TECHNICAL REPORT

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Determination of the resistance to jet fires of passive fire protection —

Part 2: Guidance on classification and implementation methods

Détermination de la résistance aux feux propulsés de protection passive contre l'incendie —

Partie 2: Directives relatives à la classification et aux méthodes de mise en oeuvre

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Contents

Page

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO/TR 22899-2:2013
https://standards.iteh.ai/catalog/standards/sist/26f50c34-b716-4d15-8a1e-dd97611ccd78/iso-tr-22899-2-2013

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Foreword

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The committee responsible for this document is ISO/TC 92, *Fire safety*, Subcommittee SC 2, *Fire containment*.

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ISO 22899 consists of the following parts, under the general title *Determination of the resistance to jet fires of passive fire protection materials* —:

— *Part 1:General requirements*

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— *Part 2: Guidance on classification and implementation methods* [Technical Report]

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Introduction

The jet fire test described in ISO 22899-1 is one in which some of the properties of passive fire protection materials can be determined. The test specified in ISO 22899-1 is designed to give an indication of how passive fire protection materials will perform in a jet fire. Although the test method has been designed to simulate some of the conditions that occur in an actual jet fire, it cannot reproduce them all exactly and the thermal and mechanical loads do not necessarily coincide. The results of the jet fire test do not guarantee safety but may be used as elements of a fire risk assessment for structures or plant. One should also take into account all the other factors that are pertinent to an assessment of the fire hazard for a particular end use. The jet fire test is not intended to replace the hydrocarbon fire resistance test (ISO/TR 834-3; EN 1363) but is seen as a complementary test.

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Determination of the resistance to jet fires of passive fire protection —

Part 2: Guidance on classification and implementation methods

1 Scope

The test specified in ISO 22899-1 is designed to give an indication of how passive fire protection materials will perform in a jet fire.

This part of ISO 22899 provides:

— background information on the applicability and validation of the jet fire test;

— further details on testing pipe penetration seals;

— guidance on the interpretation of the tests results and on an optional classification system;

— guidance on the combination of results from hydrocarbon furnace tests and resistance to jet fire tests.

ISO 22899-1 describes the thickness of fire protection material (sometimes referred to as passive fire protection; PFP) required to resist the application of a 'jet fire'. This part of ISO 22899 provides information on the 'erosion factor' which is the additional thickness required above and beyond that required to satisfy the relevant criteria of ISO 834 (or other national or regional standards designed to evaluate the fire resistance with respect to a fully developed fire) for the element/construction under test.

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ISO/TR 22899-2:2013
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2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 22899-1, *Determination of the resistance to jet fires of passive fire protection materials — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 22899-1 and the following apply.

3.1
critical temperature
maximum temperature that the equipment, assembly or structure to be protected may be allowed to reach

3.2
critical time
minimum time required to reach the critical temperature

3.3
erosion factor
extra thickness of passive fire protection required when comparing the results from a jet fire test with those from a furnace test on specimens with a similar section factor (e.g. 100 m^{-1}) and period of fire resistance, the critical temperature or critical time or both

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3.4
integrity
ability of a fire barrier to prevent the transmission of flame, smoke, hot and toxic gases

3.5
section factor
ratio of the area per unit length of steel exposed to fire divided by the volume per unit length of the section

Note 1 to entry: The lower the section factor, the slower the rate of heat increase for a given volume of steel. See 9.2 for a more detailed explanation.

4 Symbols and abbreviated terms

A	Heated area per unit length (m^2)
k_0, k_1, k_2	Coefficients of linear regression
S_f	Section factor (m^{-1})
t_{final}	Time (rounded to the nearest half minute) from jet ignition to final jet extinguishment.
$t_{resistance}$	Period (rounded down to the nearest half minute) of fire resistance
$T_{ambient}$	Average initial substrate temperature (°C)
$T_{critical}$	Critical temperature or critical temperature rise (°C)
$T_{maximum}$	Maximum temperature during test (°C)
$T_{tolerance}$	Tolerance (usually 5 °C) on the allowed temperature rise
V	Volume per unit length (m^3)
w	Fire protection coating thickness (mm)

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ISO/TR 22899-2:2013
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5 Principle

The objective of the jet fire test is to establish the additional amount of passive fire protection material that needs to be applied to a structural member, valve, penetration sealing system, etc., in order to resist exposure to a jet of ignited fuel, above and beyond that needed to satisfy the criteria of the ISO/TR 834-3 hydrocarbon fire resistance test. This additional thickness of material, known as the erosion factor, is determined once for each similar element or construction, which may be added to the thickness of material determined for a similar range of such elements, when evaluated for fire resistance against the methods given in ISO/TR 834-3 using the principles provided below.

The method provides an indication of how passive fire protection materials perform in a jet fire that may occur, for example, in petrochemical installations where ignitable gases are stored at pressure. It aims to simulate the thermal and mechanical loads imparted to passive fire protection material by large-scale jet fires resulting from high-pressure releases of flammable gas, pressure liquefied gas or flashing liquid fuels. Jet fires give rise to high convective and radiative heat fluxes as well as high erosive forces. To generate both types of heat flux in sufficient quantity, a 0,3 kg s^{-1} sonic release of gas is aimed into a shallow chamber, producing a fireball with an extended tail. The flame thickness is thereby increased and hence so is the heat radiated to the test specimen. Propane is used as the fuel since it has a greater propensity to form soot than does natural gas and can therefore produce a flame of higher luminosity. High erosive forces are generated by release of the sonic velocity gas jet 1 m from specimen surface. The jet velocity is ca. 100 ms^{-1} at 0,25 m from the back of the flame recirculation chamber (e.g. the front of the web of a structural-steel specimen) and ca. 60 ms^{-1} at the back of the chamber. The average heat flux is

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approximately 240 kW m^{-2} and the maximum heat flux 300 kW m^{-2}.[1] The heat fluxes are highest in the upper part of the chamber and lowest in the corners and at the jet impact zone. The combination of fuel, release rate and experimental arrangement is intended to apply a similar heat loading to the specimens as would be given by a 3 kg s^{-1} natural gas (60 bar, 20 mm orifice) jet fire released 9 m (the distance for the most severe combination of erosive forces and heat transfer) from a target (see Clause 6).

6 Applicability of the test

6.1 General

The background to the development and applicability of the test is provided to give the basis for the principles of the test.

6.2 Jet fires

The main sources of detailed information on the characteristics of jet fires are the reports on the two programmes of jet fire research co-funded by the European Community. These programmes studied single fuel natural gas and propane jet fires,[2] and jet fires fuelled by mixtures of natural gas and butane.[3][4] The results of large-scale experiments to study natural gas jet fires impacting onto a large flat surface have been published.[5] The fuel release rates involved in these experiments ranged up to 12 kg s^{-1}, at release pressures of up to 60 bar. Measurements included the flame size and shape and thermal radiative properties, flame velocities and temperatures in some experiments, and in the impacting experiments, the total and radiative heat fluxes incident upon the target at different locations (using instruments maintained at a nominally constant temperature of 60 °C).

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Although a formal peer reviewed interpretation of the whole range of experimental data is not available, the basic information on the heat loading for different types of fire has been accepted by industry experts and summarized.[6] General observations are made here.

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— Experiments involving jet fires impacting on a pipe or a vessel demonstrated that the heat fluxes incident upon the target varied considerably over the surface of the object, and also varied depending on how far the target was from the release point. Such variations can be caused by variations in the velocities of the gases passing over the object (influencing the convective component of heat flux) or the amount of thermal radiation incident upon different parts of the surface.

— Four different natural gas release types were studied in the initial EC-supported Project AA,[2] with different pressures and release rates. The experiments covered flow rates from 2,5 to 8,5 kg s^{-1}, and pressures up to 60 bar. For this range of conditions, the maximum total heat fluxes were similar, typically 250 kW m^{-2}, increasing to 320 kW m^{-2} for positions towards the end of the flame. However, there were significant detailed variations in the areas engulfed, and in the distribution of the heat fluxes and the balance between the radiative and convective components.

— Other experiments were carried out as part of that project involving two-phase propane releases, with flow rates in the range 2 to 12 kg s^{-1} at discharge pressures of 20 bar. The fires generated were found to be more strongly radiative than the natural gas jet fires, but the heat fluxes incident upon a target had a lower convective component, the overall effect being to give lower maximum total heat fluxes.

— A further series of experiments (all with a total flow rate of nominally 2,5 kg s^{-1}) were carried out as part of the EC-supported Project JIVE[3,4] with jet fires fuelled by mixtures of natural gas and butane. The aim was to investigate the balance between radiative and convective components and to identify whether a worst case existed for which the total heat fluxes were at a maximum.

The results of these experiments showed that although the radiative properties of the fires increased with increasing butane concentration, the maximum total heat fluxes were in a similar range to the earlier Project AA[2] natural gas and propane fire experiments.

The EC-supported programmes generated experimental data for horizontal jet fires. Information is available for free vertical fires, and for natural gas fires impacting vertically onto a flat plate.[5] The results show that although there are major variations in the distribution of incident heat fluxes, in

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general the maximum values were no greater than the maximum values observed in the horizontal jet fire experiments.

Larger flow rates at similar pressures may be expected to give similar velocities to the releases already studied. The initial gas exit velocities for sonic releases will be equal. However, higher pressure releases will tend to maintain higher velocities over greater distances. Similarly, the flame temperature is dependent primarily on the fundamental combustion properties of the fuels, and again may not increase significantly with increasing flow rate.

6.3 Large scale testing of passive fire protection

Based on the results of the EC-funded programmes, one of the natural gas fires was subsequently chosen[7] as the basis of a large scale demonstration of the resistance to jet fires of passive fire protection. This natural gas jet fire comprised a release of 3 kg s^{-1} at a discharge pressure of 60 bar through a circular hole of diameter 20 mm. This test was considered to be representative of the range of single fuel natural gas, propane and butane jet fires studied, with the advantage that the flow rate and pressure met the practical requirements for a test which could be carried out at the site for long durations. The maximum heat fluxes generated by this release were either similar to, or higher than, the maximum heat fluxes generated by any of the releases in the EC-supported programmes. The release was at the highest pressure studied, and consequently maintains higher velocities over a greater distance. It was therefore expected to be a more severe test than one in which the heat fluxes were similar but with a greater radiative component, since the erosive effect of higher velocities on a test material would be greater. Similar considerations led to the distance from the release hole to the target being the closest characterized in the previous work (9 m), where the gas velocities and hence the erosive effect, would be greater than for positions further away. The long duration jet fire test differed only in detail from the fires characterized previously, principally in that the position of the release hole could be altered during a test to maintain the engulfed region constant during a test, which would otherwise have been affected by changes in wind conditions.

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ISO/TR 22899-2:2013
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6.4 Development

To provide a test of fire protection materials or systems at a scale which is more manageable (and cheaper), and which can be carried out under more controlled conditions (in particular, wind conditions), a medium scale jet fire test was developed,[1],[8] which has been used to examine the performance of a number of materials in jet fires. The test is based on an ignited sonic release of gaseous propane with mass flow rates up to 0,3 kg s^{-1}. Since this work had indicated that this medium scale jet fire test could reproduce the key conditions found in large scale jet fires, it was considered possible that it could be used as a 'standard jet fire test'. In order to develop this further, an international working group was set up under the auspices of the United Kingdom Health and Safety Executive (HSE) and the Norwegian Petroleum Directorate (NPD). This working group had the objective of producing a test procedure for jet fire testing fire protection materials.

Large flames produced by high pressure, high velocity, sonic gas jets give rise to high convective heat fluxes as well as high radiative heat fluxes. A sonic gas jet is also used in the medium scale Jet Fire Resistance Test,[8] since it is desirable to examine the combined effect of both types of heat flux on passive protection materials. To generate both types of heat flux in sufficient quantity, a 0,3 kg s^{-1} sonic release of gas is aimed into a shallow box, producing a fireball with an extended tail, thereby increasing the flame thickness and hence the heat radiated to the test specimen, comprising the rear wall of the box.[1] Propane, chosen as a convenient fuel for a medium scale test, has a greater propensity to form soot than does natural gas and can therefore produce a flame of higher luminosity. Without the box creating recirculation and producing the fireball and the higher luminosity of the propane flame, it would not be possible to achieve the high radiative heat flux found in the much larger jet fires. Heat flux measurements using gauges maintained at 60 °C have shown[1] that an area average total flux of 240 kW m^{-2} is achieved on the rear wall of the box with a maximum value of about 300 kW m^{-2}. Measurements of radiation flux alone were also made and found to be about 50 % of the maximum total flux. Velocity measurements are not available for comparison with the large scale experimental data, however, significant velocities (ca. 60 m s^{-1} 1m from the release) are known to be present because of the relatively high convective heat fluxes measured, and the observation that test specimens can suffer physical damage from erosion

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effects. Claims of heat flux values much greater than 300 kW m^{-2} at any scale, fuel type, or combination have not been substantiated.

In 1996, OTI 95 634 “Jet fire resistance test of passive fire protection materials”[8] was issued, replacing the earlier OTO 93 028 “Interim jet fire test for determining the effectiveness of passive fire protection materials”[9]. The United Kingdom, Health and Safety Executive (HSE) issues Offshore Technology reports in a series of publications, namely:

— OTO – These publications, known as Offshore Technology Order reports, are made available by the HSE as part of a series of reports of work which has been supported by funds formerly provided by the United Kingdom, Department of Energy and lately by the HSE.

— OTI – These publications, known as Offshore Technology Information reports, are published by the HSE as part of a series of reports of work which have been supported by funds provided by the Executive. Background information and data arising from research projects are published in the OTI series of reports.

6.5 Applicability

As discussed above, the jet fire resistance test may be regarded as representative of a large scale natural gas jet fire test used[7] to test fire protection materials and systems. The thermal characteristics of the large scale test may also be considered to a first approximation to be representative of other large scale jet fires studied, involving releases of pressurized gaseous fuels. There are reasons to believe that the natural gas jet fire test[7] is likely to be a more severe test than other natural gas jet fires of either lower flow rates at similar pressures (because the radiative component will be less) or similar flow rates at lower pressures. Similarly, the test is likely to be more severe than comparable releases of liquids such as propane or butane, which vaporize readily upon release.

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ISO/TR 22899-2:2013

While the jet fire resistance test was originally developed for offshore applications, HSE sponsored a test programme to see if it was equally valid for onshore applications. The test programme[13] involved approximately 1,7 kg s^{-1} flashing liquid jet fire engulfment of 2 tonne propane tanks protected with a passive fire protection material designed to give 90 min protection. Jet Fire Resistance Test specimens were prepared to the same specification and tested. Broadly similar results were found to those obtained with engulfment of the tanks by the flashing liquid propane jet fire, indicating that the appropriate version of the Jet Fire Resistance Test can be used for onshore applications.

There are concerns regarding the application and performance of passive fire protection materials and products when subjected to extreme fire events. Limited information is available about how passive fire protection materials and products (developed for buildings only to withstand relatively slow build up fire tests such as the ISO 834 standard fire) if subjected to a fire exposure significantly more severe. A fire protection material or system intended to withstand a conventional building fire for a specified period may not perform adequately in an extreme event scenario. Products that have demonstrated the ability to withstand a jet fire can be used to protect structural elements and installations against extreme fires.

The experimental data upon which the above discussion is based was obtained for free jet fires impacting in the open onto a range of different targets. The experiments do not represent fires in areas of significant confinement, for example where the ventilation rate allows insufficient air for complete combustion (“ventilation-controlled”). The behaviour of such fires may be very different from the free flame equivalents.[14] Radiative heat fluxes may be higher than the equivalent free flames, because reduced heat loss from confined fires can result in higher gas temperatures, ventilation-controlled fires can produce more soot and hence increase the flame emissivity, and creation of a recirculating flame can increase the radiative path length through the flame. However, in many practical situations offshore, releases may occur in areas of partial confinement, where these effects would be limited. In those cases, the large scale natural gas jet fire test (and hence the resistance to jet fires test) may be considered to be a reasonable test of materials which will be used in practical situations.

There are certain types of release whose likely effects on fire protection materials cannot be regarded as being represented by the large-scale natural gas jet fire test (and hence the resistance to jet fires test). The thermal properties of jet fires of liquid higher hydrocarbon fuels such as crude oil, or jet fires fuelled

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