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

Détermination de la résistance aux feux de nappe d'hydrocarbure des matériaux et systèmes de protection incendie des récipients sous pression

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Foreword

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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).

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

For an explanation of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 2, *Fire containment*.

This second edition cancels and replaces the first edition (ISO 21843:2018), which has been technically revised.

The main changes are as follows:

— the calibration conditions have been modified;

— an alternative method for confirming test conditions has been provided.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document describes a test procedure for assessing 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 liquefied petroleum gas (LPG) and petroleum products.

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

1 Scope

This document specifies a test method for determining the fire resistance of pressure vessels with a fire protection system when subjected to standard fire exposure conditions. It does not address vessels cooled by water deluge or water monitor. The test data thus obtained permits subsequent classification on the basis of the duration for which the performance of the pressure vessel under these conditions satisfies specified criteria. The design of the pressure vessel is not covered in this document.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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
blowdown valve
BDV
blowdown device
valve or device that opens to depressurize a pressure vessel

EXAMPLE Fusible plug.

3.2
burner arrangement
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

3.3
burst pressure
calculated burst pressure
<vessel> pressure at which the vessel is expected to fail based on the known vessel and material properties and the peak wall temperatures

Note 1 to entry: The burst pressure depends on how quickly and severely the vessel is heated. One approximate estimate of the burst pressure is that pressure that gives a hoop stress equal to the yield strength of the vessel material at the specific wall temperature of interest.

Note 2 to entry: Other failure criteria can be more appropriate. For long duration tests, high temperature stress rupture analysis is also considered a realistic failure mode.

3.4
calibration test
test performed by the laboratory prior and separate to customer tests, to confirm that the chosen burner arrangement in combination with the desired test specimen conforms to the required conditions of this document

3.5
critical pressure
pressure calculated for a given critical wall temperature as the burst pressure divided by a factor of safety (FOS)

3.6
critical temperature
design limiting temperature, or a specified limiting wall temperature, that the vessel wall temperature is required not to exceed during fire exposure

Note 1 to entry: This temperature is related to a factor of safety (FOS) for the vessel when exposed to fire.

3.7
directional flame thermometer
DFT
passive thermocouple-based sensor that can be used for the estimation of the fire-effective blackbody temperature and radiation convection balance

Note 1 to entry: Various designs are available. A simple design is described in this document.

3.8
factor of safety
FOS
ratio of the actual burst pressure of the vessel at the temperature of interest (e.g. critical temperature) divided by the actual working pressure in the vessel

Note 1 to entry: A typical FOS at ambient temperature conditions is in the range of 2 to 3.

3.9
fire protection system
thermal 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 (such as a jacket), and supporting system (such as mesh reinforcement or a framing system) and any specified primer and top coat if applicable

Note 1 to entry: Often referred to as a thermal protection system in North America.

3.10
pool fire
hydrocarbon diffusion fire that occurs over a static or flowing release of flammable liquids

Note 1 to entry: It simulates large turbulent diffusion flames that are strongly radiating.

3.11
pressure relief valve
pressure safety valve
PRV
pressure-activated valve intended to limit pressure rise to a specified value

Note 1 to entry: These valves have set opening and reclosing pressures.

3.12
pressure vessel
vessel capable of containing pressures significantly above ambient, even if normal operational procedure does not involve pressure rise above ambient

Note 1 to entry: Pressure vessels are often referred to as vessels or tanks.

3.13
radiation-convection balance
fraction or percentage of the total heat transfer to a cool surface that is due to thermal radiation

Note 1 to entry: The cool surface may be a water-cooled calorimeter at a temperature of under 120 °C.

3.14
test-related tube and pipe
additional tube or pipe added to the vessel for the purposes of performing the tests

Note 1 to entry: These can potentially not be present on the real application vessel.

3.15
vessel shell
primary wall of the vessel

4 Symbols

$\Delta T_{S,m}$	vessel shell temperature, at time m, assumed to be equal to $\Delta T_{w,m}$
$\Delta T_{w,m}$	result of $T_{w,m} - T_{w,0}$
A_S	surface area of vessel shell
c_s	specific heat capacity of steel
c_w	specific heat capacity of water
e	Euler's number
f_{rad}	radiation fraction
h	convection heat transfer coefficient
L	length
L_{int}	intermediate length
m_s	mass of steel
m_w	mass of water
P	pressure
P_m	measured pressure
P_u	burst pressure based on the ultimate tensile strength
P_y	burst pressure based on the yield strength
q_{conv}	convection component (heat flux due to convection)
q_{net}	net heat flux

q_{rad} radiation component (heat flux due to radiation)

r radius

T_{amb} ambient temperature

T_{cal} calorimeter temperature

T_{DFT} directional flame thermometer temperature

T_{f} flame temperature

$T_{n,m}$ temperature of thermocouple n at time m.

$T_{w,m}$ average water temperature at time m;

t time

t_{T} duration of test (time of termination)

$\overline{X}$ mean average

ε_{f} fire emissivity

ε_{s} surface emissivity

σ Stefan-Boltzmann constant (5,67 × 10^{-8} W·m^{-2}·K^{-4})

t time

5 Principle

The method described in this document 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. 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.

6 Test equipment

6.1 General

The test procedure is intended to simulate a liquid hydrocarbon pool fire that achieves a steady heat flux to a cool surface of 90 kW/m^2 to 120 kW/m^2 over a specified period of time.

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

An example piping and instrumentation diagram for a vessel testing facility is shown in Annex A. Test equipment employed in the conduct of the test consists essentially of the following:

a) a specially designed burner arrangement 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;

d) equipment to vent and purge the vessel after testing.

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.

6.2 Burner arrangement

This test procedure uses liquid-propane-fuelled burners to simulate a pool fire. Burners are used because they provide more control over the test conditions. The burner system shall be designed to produce a low momentum and luminous fire of sufficient thickness so that the resulting heat flux is predominantly by radiation (i.e. radiation fraction greater than 75 %).

To simulate pool fire conditions a burner system shall be used. Burners shall be designed to achieve total engulfment and uniformity of heating and shall be present on all four sides and both ends of the vessel. The maximum nozzle spacing shall be no greater than 0,5 m.

The burner design can be varied by the test laboratory to meet the calibration requirements; for informative purposes, an example of burner design is shown in Annex A.

The burner arrangement 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 arrangement 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 fuel flow rate and stabilization of the flame temperatures [as defined by directional flame thermometers (DFTs) in Clause 9 and Annex B] within 2 min of the flame ignition and test commencing.

6.3 Fuel supply for burners

The burner system fuel shall be commercial propane or LPG. The fuel supply shall be capable of delivering up to 1,2 kg/s to the burner arrangement and controlling the flow rate to within ±0,05 kg/s of the target flow rate as determined by calibration testing.

6.4 Test fluids

The test fluid for the test vessel shall be commercial propane or LPG or any other fluid specified by the sponsor. Means of filling the test vessel (including air purge) prior to a test, and purging the vessel after the test to allow safe inspection, shall be provided. Equipment to pump or push liquid propane from the test vessel back to a storage vessel after the test may be utilized. A means of determining the total propane loss from the test vessel throughout the test shall be available.

6.5 Test building

Large-scale exterior fire tests are subject to environmentally-induced variations due to wind. Stricter tolerances in deviation from the as-tested environmental conditions are imposed for testing if the test is not protected from the environment through the use of an enclosure in the form of a shed or building. These tolerances are described in 7.7.

If used, environmental protection 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.

7 Calibration tests

7.1 General requirements

Due to the variations involved in external large-scale testing, it is required to successfully perform three calibration tests before a particular fire burner system and test configuration is considered suitable as the basis for fire testing.

The net heat flux to a water-filled vessel shall be determined and DFTs shall be used to assess both the uniformity of heating and the radiation-convection balance. A thermal imager shall also be used to confirm uniformity of heating and radiation-convection balance in the calibration tests. See Annex D for methods to estimate the radiation-convection balance. All three tests shall be performed in accordance with 7.2 and 7.3 and shall use the same vessel, burner configurations and test parameters.

The calibration test results shall be assessed in accordance with 7.4. Once a test configuration has met the requirements in 7.5, it shall be considered suitable for testing of actual test specimens in environmental conditions as defined in 7.6. The tolerances in variation from the calibration test set up during actual fire testing are given in 7.7.

Calibration testing should be repeated in the event of any modifications to the test specimen beyond the permitted tolerances in 7.7, any modifications to the burner or nozzle arrangement or propane flow rate, any significant modifications to the test equipment or test building, or any departure from the environmental conditions as defined in 7.6.

Calibration tests shall be performed at least every three years, 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 as described in 7.8 and retained by the test laboratory for reference when conducting future fire tests.

7.2 Calibration test vessel construction

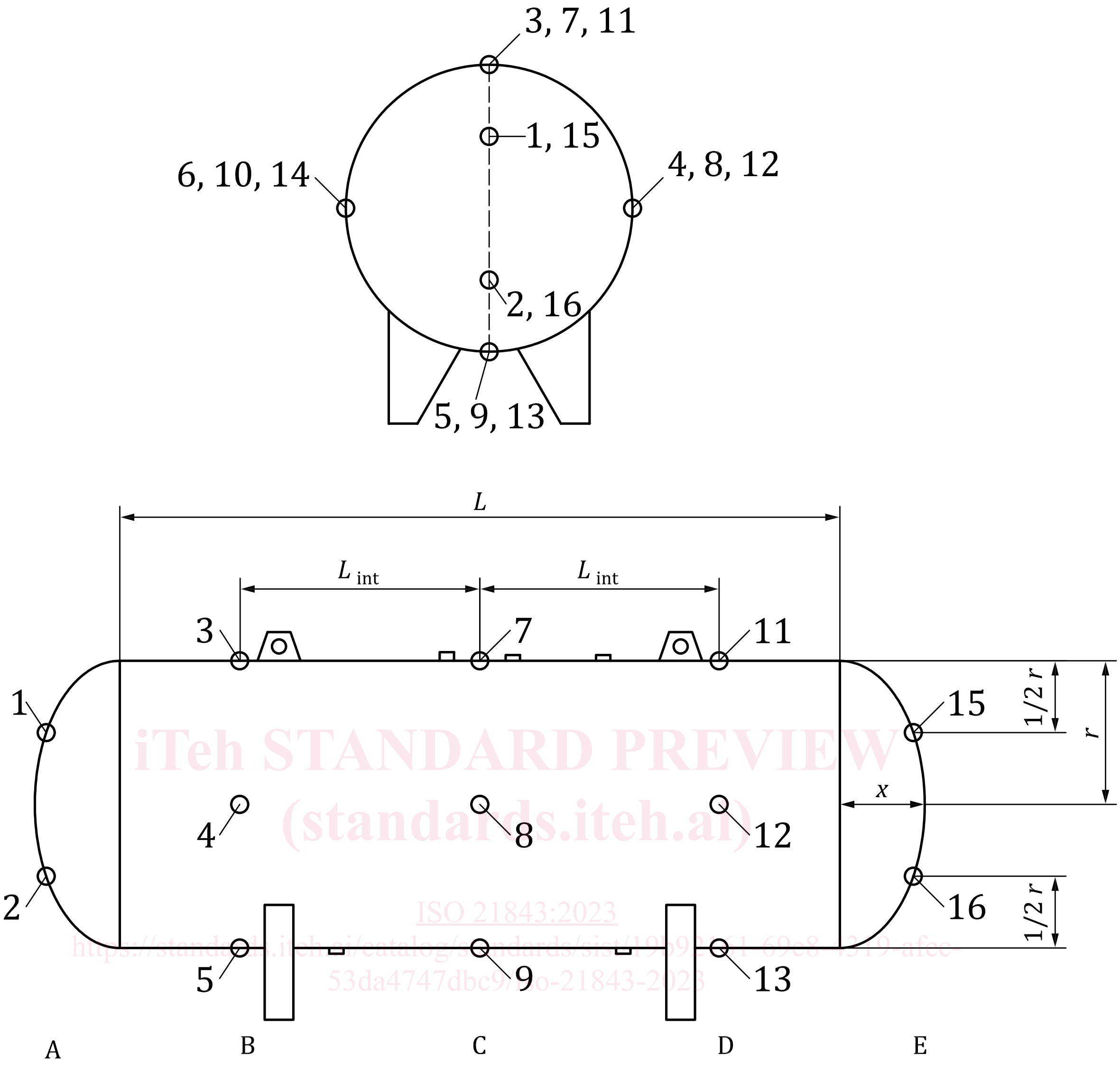
The calibration vessel shall be manufactured according to appropriate pressure vessel regulations. It shall have a minimum diameter of 1 200 mm, and a minimum length of 2 000 mm. The vessel shall be supported on two steel saddles, which shall be insulated or water-cooled. No fire protection materials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

An appropriately sized vent shall be cut at the top of the vessel to permit extraction of thermocouples (TCs) and to prevent pressurization during calibration testing. An agitator shall be installed within the vessel, located close to the middle to mix the water to maintain near uniform temperature. Only connecting piping required for operation of the agitator is permitted, and this 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 calibration vessel shell shall be instrumented with 16 DFTs. A simple design of DFTs is given as an example in Annex B. DFTs shall be attached to the vessel facing out into the fire in locations shown in Figure 1. Individual TCs that conflict with the position of lifting lugs or fittings may be moved by up to 0,15 m. TCs that conflict with saddles shall be moved horizontally towards the middle of the vessel until they are at least 0,25 m from the saddle.

The calibration vessel shall be internally instrumented with 10 insulated type k TCs (1,5 mm minimum diameter, 3 mm maximum diameter) for measurement of the water temperature. The internal TCs shall be located at two stations 1/3 and 2/3 along the primary axis of the vessel between the tangent lines (often referred to as tan lines) as shown in Figure 2. 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 added to minimize splash cooling of the outer top surface of the vessel and DFTs during the fire, without allowing pressurization of the vessel.

A thermal imager with an appropriate temperature range and resolution (at least 480 pixels × 240 pixels) shall be used to view the fire to assist in the confirmation of radiation-convection balance.



Key

1 to 16 directional flame thermometer (DFT) positions

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

L_{int} intermediate length, calculated using the following formula:

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

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

e Euler's number

x length from cylindrical body part of the vessel to the end of the vessel

Figure 1 — Calibration test vessel

7.3 Calibration test procedure

Unless explicitly stated otherwise, the calibration tests shall be performed in accordance with Clause 11.

