for the general parameters, can be assessed together. In general, it is possible to include the data of one specimen for different test sets. A change or extension of a test set is possible by changing or adding new values for a variable parameter. For the variable parameter a range can be specified. A change of the variable parameters does

not require a new test set. Recommendations and details for the selection of the specimens of a test set are given in 5.6. The following scheme describes in Table 1 the general structure of a test programme for mechanically loaded specimens.

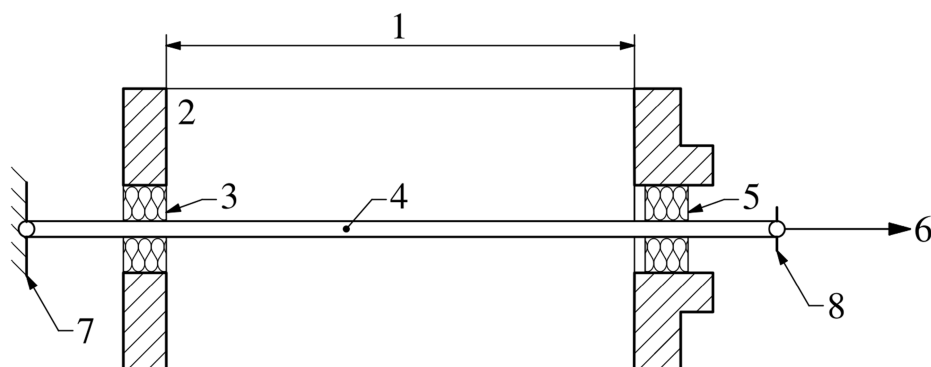
Table 1 — Test programme to specify the intended scope of application of the reactive fire protection system

General parameter:	Examples (If more than one entry per line is selected several test sets are required)
1) Reactive fire protection material	Name of the product
2) Fire resistance class	R30, R60, R90, ...
3) Steel type	Hot-rolled steel; cold-formed steel
4) Steel grade	S designation (S235; S275; S355; S420; S460)
5) Profile type	Circular; rectangular (including square)
6) Orientation of the loaded bar	Horizontal; inclined; vertical
7) Load utilization factor in case of fire	$\mu_{fi} \leq 0,65$ (fully loaded steel bar); $\mu_{fi} \leq 0,60$, ...
8) Fire exposed length of the steel bar	L_F
Variable parameter:	Examples (In each line a range has to be defined)
8) Steel temperature range for thermal assessment purpose (design temperature)	θ_i (min., int., max.), e.g.: (350, 400, ..., 750 °C)
9) Steel bar dimension	Section factor and cross-sectional dimension: (min., int., max.)
10) Thickness of reactive fire protection system	d_p (min., int., max.)

The aim of the information addressed in the test programme is to set an intended scope of application for the reactive fire protection system. The amount of testing influences the assessment and limits the final scope of application for the product. Generally, an increase of the intended scope of application or an increase of the gradations of the defined parameters requires a more extensive test programme, i.e. higher number of test sets. However, in many cases the final scope of application of the tested reactive fire protection system could be larger than specified in the test programme. All permitted direct extensions are given in Clause 15.

5.2 Mechanical loading conditions

The mechanically loaded steel bars shall be oriented horizontally within the furnace. Each end of the bar shall be connected to the load device, which consist of a load frame and a hydraulic actuator. For this purpose, a sample holder designed for transferring tensile forces shall be provided. The connections between the specimen and the loading device shall be located outside the furnace. The penetration of the specimen through the furnace walls shall be designed in such a way that the reactive fire protection system does not peel off the specimen during the fire test. For this purpose, a moveable insulation, which is attached to the specimen, is recommended. A proposal of the basic structure of the load device to perform mechanically loaded fire tests on steel bars with reactive fire protection system is given in Figure 2.

**Key**

- 1 fire exposed length of the specimen ($L_F = 1\,000\text{ mm}$)
- 2 furnace interior
- 3 furnace wall with opening for passing the specimen
- 4 specimen (steel bar)
- 5 movable insulation (attached to the specimen)
- 6 tensile force
- 7 hinged connection of the specimen to the load frame (none movable end)
- 8 hinged connection of the specimen to the hydraulic actuator (movable end)

Figure 2 — Schematic drawing of the basic structure of the load device and the furnace

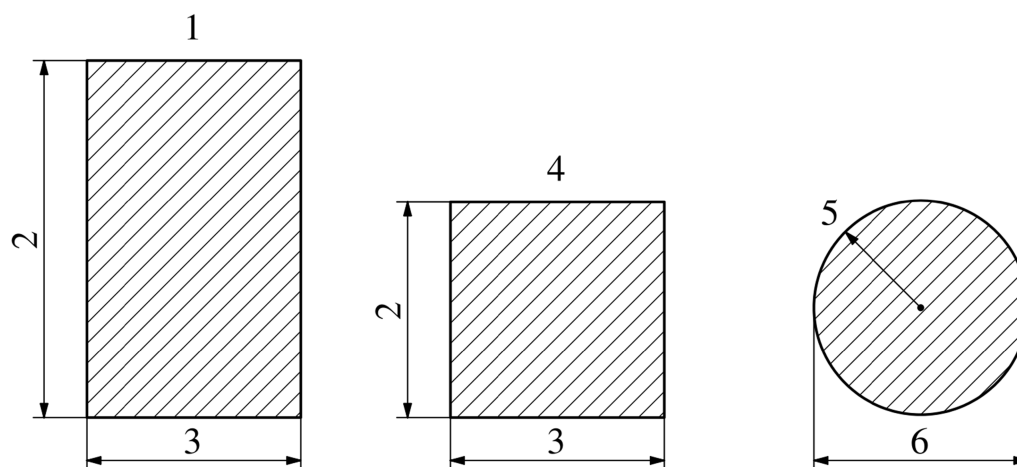
5.3 Number of specimens

The number of specimens depends on the scope of testing (see 5.1 and 5.6). The specimens shall be tested with mechanical tensile load. Since the loaded tests are usually only performed in one bar orientation, i.e. horizontally, additional unloaded specimens can be tested to assess the influence of other bar orientations and thus to increase the intended scope of application (see Clause 12).

5.4 Size of specimens

5.4.1 General

The cross-section of the steel bar is characterized by the profile type, the largest cross-sectional dimension (s) and the section factor (A_m/V). The steel bar can have a rectangular (including square) or circular shape (see Figure 3). The size of rectangular solid bars is defined by the width (b) and the height (h). The height of rectangular bars shall be always larger than the width. For circular solid bars the radius (r) or the diameter (D) characterizes the size of the cross-section. The largest cross-sectional dimension of a specimen is equal to the height of a rectangular bar or the diameter of a circular bar. The section factor is the ratio of the fire exposed outer perimeter area of the steel bar per unit length to its cross-sectional volume per unit length.



Key

Left	rectangular bar ($h \geq b$)
Middle	square bar
Right	circular bar
1	$h \geq b$
2	height (h)
3	width (b)
4	Square bar ($h = b$)
5	radius (r)
6	diameter (D)

Figure 3 — Possible profile types (cross-sectional shapes of a steel bar to be tested)

The length of the mechanically loaded specimen depends on the fire exposed length of the specimen (L_F) within the furnace and the required length to connect the specimen with the load frame and the hydraulic actuator outside of the furnace. The fire exposed length of the specimen shall be at least fifteen times the largest cross-sectional dimension (s), but not less than 1 000 mm (see Construction of steel specimens

5.4.2 Steel specification

The grade of steel used shall be any structural grade (S designation) to EN 10025-1, excluding S185. Engineering grades (E designation) shall not be used. The actual dimensions of the steel bar shall be measured. For the calculation of the tensile load, see 6.4, the actual steel strength at room temperature (for hot-rolled steel $f_{y,20^\circ\text{C}}$; for cold-formed steel $f_{p0.2,20^\circ\text{C}}$) shall be determined (e.g. factory certification or tensile test).

5.4.3 Surface treatment and application of the fire protection material

The surface of the steel shall be prepared and the reactive fire protection system shall be applied to the bars in a manner representative of practice. It is recommended that the reactive fire protection system shall be applied to the entire length of the specimen and not only to the fire exposed length.

Care shall be taken to ensure that during the installation of the specimens into the furnace, or as a result of any movement of the specimens during the test, the reactive fire protection system is not subjected to any expansion or restraint stresses contrary to its use in practice.

5.5 Composition of reactive fire protection system

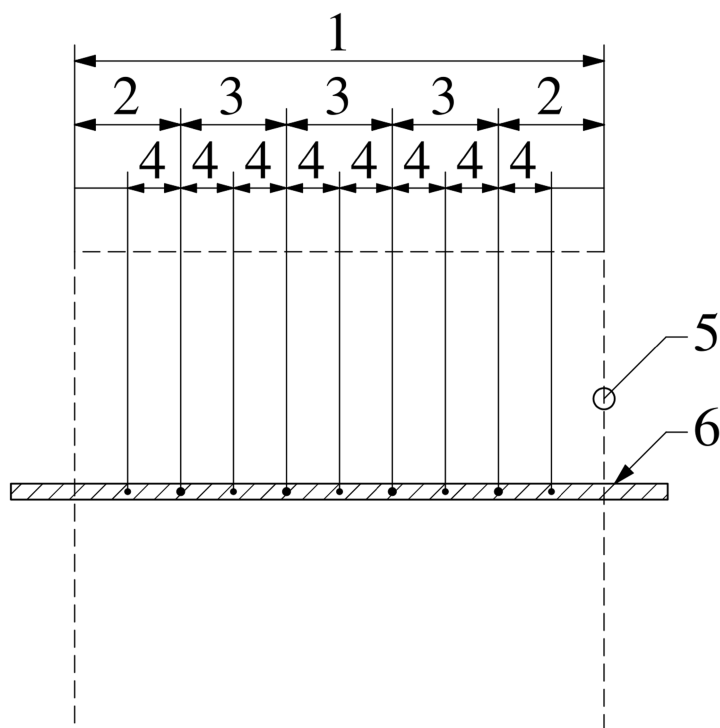
5.5.1 General

The composition, dimensions, verification and properties of the reactive fire protection system shall be determined in accordance with the requirements of EAD 350402-00-1106 - Reactive coatings for fire protection of steel elements. The reactive fire protection system shall be applied after fixing the thermocouples and before applying the mechanical tensile load. The application of the reactive fire protection system shall be applied according to the instruction of the manufacturer.

5.5.2 Thickness of applied reactive fire protection system

The thickness of the reactive fire protection system shall be constant over the entire surface of the specimen and fire exposed length of the specimen. The dry film thickness of the coating excluding primer and top coat shall be measured. Devices used to determine the thickness of reactive fire protection systems on specimens with curved surface shall be calibrated on a similar bar or any other method agreed with the test laboratory.

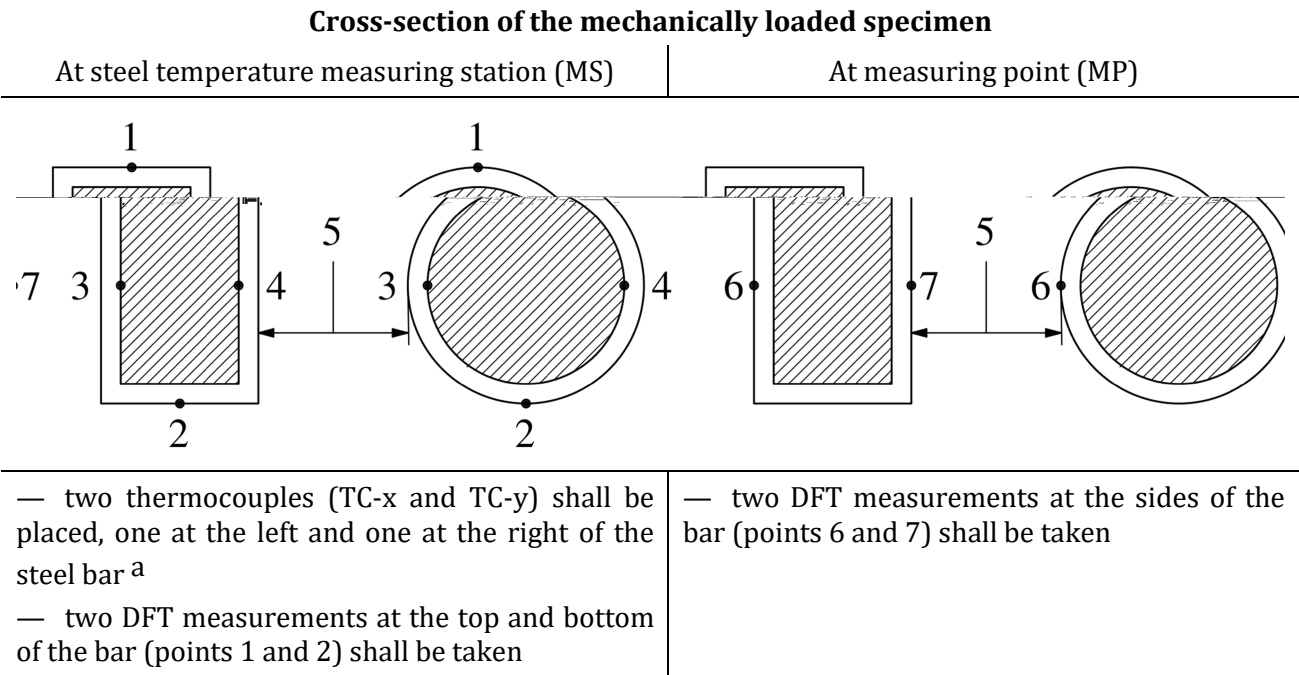
Upper view of the mechanically loaded specimen



Key

- 1 fire exposed length of the specimen ($L_F = 1\,000\text{ mm}$)
- 2 ≤ 200
- 3 200 (steel temperature measuring stations every 200 mm)
- 4 100 (fire protection thickness measuring point every 100 mm)
- 5 furnace interior
- 6 specimen (steel bar)

Figure 4 a — Position of the dry film thickness measurement points



^a Due to the geometric symmetry for steel bars with either circular or square solid section the thermocouple and DFT position can be turned 90° around the cross-section.

Key

- 1 DFT measurement
- 2 DFT measurement
- 3 TC-x
- 4 TC-y
- 5 reactive fire protection system
- 6 DFT measurement
- 7 DFT measurement

Figure 4 b — Position of the dry film thickness measurement points

The thickness of the reactive fire protection material shall be measured at the position of the steel temperature measuring stations as well as 100 mm before and after them (see Figures 4 a and 4 b). At each DFT measurement point two measurements shall be taken. The measurements shall be alternately arranged, i.e. at the position between the thermocouples measure at the left and right side of the bar (point C and D) and at the position of the thermocouples measure the DFT at the top and bottom of the bar (point A and B). At the discretion of the test laboratory, it is acceptable to undertake additional random thickness measurements to ensure even DFT distribution over the surface of the specimen.

To consider deviations between the target thickness selected in the scope of testing and the actual thickness of the reactive fire protection system, the mean value from all fire protection thickness measurements of a bar (DFT_{mean}) shall be used in the assessment. For an uniform DFT along the specimen it is recommended that all measured individual DFT values should not differ from the mean value by more than $\pm 10\%$.

5.6 Selection of specimens

The intended scope of testing will determine the selection of the specimens. The general matrix of the test set is given in Table 2. A change to one of the general parameters requires an additional test set.

Based on the test programme defined in Clause 5 each combination of a steel bar dimension and a fire protection thickness selected in a test set shall be examined by a loaded fire test.

Table 2 — Template of a test set for fire tests of steel bars with fire protection material

Table of general parameter of tested steel bar					
Fire resistance class: ...					
Steel grade: ...					
Fire exposed length of the steel bar: ...					
Shape of the steel bar: ...					
Fire protection material: ...					
Load utilization factor μ_{fi} : ...					
Orientation of the steel bar ^a : ...					
Variable parameters					Number of loaded fire tests
Steel dimension	A_m/V	Diameter / $b \times h$	Protection thickness b	Design steel temperature range	
[-]	$[m^{-1}]$	[mm]	[mm]	[°C]	[-]
Small profile	max	min	...	...	1
Intermediate profile	int	int	...		...
Large profile	min	max	...		1
A test set shall consist at least of a small and a large profile. It is possible to add one or several intermediate steel profiles to the test set.					
^a To enable the use of reactive fire protection materials for all bar orientations, unloaded fire tests according to Chapter 0 shall be carried out to assess the performance of the product. Each test set requires an unloaded fire test, where the specimens shall have same profile type and the same dimension of the small profile as well as the corresponding DFT in this test set.					
^b The individual thickness of protection material (minimum/maximum) shall be selected based on the intended scope of application.					

6 Installation of the specimens

6.1 Specimen installation patterns

The specimens should be positioned within the furnace to ensure the specimens are not shielded or affected by furnace walls, other specimens or obstacles. A minimum distance of separation of 300 mm is required. Specimens should be placed to avoid direct impact from the furnace burner (see also 4.2).

6.2 Installation of the steel bars

The installation of the mechanically loaded steel bar is described in 5.2.

The installation of the unloaded steel bars is described in 12.2.

6.3 Furnace load

The burners shall ensure a heating of the furnace according to the standard temperature/time curve given in EN 1363-1.

Fire tests with the slow heating (smouldering fire) temperature/time curve are described in Annex E.

6.4 Mechanical tensile load

The tensile load (F_{Load}) applied to the mechanically loaded steel bar depends on the load utilization factor in case of fire (μ_{fi}), the actual cross-sectional area of the specimen $A_{section}$, the actual steel strength at ambient temperature ($f_{y,20^{\circ}C}$ or $f_{p0.2,20^{\circ}C}$) and can be calculated according to Formula (1) a) for hot-rolled steel and Formula (1) b) for cold-formed steel. The actual steel strength at ambient temperature shall be determined from a 3.1 certificate according to EN 10204 or from a tensile test according to EN ISO 6892-1. A load utilization factor in case of fire of $\mu_{fi} = 0,65$ corresponds to a fully utilized steel bar at ambient temperature ($\mu_0 = 1,0$). If sheath thermocouples are used for the steel temperature measurement the boreholes required for the attachment shall not be considered, i.e. ignored, in the calculation of the cross-sectional area. The application of the tensile load shall be completed at least 15 min before the fire test and shall be kept constant over the entire duration of the fire test. The accuracy of the actuators shall not be worse than class 2 according to EN ISO 7500-1. The target value of the tensile load shall be calculated according to the Formulae (1 a) and (1 b). The mechanical loading ends with the rupture of the specimen. The load can also be removed, when the limiting temperature defined in the scope of testing (see 5.1) is reached. However, this may reduce the potential field of application.

$$F_{Load} = f_{y,20^{\circ}C} \cdot A_{section} \cdot \mu_{fi} \quad [kN] \quad (1 a)$$

$$F_{Load} = f_{p0.2,20^{\circ}C} \cdot A_{section} \cdot \mu_{fi} \quad [kN] \quad (1 b)$$

7 Conditioning of the specimens

The reactive fire protection system, its components and any test samples taken for determination of material properties shall be conditioned as required in EN 1363-1 or for a period specified by the manufacturer for adequate curing.

8 Application of instrumentation

8.1 General

The instrumentation for measurement of steel and furnace temperature, furnace pressure, tensile load and longitudinal deformation of the loaded specimens shall comply with the requirements of EN 1363-1.

8.2 Instrumentation for the measurement of test load and deformation

Load application (according to 6.4) is used at least 15 min before the fire test. During the fire test the deformation shall be measured continuously (not exceeding 1 min) until rupture of the steel bar. The measured deformation of the steel bar will be used in the assessment in 11.2, Table 5.

The instrumentation for measuring the applied tensile load and measured deformation shall be provided and used as specified in EN 1363-1. A computer-based controlling of the loading system and deformation measurement is recommended.

8.3 Instrumentation for measurement and control of the furnace temperature

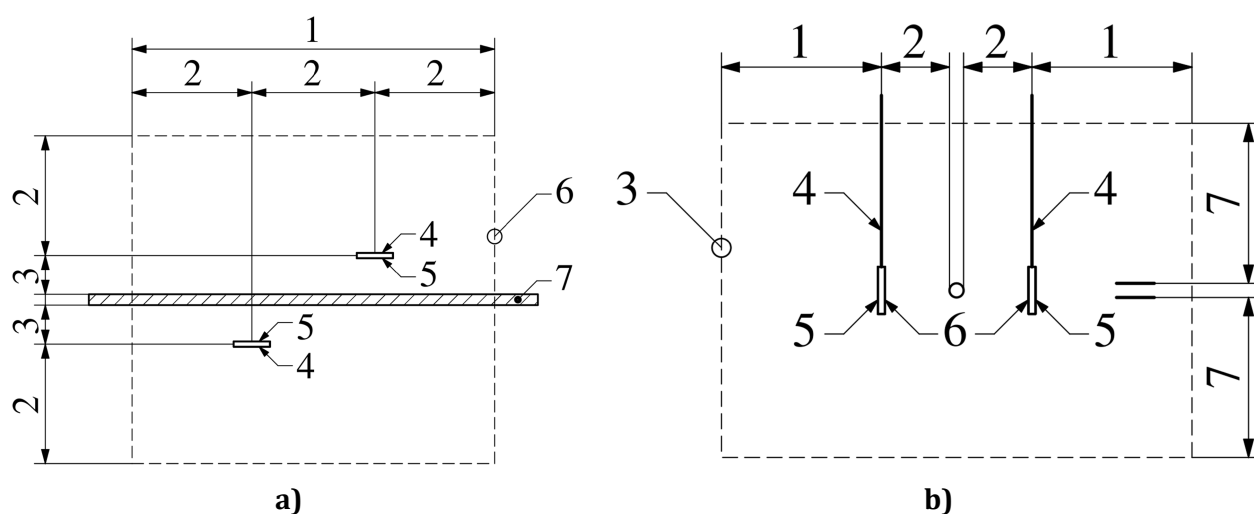
8.3.1 General

Plate thermocouples, of the type specified in EN 1363-1, shall be provided to measure and control the temperature of the furnace and shall be uniformly distributed, as given in EN 1363-1 unless otherwise stated in this document, to give a reliable indication of the temperature in the region of the specimen. The plate thermocouples shall not be placed in positions where they are unable to measure the furnace temperature correctly because they are obstructed by the specimen or other obstacles.

8.3.2 Furnace temperature

Furnace temperatures shall be measured by calibrated and certified plate thermocouples. They shall be located as specified in the following text and as illustrated in Figure 6. At each mechanically loaded specimen at least two plate thermocouples shall be installed in the furnace. The plate thermocouples shall be positioned in such a way that they are not in contact with flames from the furnace burners and that they are at least 300 mm away from any wall, floor or roof of the furnace. They shall be placed adjacent to the steel bar with a lateral distance of about $100 \text{ mm} \pm 50 \text{ mm}$. Usually, at each side of the mechanically loaded steel bar one plate thermocouple should be positioned (see Figure 5). The insulated side of the plate thermocouple (side B) shall face to the specimen and the other one (side A) to the side walls of the furnace.

For fire test with unloaded steel bars, the furnace temperature instrumentation is specified in 12.2.

**Key a)**

- 1 ≥ 300 mm
- 2 (100 ± 50) mm
- 3 furnace wall
- 4 plate thermocouples (P_t)
- 5 side A
- 6 side B
- 7 ≥ 300 mm

Key b)

- 1 fire exposed length of the specimen ($L_F = 1\,000$ mm)
- 2 ≥ 300 mm
- 3 plate thermocouples (P_t)
- 4 side A
- 5 side B
- 6 furnace wall
- 7 specimen (steel bar)

**Figure 5 — Schematic position of plate thermocouple in furnace:
a) transverse cross-section of furnace; b) upper view of furnace**

8.4 Instrumentation for the measurement of the steel temperature

Thermocouples for measurement and recording of steel temperatures of the bars shall be sheath or flexible thermocouples with a calibration certificate. The accuracy provided by calibration certificate of the thermocouple shall be included in the test report.

Several different kinds of thermocouple wire are suitable, including types "T", "N", "K" and "J" as specified in IEC 60584-1. It is preferable that mineral-insulated stainless steel sheathed thermocouples with an isolated hot junction are used; the overall diameter over the sheath shall be at least 1,5 mm.

Other thermocouples may be used subject to consultation between the laboratory and the test sponsor regarding their suitability. Suitable thermocouples shall be provided with individual wires at least 0,5 mm in diameter and be provided with insulation between the two wires and between each wire and any external conducting material such that there is no failure during test.

To measure the steel temperature, measuring stations shall be provided every 200 mm along the longitudinal axis of the mechanically loaded steel bar. A mechanically loaded steel bar with a fire exposed length of 1 000 mm requires a minimum of four measuring stations (see Figure 4). Specimens with a higher fire exposed length require additional measuring stations. At each measuring station two measuring points shall be arranged on the circumference of the steel bar (see Figure 6). The steel temperature should not be measured at corners of the cross-section. Instrumentation for measurement of the steel temperature at unloaded steel bars is given in 12.2.

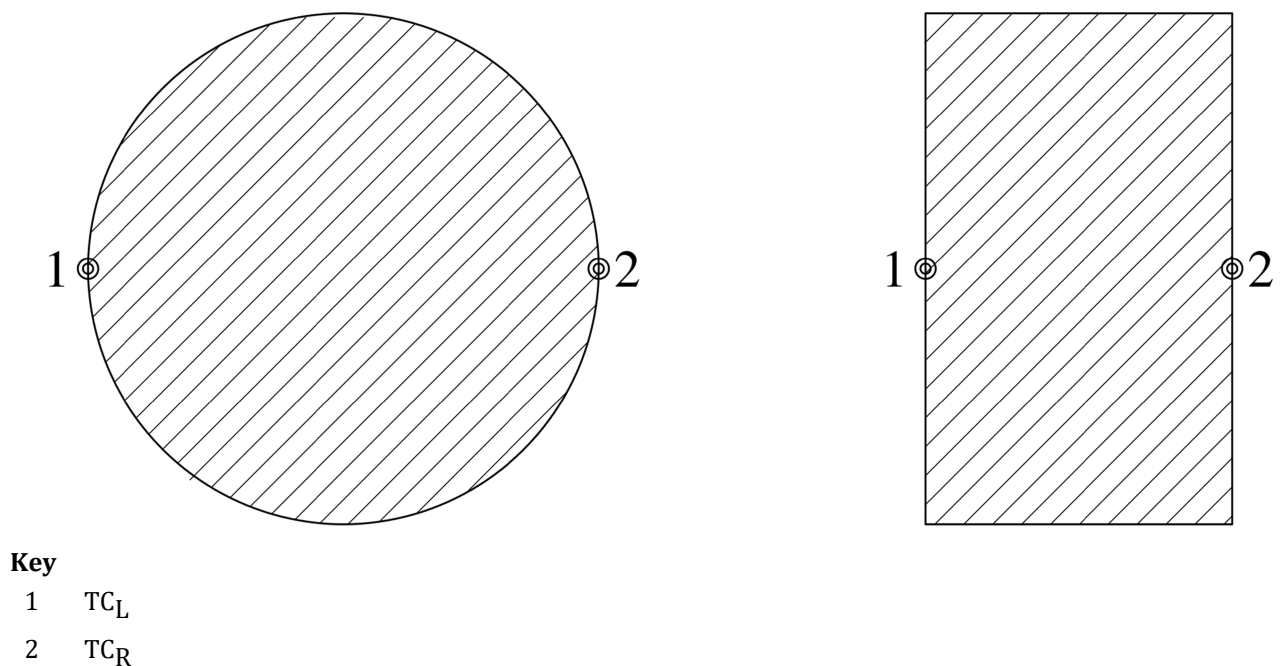


Figure 6 — Position of the thermocouples (TC) at the cross-section of the steel bar

The thermocouples for measuring the steel temperature shall be attached to the steel bar before the application of the fire protection material. Flexible thermocouples shall be attached to the steel bar surface by spot welding. To prevent the unravel of the insulation of the flexible thermocouple cable, the use of a shrink tube is recommended (see Figure 7). The shrink tube should be applied before the thermocouple is attached to the specimen. The shrink tube should end before the strain relief starts. Sheath thermocouples shall be attached to the steel bar by peening. The example of attachment of the thermocouples is shown in Figure 7. Generally, the temperature measuring points shall be designed in such a way that the behaviour, performance or structure of the fire protection material is not disturbed. With regards to reactive fire protection systems, a concentration of the coating material at the measuring points shall be omitted.

It is recommended to install the thermocouple cable with a strain relief. The thermocouple cable should run vertically away from the steel bar. In this case the fire protection material is penetrated by the cable. The strain relief should have a length between 25 mm and 75 mm. To not affect the foaming of the reactive fire protection system, the coating material adhering to the thermocouple cables shall be removed before the fire test (see Figure 7).