



BSI Standards Publication

**Determination of the resistance to
hydrocarbon pool fires of fire protection
materials and systems for pressure
vessels — Test method**

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Foreword

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 August 2020. It was prepared by Technical Committee FSH/22, *Fire resistance tests*. A list of organizations represented on this committee can be obtained on request to its committee manager.

Relationship with other publications

BS 8619 was developed to meet an industry demand, using ISO 21843:2018 as a basis. BS 8619 is intended to be compatible with ISO 21843:2018, and will be revised or withdrawn in the future, as appropriate, if ISO 21843:2018 is revised.

Information about this document

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Where websites and webpages have been cited, they are provided for ease of reference and are correct at the time of publication. The location of a webpage or website, or its contents, cannot be guaranteed.

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its methods are expressed as a set of instructions, a description, or in sentences in which the principal auxiliary verb is “shall”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. “organization” rather than “organisation”).

Requirements in this standard are drafted in accordance with *Rules for the structure and drafting of UK standards*, subclause **G.1.1**, which states, “Requirements should be expressed using wording such as: ‘When tested as described in [Annex A](#), the product shall ...’”. This means that only those products that are capable of passing the specified test will be deemed to conform to this standard.

The word “should” is used to express recommendations of this standard. The word “may” is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word “can” is used to express possibility, e.g. a consequence of an action or an event.

Tables and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

0 Introduction

This British Standard describes a test procedure to assess the protection afforded by fire protection materials and systems to pressure vessels. It gives an indication of how fire protection materials perform when exposed to a set of specified fire conditions. Actual vessels can vary in construction from that tested and can utilize additional protection systems. The test conditions have been shown to be representative of the severity of unconfined pool fires fuelled by light and medium oil distillates such as liquid petroleum gas (LPG) and petroleum products.

1 Scope

This British Standard specifies a test method for the determination of the resistance to hydrocarbon pool fires of pressure vessels with a fire protection system when subjected to standard fire exposure conditions. It does not apply to vessels cooled by water deluge or water monitor. The pressure vessel can be classified based on its performance during the test. The design of the pressure vessel is not covered in this British Standard.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions of this document. For dated references, only the edition cited applies.¹⁾ For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN 12542, *LPG equipment and accessories — Static welded steel cylindrical tanks, serially produced for the storage of Liquefied Petroleum Gas (LPG) having a volume not greater than 13 m³ — Design and manufacture*

PD 5500, *Specification for unfired fusion welded pressure vessels*

[N1] IEC Electropedia (<https://www.electropedia.org>)

[N2] ISO Online Browsing Platform (<https://www.iso.org/obp/ui>)

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in the IEC Electropedia [N1], the ISO Online Browsing Platform [N2] and the following apply.

3.1.1 blowdown valve

valve or device that opens to depressurize a pressure vessel

NOTE For example, a fusible plug.

3.1.2 burner system

configuration of the equipment designed to engulf the test specimen in fire, with specific reference to the size, orientation, frequency and spacing of burner heads and the design of fuel supply piping

¹⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

3.1.3 burst pressure (calculated burst pressure)

vessel pressure that gives a hoop stress equal to the ultimate strength of the vessel material at the specific critical wall temperature of interest

NOTE Stress rupture analysis is also considered a realistic failure mode for long duration tests.

3.1.4 calibration test

test performed by the laboratory prior to and separate from customer tests, to confirm that the chosen burner system in combination with the desired test specimen can be used

3.1.5 critical pressure

pressure calculated for a given critical wall temperature as the burst pressure divided by a factor of safety

3.1.6 critical temperature

design limiting temperature, or a specified limiting wall temperature, that the vessel wall temperature might reach during fire exposure

NOTE This temperature is related to a factor of safety (FOS) for the vessel when exposed to fire.

3.1.7 directional flame thermometer

passive thermocouple-based sensor that can be used for the measurement of both temperature and heat flux

NOTE A simple design is described in [Annex A](#).

3.1.8 factor of safety (FOS)

ratio of the calculated ultimate strength of the vessel steel at the temperature of interest divided by the actual hoop stress in the vessel

NOTE 1 For example, the temperature of interest might be the critical temperature.

NOTE 2 A typical factor of safety is in the range 2 to 3.

3.1.9 fire protection system

protection afforded to the vessel to reduce the rate of heat transfer from the fire to the vessel throughout the period of exposure to fire, including any protection materials together with any encasement and supporting system and any specified primer and top coat if applicable

NOTE 1 For example, an encasement might be a jacket.

NOTE 2 For example, a supporting system might be mesh reinforcement or a framing system.

NOTE 3 A fire protection system is also referred to as a "thermal protection system".

3.1.10 pool fire

hydrocarbon diffusion fire that occurs over a static or flowing release of flammable liquids

NOTE The pool fire simulates large turbulent diffusion flames that are strongly radiating.

3.1.11 pressure relief valve

pressure-activated valve intended to limit pressure rise to a specified value

NOTE These valves have set opening and reclosing pressures.

3.1.12 pressure vessel

vessel capable of containing pressures significantly above ambient, even if normal operational procedure does not involve pressure rise above ambient

NOTE Pressure vessels are often referred to as vessels or tanks.

3.1.13 radiation-convection balance

fraction or percentage of total heat transfer to a cool surface that is due to radiation

NOTE The cool surface might be a water-cooled calorimeter at a temperature of up to 373 K.

3.1.14 test related tube and pipe

additional tube or pipe added to the vessel for the purposes of performing tests

NOTE They might not be present on the real application vessel.

3.1.15 total containment pressure vessel

pressure vessel that has no automatic means of pressure relief or depressurization

3.1.16 vessel shell

primary wall of the vessel

3.2 Symbols

For the purposes of this British Standard, the following symbols apply.

A	area (m ²)
A_s	surface area of vessel shell (m ²)
c_s	specific heat capacity of steel (J.kg ⁻¹ K ⁻¹)
c_w	specific heat capacity of water (J.kg ⁻¹ K ⁻¹)
Fl	fire-line
f_{rad}	radiation fraction
h	heat transfer coefficient (W.m ⁻² K ⁻²)
L_{line}	path length, equal to the depth of fire at the measuring point (m)
L_m	mean path length for the flame volume, equal to 1.8 L , where L is the depth of fire at the measuring point (m)
m	measuring point
m	mass (kg)
m_s	mass of steel (kg)
m_w	mass of water (kg)
q_{conv}	heat flux due to convection (W.m ⁻²)
q_{net}	net absorbed heat flux (W.m ⁻²)
q_{rad}	heat flux due to radiation (W.m ⁻²)
T	temperature (K)
T_{amb}	average ambient temperature during the calibration test period (K)

T_{cal}	calorimeter temperature (K)
$T_{\text{cal-indic}}$	indicated calorimeter vessel temperature (K)
T_{DFT}	DFT temperature (K)
$T_{\text{DFT-av}}$	average of all valid DFT average temperature values (K)
$T_{\text{DFT-indic}}$	indicated DFT vessel temperature (K)
T_{f}	assumed flame temperature (K)
$T_{\text{n,t}}$	temperature of thermocouple (n) at time (t), (K)
$T_{\text{w,0}}$	average water temperature at the start of a test (°C) (see 6.4)
$T_{\text{w,t}}$	average water temperature at time (t), (K)
t	time (s)
t_{t}	duration of test (time of termination) (s)
$\bar{X}$	mean average
α	flame extinction coefficient (m^{-1})
$\Delta T_{\text{s,t}}$	vessel shell temperature, assumed equal to $\bar{\Delta} T_{\text{w,t}}$ (°C)
$\Delta T_{\text{w,t}}$	result of $T_{\text{w,t}} - T_{\text{w,0}}$ (°C)
ε	emissivity
ε_{s}	surface emissivity
ε_{f}	flame emissivity
ε_{fl}	fire-line emissivity
σ	Stefan-Boltzmann constant ($5.67 \times 10^{-8} \text{ W} \cdot \text{m}^{-2} \cdot \text{K}^{-4}$)

3.3 Abbreviations

For the purposes of this British Standard, the following abbreviations apply.

BDV	blowdown valve
DFT	directional flame thermometer
FOS	factor of safety
LPG	liquid petroleum gas
P&I	pipng and instrumentation
PFP system	pre-fabricated protective system
PRV	pressure relief valve
R-C balance	radiation-convection balance
TC	thermocouple

4 Principle

This method provides an indication of how vessels protected with fire protection materials, or systems, perform when exposed to pool fires on solid surfaces. It simulates the thermal loads to a vessel engulfed in a large pool fire through the use of burners to create a flame capable of engulfing a vessel. The simulated liquid hydrocarbon pool fire achieves a heat flux to a cool surface of 90 kW.m^{-2} to 120 kW.m^{-2} .

NOTE The literature suggests that heat flux to a cool surface in a large pool fire is 80% to 90% due to radiation and the remainder is by convection.

To ensure that suitable test conditions are achieved and maintained, it describes calibration tests to be performed prior to fire testing, sets permitted tolerances from the calibrated set-up, and delimits environmental conditions.

5 Apparatus

COMMENTARY ON CLAUSE 5

Test laboratories should be aware of the significant potential hazards involved in pressure vessels testing. Facilities intending to undertake tests in accordance with this document should be designed to be safe in the event of vessel failure.

Apparatus employed in the testing should consist of the following:

- a) a specially designed burner system to subject the test specimen to the conditions specified in the calibration section;*
- b) propane storage capable of fuelling the test for the required duration;*
- c) equipment to control and monitor the propane flow rate throughout the test; and*
- d) equipment to vent and purge the vessel after testing.*

An example P&I diagram for a vessel testing facility is shown in [Annex B](#).

5.1 Burner system

Liquid propane fuelled burners shall be used to simulate a pool fire.

NOTE 1 Burners are used because they provide more control over the test conditions.

The burner system shall be designed so that the resulting heat flux has a radiation fraction greater than 75%.

NOTE 2 The burner system should produce a low momentum and luminous fire of sufficient thickness so that the resulting heat flux is predominantly by radiation.

Burners shall be designed to achieve total engulfment and uniformity of heating that shall be present on all four sides of the vessel. The maximum nozzle spacing shall be not greater than 500 mm.

The burner system shall be designed to receive equal mass flow rates of propane to two diametrically opposite locations at the ends of the vessel to ensure broadly symmetrical heating. The supply line length and fittings shall also be designed to ensure equal propane flow to the burner system and all supply lines. Cooling of the supply shall be provided as necessary to protect the burner supply for the duration of the test.

The burner system shall be designed to ensure stabilization of the flow rate and stabilization of the flame temperatures, as defined by DFTs in [6.2](#), which shall be achieved within 2 min of the test commencing.

NOTE 3 The burner system may be varied by the test laboratory to meet the calibration requirements. For informative purposes, an example of a burner system is shown in [Annex A](#).

5.2 Fuel supply for a burner system

The burner system fuel shall be commercial propane or LPG. The fuel supply shall be capable of delivering up to 1.0 kg/s to the burner system and controlling the flow rate to within ± 0.05 kg/s of the target flow rate as determined by calibration testing.

5.3 Test fluids

The test fluid for the test vessel shall be commercial propane or LPG. Means of filling the test vessel (including air purge) prior to a test, and purging the vessel subsequent to the test to allow safe inspection, shall be provided.

NOTE 1 Equipment to pump or push test fluid from the test vessel back to a storage vessel after the test may be utilized.

NOTE 2 A means of determining the total test fluid loss from the test vessel throughout the test may be provided. This may be done by placing the vessel on a weighing device, via internal instrumentation, or by capturing and measuring the loss from the vessel at the end of any PRV simulation pipe.

5.4 Test enclosure

COMMENTARY ON 5.4

Large-scale exterior fire tests are subject to environmentally induced variations due to wind.

If the test is not protected from the environment through the use of an enclosure in the form of a shed or a building, stricter tolerances in deviation from the environmental conditions recorded during the calibration tests shall be applied.

NOTE These tolerances are set out in [6.7](#).

If environmental protection is used, it shall be suitably enclosed on all four sides and have full roof coverage. Openings for ventilation shall be equally distributed and sized, so far as is practicable.

6 Calibration tests

6.1 General

Three valid calibration tests shall be performed before a fire burner system and test configuration are deemed suitable as the basis for fire testing.

NOTE 1 This is due to the variations involved in external large-scale testing.

The net absorbed heat flux to a water-filled vessel shall be determined and DFTs shall be used to assess both the uniformity of heating and the R-C balance. A thermal imager shall be used to confirm uniformity of heating and R-C balance in the calibration tests. All three tests shall be set up and performed in accordance with [6.2](#) and [6.3](#) and shall use the same vessel, burner system and test parameters.

NOTE 2 See [Annex C](#) for methods to estimate the R-C balance.

The calibration test results shall be assessed in accordance with [6.4](#). Once a calibration test configuration has conformed to [6.5](#), it shall be deemed suitable for testing of actual fire test specimens in environmental conditions as defined in [6.6](#). The tolerances in variation from the calibration test set up during actual fire testing shall be in accordance with [6.7](#).

Calibration testing shall be repeated in the event of any:

- a) modifications to the test specimen beyond the tolerances set out in [6.7](#);
- b) modifications to the burner or nozzle arrangement or burner system fuel flow rate;
- c) significant modifications to the apparatus or test enclosure; or
- d) departure from the environmental conditions as defined in [6.6](#).

Calibration tests shall be performed every three years as a minimum, even in the event of no changes as listed above, to ensure equipment functions as intended. Calibration test results shall be written up as calibration reports in accordance with [6.8](#) and retained by the test laboratory for reference when conducting future fire tests.

6.2 Calibration test vessel construction

The calibration vessel shall be manufactured in accordance with PD 5500. It shall have a minimum diameter of 1 200 mm, and a minimum length of 2 000 mm. The vessel shall be supported on two steel saddles, which shall be insulated or water-cooled. No fire protection materials or system shall be installed on the calibration vessel shell.

A vent shall be cut at the top of the vessel to permit extraction of TCs and to prevent pressurization during calibration. An agitator shall be installed within the vessel, located as close as practicable to the centre. Only connecting piping used for the operation of the agitator shall be permitted to be connected to the agitator.

NOTE 1 The piping may be water-cooled if necessary.

Any covers or guards for gauges and connections shall be removed, and all remaining connections shall be sealed.

The vessel shell shall be instrumented with 16 DFTs. DFTs shall be attached to the vessel in locations shown in [Figure 1](#). TCs that conflict with saddles shall be moved horizontally towards the middle of the vessel until they are at least 250 mm from the saddle.

NOTE 2 A simple design of a DFT is given as an example in [Annex A](#).

Individual TCs that conflict with the position of lifting lugs or fittings shall be moved by up to 150 mm.

The calibration vessel shall be internally instrumented with ten insulated type k TCs (1.5 mm minimum diameter) for measurement of the water temperature. The internal TCs shall be located at two stations $\frac{1}{3}$ and $\frac{2}{3}$ along the primary axis of the vessel between the tangent lines as shown in [Figure 2](#).

NOTE 3 Tangent lines are often referred to as tan lines.

The TCs shall be spaced to measure the temperature of five horizontal zones of equal volume. The vessel shall be filled 100% with water and a splash cover shall be added.

NOTE 4 The splash cover minimizes splash cooling of the outer top surface of the vessel during fire exposure, without allowing pressurization of the vessel.

NOTE 5 A thermal imager with an appropriate temperature range and resolution may be used to view the fire to assist in the confirmation of R-C balance.

Figure 1 consists of two diagrams illustrating the DFT positions on a cylindrical vessel. The top diagram is a cross-section of the vessel, showing a circle with 16 DFT positions marked by small circles and numbered 1 through 16. The positions are distributed as follows: 1, 15 and 2, 16 are on the vertical centerline; 3, 7, 11 and 4, 8, 12 are on the top half; 5, 9, 13 and 6, 10, 14 are on the bottom half. The bottom diagram is a longitudinal section of the vessel, showing a rectangle with rounded ends. The total length is L, and the radius is r. The DFT positions are distributed as follows: 1, 15 and 2, 16 are on the top and bottom of the central part; 3, 7, 11 and 4, 8, 12 are on the top of the central part; 5, 9, 13 and 6, 10, 14 are on the bottom of the central part. The longitudinal section also shows the vessel is divided into three parts: a central cylindrical part of length L and two hemispherical end caps of radius r.

Key

1 to 16 DFT positions

L Length of cylindrical part body of vessel (tan to tan length)

L_{int}
$$\frac{L + r \left(1 + \frac{1 - e^2}{e} \tanh^{-1} e \right)}{4}$$

where:

$$e^2 = \frac{x^2}{r^2}$$