Recommendations for documentation of reaction-to-fire properties of materials offshore

Anne Steen-Hansen, Karolina Storesund

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AUTHORS
Anne Steen-Hansen, Karolina Storesund

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ABSTRACT

This report presents a set of recommended reaction-to-fire test methods and related criteria for different construction products and furnishing products for use on offshore petroleum industry facilities.

The principle reaction-to-fire properties that will be critical for fire development are

- heat release
- smoke production
- production of toxic smoke
- spread of flames
- production of burning droplets/debris.

The test methods presented in this report documents one or several of these properties for a range of different products.

PREPARED BY	SIGNATURE
Karolina Storesund	Karolina Storesund

CHECKED BY	SIGNATURE
Anne Steen-Hansen	Anne Steen-Hansen

APPROVED BY	SIGNATURE
Paul Halle Zahl Pedersen	Paul-Halle Zahl Pedersen

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Preface

This report is based on the Norwegian report *Branntekniske krav til materialer offshore ("Requirements to reaction-to-fire properties in offshore applications") from 2008.* The recommendations have been revised and updated to take revisions and developments of regulations, standards and test methods into account. In addition, recommendations for criteria for evaluation of cone calorimeter test results (ISO 5660-1) are included.

Summary

It is natural to set different requirements for combustible materials depending on the application on the petroleum offshore facility. Fire risk will be considerably different in living quarters as compared to areas near or in the process areas. Possible fire scenarios will be different both in terms of ignition sources, fire development, the spread of fire and smoke and possible consequences. We have therefore added the following philosophy as the basis for assessment of the requirements that should apply to combustible materials offshore:

Requirements for living quarters
Combustible materials used in living quarters should be selected to ensure that a fire does not spread from the room of origin. A fire in a living quarter shall normally not be able to lead to flashover, and material properties should be of such a quality that the emergency response team will have a high probability of controlling the fire.

Requirements for process areas
A fire shall not occur in combustible materials on offshore facilities without the contribution of fire in petroleum products. Combustible materials shall not contribute substantially to worsen the conditions during a fire in petroleum products.

The reaction-to-fire properties that will be critical for fire development are

- heat release
- smoke production
- production of toxic smoke
- spread of flames
- production of burning droplets or debris

The test methods presented in this report document one or several of these properties for a range of different product categories.

We are of the opinion that documentation of fire properties of materials using other test methods than those presented in this report should not be accepted without thorough evaluation, unless the test method in question clearly represents more severe fire exposure than those listed in Table 1 below.

Table 1 Recommendations for selection of test method and criteria

Application	Recommended test methods and criteria for materials
Thermal insulation and sound insulation materials	– Non-combustible and tested according to ISO 1182 and meet the criteria as described in IMO 2010 FTPC Part 1 – ISO 5660-1. Test conditions and criteria are listed in Table 2.
Passive fire protection for structures and equipment	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – IMO 2010 FTPC Part 5 and Part 2. Significant fire risk: criteria for bulkhead, wall and ceiling linings. Moderate fire risk: criteria for floor coverings and primary deck coverings. or – Euroclass B-s1,d0 (EN 13501-1) or – IMO 2010 FTPC Part 10 (ISO 9705) or – ISO 5660-1. Test conditions and criteria are listed in Table 2. In case the materials are used outdoors, in areas where the risk for exposure of persons to smoke is small, lower requirements on smoke production may be considered.
Surface materials on walls and ceilings	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – IMO 2010 FTPC Part 5 and Part 2, criteria for bulkhead, wall and ceiling linings. or – Euroclass B-s1,d0 (EN 13501-1) or – IMO 2010 FTPC Part 10 (ISO 9705) or – ISO 5660-1. Test conditions and criteria are listed in Table 2. In case the materials are used outdoors, in areas where the risk for exposure of persons to smoke is small, lower requirements on smoke production may be considered.

Table 1 (continued) Recommendations for selection of test method and criteria

Application	Recommended test methods and criteria for materials
Tarpaulins	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – IMO 2010 FTPC Part 5 and Part 2, criteria for bulkhead, wall and ceiling linings. or – Euroclass B-s1,d0 (EN 13501-1) or – IMO 2010 FTPC Part 10 (ISO 9705) ISO 5660-1 is not suited for this type of product.
Noise reduction curtains	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – IMO 2010 FTPC Part 5 and Part 2, criteria for bulkhead, wall and ceiling linings. or – Euroclass B-s1,d0 (EN 13501-1) or – IMO 2010 FTPC Part 10 (ISO 9705) or – ISO 5660-1. Test conditions and criteria are listed in Table 2.
Floorings and primary deck coverings	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – IMO 2010 FTPC Part 5 and Part 2, criteria for floor and primary deck coverings. or – Euroclass D_{fl}-s1 (EN 13501-1) can be acceptable in *living quarters*, subject to evaluation or – ISO 5660-1. Test conditions and criteria are listed in Table 2.

Table 1 (continued) Recommendations for selection of test method and criteria

Application	Recommended test methods and criteria for materials
Gratings	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – IMO 2010 FTPC Part 5 and Part 2, criteria for bulkhead, wall and ceiling linings (criteria for floor covering can be considered under certain conditions). or – Euroclass B-s1,d0 (EN 13501-1) or – IMO 2010 FTPC Part 10 (ISO 9705) or – ISO 5660-1. Test conditions and criteria are listed in Table 2.
Pipes and insulation for pipes and ducts	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – IMO Res. A.753(18) or – IMO 2010 FTPC Part 5 and Part 2, criteria for bulkhead, wall and ceiling linings. or – Euroclass B_L-s1,d0 (EN 13501-1) or – ISO 5660-1. Test conditions and criteria are listed in Table 2.
Electric cables	Selection of class must be made based on area of application as well as other available fire safety measures. In high risk applications Euroclass A_{ca} (EN 13501-6) is recommended. Euroclasses $B1_{ca}$ and $B2_{ca}$ would normally be acceptable in living quarters.
Materials for the construction of lifeboats	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – IMO MSC/Circ.1006
Draperies, curtains and other supported textiles in living quarters	– NT FIRE 043, class I. Acceptable for all areas. or – IMO 2010 FTPC Part 7

Table 1 (continued) Recommendations for selection of test method and criteria

Application	Recommended test methods and criteria for materials
Upholstered furniture in living quarters	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – BS 5852, crib 7 (or equivalent method). Acceptable for all areas. or – Testing with smouldering and small flaming ignition sources (e.g. IMO 2010 FTPC Part 8, or EN 1021-1 and EN 1021-2) can be acceptable, subject to evaluation with respect to hazard area and available additional fire protective measures).
Mattresses in living quarters	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – BS 6807, crib 7 (or equivalent method). Acceptable for all areas. or – Testing with smouldering and small flaming ignition sources (e.g. IMO 2010 FTPC Part 9, or EN 597-1 and EN 597-2) can be acceptable, subject to evaluation with respect to hazard area and available additional fire protective measures)
Materials for furniture and fixtures in living quarters	– Non-combustible products according to ISO 1182, satisfying the criteria described in IMO 2010 FTPC Part 1 or satisfying Euroclass A1 or A2-s1,d0 (EN 13501-1). **Combustible products:** – IMO 2010 FTPC Part 5 and Part 2, criteria for bulkhead, wall and ceiling linings or – Euroclass B-s1,d0 (EN 13501-1) – IMO 2010 FTPC Part 10 (ISO 9705 or ISO 5660-1 as relevant) or – ISO 5660-1. Test conditions and criteria are listed in Table 2. These materials can be used in both smaller components and larger surfaces. Therefore the choice of test method should be determined with respect to the application area and amount of material used.

Table 2 Recommended criteria for results from testing according to ISO 5660-1.

Product	Heat flux density level [kW/m^2]	Test duration [s]	t_{ign} [s]	$HRR_{avg,300s}$ [kW/m^2]	HRR_{max} [kW/m^2]	THR [MJ/m^2]	SPR_{avg} *) [s^{-1}]
- Non-combustible materials and materials with low combustibility - Thermal insulation and sound insulation materials.	50	900	≥ 150	-	≤ 10	≤ 10	≤ 0.17
- Surface materials on walls and ceilings - Passive fire protection for structures and equipment. - Noise reduction curtains. - Insulation for pipes and ducts - Pipes of plastic and composite materials - Materials in ventilation ducts	Either						
	50	900	≥ 150	-	≤ 50	≤ 10	≤ 0.17
	Or						
	50	900	≥ 150	≤ 50	≤ 65	-	≤ 0.17
	Or						
	75	900	≥ 90	≤ 100	≤ 100	-	≤ 0.17
- Flooring and primary deck coverings in process areas - Gratings	50	900	≥ 150	-	≤ 100	≤ 25	≤ 0.3
- Flooring in living quarters	50	900	≥ 150	-	≤ 100	≤ 25	≤ 0.17
- Materials for furniture and fixtures in living quarters	50	1200	≥ 20	-	≤ 60 NB! Average of 30 s	≤ 25	≤ 0.57
- Upholstered furniture Mattresses and bedding components	The cone calorimeter is not best suited but may be an alternative. **)						
- Electric cables - Tarpaulins - Draperies, curtains and other supported textiles in living quarters	The cone calorimeter is not suited.						

*) The requirements on smoke production should be assessed in relation with the possibilities for human exposure.
**)The research program *Combustion Behaviour of Upholstered Furniture (CBUF)* in the early 1990's specified a method of testing materials in upholstered furniture and mattresses in the cone calorimeter [1]. The heat flux density level was 35 kW/m^2 and the test duration was set to flameout of mass loss below 150 g/m^2 during 1 minute.

1 Introduction

1.1 Background

The offshore petroleum industry is an area where the consequences of a fire may be very large. Fires on offshore facilities may start in several types of equipment and areas. An analysis of 985 fire incidents registered in the Norwegian Petroleum Safety Authority's database between 1997 and 2014 showed that approximately 67 % of the incidents are registered as fires or explosions that did not involve hydrocarbons [2], [3]. About one third of the fires took place in so called *ancillary system*, which are areas in support of the production areas, and cover a wide range of characteristics. Most of the platform systems that are not categorised as belonging to the main process are ancillary systems, which could explain the large share of incidents. Six of the 985 incidents were categorized at the highest severity level, having a large potential for serious accident or fatalities – three of these occurred on offshore facilities. 66 of the incidents occurred in living quarters. Thus, severe incidents related to fire do not occur very often. However, some incidents reported could have developed into disastrous events, which indicate the need for continued work to increase safety and a focus on barriers preventing possible consequences of an escalating incident.

Therefore the safety regime on offshore installations has to be very strict, and barrier management is one of the strategies to obtain a high safety level. According to the Norwegian Petroleum Safety Authority, *Barrier management includes the processes, systems, solutions and measures which must be in place to ensure the necessary risk reduction through the implementation and follow-up of barriers* [4]. A proper selection of materials in components, construction and interior is an important barrier preventing fires from starting, and preventing small fires from developing into larger fires that will be difficult to control. The regulations for health, safety and environment (HSE) in the Norwegian petroleum sector contain mainly risk- and performance based requirements [5]. Risk management is defined in the international standard ISO 31000 as *coordinated activities to direct and control an organization with regard to risk* [6]. Risk based safety management should include all safety related activities required to manage an organization, and includes both human resources and material goods. The principles of risk based safety management are usually applied at a general level in an organization, but may very well include detailed information like reaction-to-fire behaviour of construction products in areas with a high probability of fire. According to ISO 31000, risk management is based on the best available information.

This report presents a set of recommended reaction-to-fire test methods and related criteria for different construction products and furnishing products for use on offshore petroleum industry facilities. The system was first developed and published in Norwegian in 2008, as a response to performance based fire safety regulations [7]. It has since then been extensively used by petroleum companies operating on the Norwegian shelf. This report is a revision, update and translation of the previous recommendations in order to take revisions and developments of regulations, standards and test methods into account.

1.2 Objective

The objective is to present guidelines and recommendations for suitable requirements on fire safety in materials used in offshore applications. The recommendations follow the facilities regulations with guidance, but are also an interpretation and a supplement to these regulations.

The recommendations presented are based on available literature and on SP Fire Research's expertise from reaction-to-fire testing using relevant test methods.
The criteria must be understood as recommendations and must be evaluated against the actual application. In some instances it might be relevant to ease on the criteria whereas under other conditions it may be important to use stricter requirements than what is recommended here. For example, it can be relevant to lower the requirements on smoke production for applications in areas where it is unlikely that people will be exposed to the smoke. In some areas it may be unacceptable to choose anything but a non-combustible flooring, even though the recommendations for flooring and primary deck coverings allow for combustible materials.

1.3 Limitations

These recommendations contain test methods and approval systems known and acknowledged in our part of the world. Other relevant and recognized test methods do exist in other parts of the world, and may very well be used for documentation of materials in the Norwegian offshore petroleum industry.

An offshore platform consists of several various hazard areas. The risk at each area must be taken into account when approving materials. However, in these recommendations the areas on the platform have been divided into *living quarters* and *process areas*. The living quarters contain for example accommodation, helicopter deck and hangar and mustering area with life boats and safety equipment, and shall offer personnel protection and shelter [8].

2 Regulations, standards and guidelines related to the Norwegian shelf oil- and gas facilities

2.1 Introduction

The regulations for the petroleum activity under the jurisdiction of the Norwegian Petroleum Directorate and the Petroleum Safety Authority consist of a resource management part and a Health, Safety and Environment (HSE) part.

The Norwegian Environment Agency, the Norwegian Directorate of Health, the Norwegian Petroleum Directorate and the Petroleum Safety Authority cooperate on regulating HSE for the petroleum activities on the Norwegian Shelf. So the different HSE regulations are established with basis in a number of legislative acts concerning e.g. petroleum activities, health and working environment, pollution control, product control, etc. There are a number of regulations with relevance for HSE, of which the facilities regulations [9] with guidelines [10] are central for reaction-to-fire properties of materials in offshore applications. Since the regulations are performance based there are also several additional guiding documents with the aim of stating specific requirements, e.g. the NORSOK standards and other specifications.

2.2 The facilities regulations with guidelines

Being performance based regulations, the facilities regulations describe principle requirements including reaction-to-fire properties for materials used on offshore installations on the Norwegian shelf [9]. Material requirements are only mentioned in the Facilities regulations §12, where it is stated that:

"Materials to be used in or on facilities shall be selected considering
...
d) fire-resistance properties".

The guidelines to the regulations elaborates on this by stating [10]:
"When choosing materials as regards fire-resistance characteristics as mentioned in litera d, non-flammable materials should be chosen. Where flammable materials are used, they should limit the spread of fire and produce little smoke, heat and toxic substances. In living quarters, electrical installations should be constructed of halon-free materials. The flame spread and smoke development qualities of the materials should be considered when textiles or surface treatment with paint or other coating is used. The following standards should be used to determine the technical fire qualities of materials:
a) ISO 1182 for non-flammability,
b) ISO 1716 for limited flammability,
c) ISO 5657 for ignitability,
d) ISO 5660-1 for heat emission,
e) ISO 5660-1 for smoke development,
f) IMO Resolution A.653 (16) for spreading of flames,
g) ISO 9705 for testing of surface products,
h) NT Fire 036 for testing of pipeline insulation,
i) in) IMO Resolution A.471 (XII) for textiles
j) IEC 60331 for cables which shall function during a fire,
k) IEC 60332 for self-extinguishing cables in areas with explosion hazard."

The wording in this text implies that these particular methods are recommended to use but not required.

However, the guidelines do not state the pass/failure criteria when using the test methods. Only a part of the methods in the guidance list have defined criteria for use for assessment of the materials. Many of the methods are connected with parallel classification systems with several possible classes, e.g. ISO 9705 [11]. Some have different criteria for different areas of application, e.g. IMO spread-of-flame testing where the criteria will depend on whether the material is used as flooring or as bulkhead/ceiling [12]. Some of the methods, such as ISO 5660-1 [13], are normally used for evaluating the fire performance and not for classification or rating. Where there is a system with criteria for rating, these are commonly not related to offshore applications, but e.g. to ships and buildings. In addition, the list is due for an update with regards to test method edition. A new edition of the IMO Fire test procedure code was published in 2012 [14], so that the IMO references in the list above are no longer valid. This means that for each project an evaluation will be required to assess whether a material should be considered suitable for offshore use or not.

2.3 Regulations of 31 January 1984 No. 227 on precautionary measures against fire and explosion on mobile offshore units

These regulations apply to mobile platforms and drilling ships registered in a Norwegian ship registry. They are placed under the jurisdiction of the Ministry of Trade, Industry and Fisheries and are maintained by the Norwegian Maritime Authority. The regulations contain a number of requirements related to fire safety but for material application, chapter 4 *"Fire safety measures"* is the most relevant. The requirements have many references to the IMO Fire Test Procedure Code (FTPC) (without stating an edition, i.e. it can be interpreted as the latest edition applies) [14] but they also include a few specific requirements [15]:

- Furniture with drawers or cabinets or cupboards shall be made of certified, non-combustible material, except that the surface of such furnishings may be a combustible veneer not more than 2 mm thick.
- Free-standing furniture such as chairs, sofas, beds and tables shall be made with frames of non-combustible material.

2.4 The NORSOK standards

The NORSOK standards were the result of an initiative in 1993 established by the petroleum industry and Norwegian authorities. The standards were developed in order to ensure satisfactory safety, value creation and cost efficiency for the operations in the oil and gas industry on the Norwegian shelf, closing the gap between international standards and the Norwegian requirements [16].

The NORSOK standards are owned by the Norwegian Oil and Gas Association, the Federation of Norwegian Industries, and the Norwegian Shipowners' Association, and the standards are developed by experts from the Norwegian petroleum industry. There are both general and specific requirements for materials stated in different NORSOK standards, mainly concerning non-combustibility, smoke production and toxicity and

spread-of-flame. The requirements are considering both living quarters and processing areas.
The most relevant NORSOK standards with regards to material fire safety are:

- NORSOK S-001 Technical safety [17]
- NORSOK C-002 Architectural components and equipment [18]
- NORSOK R-004 Piping and equipment insulation [19]

These have various references to e.g. the former IMO Fire Test Procedure Code IMO Res. MSC 61(67) [20], which was replaced in 2010, the guidance to the facilities regulation, and different references to the European testing and classification system for construction products.

General requirements on active and passive fire protection are described in NORSOK S-001 [17] In chapter 19 *Passive fire protection (PFP)* the role of passive fire protection is stated as *"PFP shall ensure that relevant structures, piping and equipment components have adequate fire resistance with regard to load bearing properties, integrity and insulation properties during a dimensioning fire, and contribute in reducing the consequences in general.*

Fire divisions shall ensure that a dimensioning fire and explosion does not escalate into surrounding areas."

Chapter 19 also states the requirement of using non-combustible materials, however:
" Materials on the installation shall be non-combustible. If it is justified from safety point of view to make use of materials that do not meet the requirements to non-combustibility, such materials shall have limited flamespread properties, low smoke development and heat generation. Documentation shall be available to support the basis for the decision regarding selection of materials.

An assessment shall be made of the toxicity of gas emitted in the event of a fire."

Furthermore, considering living quarters (LQ):
"LQs shall be designed and protected to ensure that the emergency functions therein can be maintained during dimensioning accidental events."

"Choice of materials and interior design of the LQ shall be decided in relation to the fire risk. If surface treatment of paint or other coating is used, the properties of the product with regard to flame spread shall be considered. A corresponding evaluation shall also be carried out with regard to textiles. Floor, wall and roof finishes shall pass the fire test requirements in IMO Res. A.653 (flame spread). In addition, the materials shall comply with the requirements of ISO 5660 (smoke and ignition properties). These evaluations are particularly important for LQ without water sprinkler protection. Reference is also made to SINTEF NBL report A05103."

2.5 Other guiding documents

The operators, e.g. the Norwegian petroleum company Statoil, have developed their own technical specifications. These are generally based on their risk analyses and their interpretation of the Norwegian regulative. Survey organizations, e.g. DNV GL, have also defined their set of requirements for material certification. NORSOK S-001 is also referring to a report with recommendations that has been published by SINTEF NBL (now SP Fire Research AS) [21] as can be seen in the citation above.

An overview of regulations, standards and guidelines is shown in Figure 2-1 below.

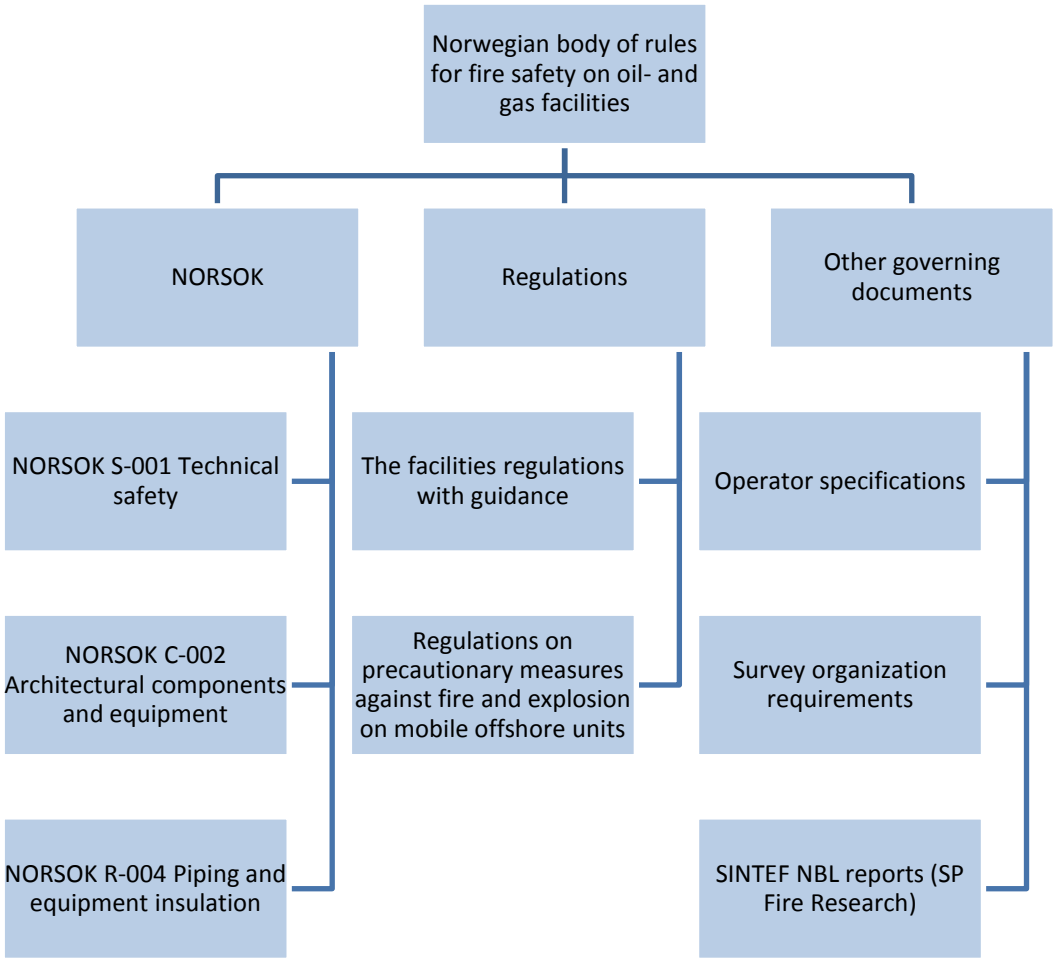

Figure 2-1 Regulations, standards and guidelines for materials in petroleum industry offshore applications on the Norwegian shelf.

3 Critical factors of fire growth

3.1 Different phases in fire development

The way in which a fire will develop will be dependent upon a number of factors, e.g. amount and type of materials, geometry and ventilation. The typical phases of a fire are shown in Figure 3-1 below.

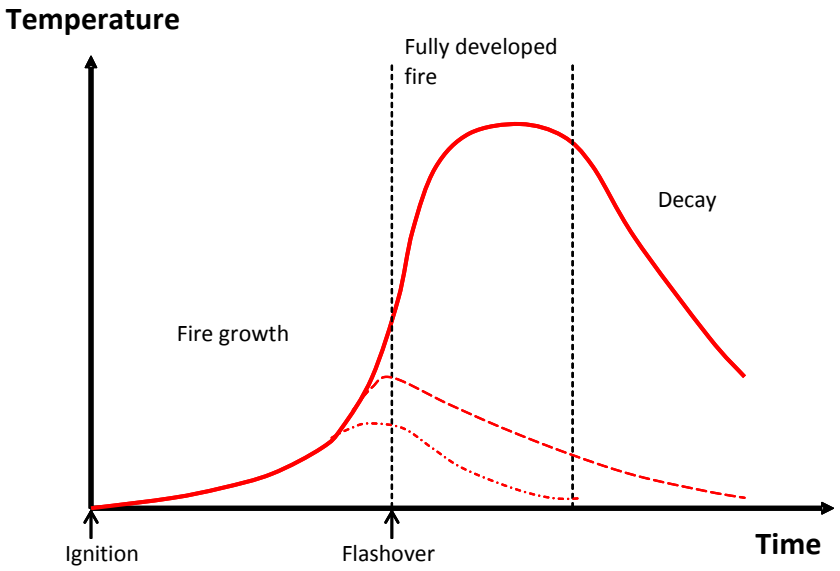

Figure 3-1 Typical phases of fire development in a confined space. The two red dotted lines show fires that do not grow into flashover.

When evaluating the reaction-to-fire properties the main consideration will be the performance during the time to room flashover, i.e. the ignition and fire growth phase. This part of the fire development will be dependent on the fuel which basically means type and amount of materials, their position and their form.

The **ignition phase** is the time until the fire can continue without the aid of an external heat source. In most cases materials are ignited by an external ignition source, e.g. an electric spark, an open flame or exposure to high temperatures. During this phase the properties of the surface of the materials will be of great importance.

Fire growth phase. Directly after the ignition the room geometry will have little or no effect on how the fire develops. If the temperature is high enough and there is enough oxygen and fuel, the fire will continue to develop. The temperature in the room will increase. The temperature increase is due to heat transfer through radiation and convection from the fire, and radiation from the smoke layer and from surrounding surfaces.

Flashover and fully developed fire. The fire will be controlled by the access to fuel as long as the fire is small compared to the access to oxygen. Flashover is a rapid transition from a flaming fire in a room to a fully developed room fire where all surfaces are contributing to the combustion. During flashover the accumulated fire effluents are

ignited and one of the characteristics of the phenomenon is flames spreading out from all openings of the room.

The time from ignition to flashover will, in a typical sufficiently ventilated room in a house with standard furnishing, often be less than 5 minutes. The reaction-to-fire properties of the surfaces on walls, ceilings and floors will have great effect on the time from ignition to flashover. Materials selection will be important for the speed of which a material is ignited, and for the heat released and the smoke production when the material has caught fire. By selecting highly fire safe surface materials, flashover can be avoided.

Decay phase. If the fire is not extinguished it will eventually die out on its own, either by the lack of oxygen or due to the restricted access to fuel.

3.2 Critical factors for humans

During a fire, people will be affected by the heat from the fire, toxic gases from the smoke and reduced visibility due to dense smoke. The principle reaction-to-fire properties that will be critical for fire development are:

- heat release
- smoke production
- production of toxic smoke
- spread of flames
- production of burning droplets

There are a number of test methods that measure one or several of these factors.

3.2.1 Heat exposure

Heat exposure may be caused either by direct contact to hot fire gases or radiation from flames or hot gases. Breathing air of high temperatures can cause painful damages to the upper respiratory tract. Heat flux of approximately 20 kW/m^2 would result in pain and burns within few seconds.

3.2.2 Toxic gases

Some toxic gases lead to reduced consciousness and eventually to asphyxiation (especially CO, CO_2 and HCN), while irritating gases (mainly HCl, NO_X, NH_3, SO_2, HF, HBr and acrolein) can irritate eyes and upper respiratory tracts making it difficult for victims to escape.

In addition, low concentrations of oxygen (O_2) in the air will act soporific. CO is commonly the largest threat for humans even though CO is not the most toxic of the fire gases. Generally the CO concentration is relatively high compared to the other toxic gases in a fire. The carbon dioxide concentrations present during a fire is not particularly toxic but even moderate CO_2 concentrations will stimulate the breathing frequency, contributing to an increased uptake of other toxic fire gases.

The toxic effect of the gases are dose dependant, where the dosage is defined as gas concentration multiplied by exposure duration. Some gases, such as CO, mainly follow Haber's law, that states that the product of time and concentration equals a constant dosage giving a predetermined effect (e.g. loss of consciousness or death). Hence, Haber's

law gives that the effect is independent on whether the exposure is of long duration at low concentrations or short duration at high concentrations. Other gases however, such as cyanic acid (HCN), does not follow this rule when the concentration exceeds a certain limit. Rapid effect will be seen from exposure at short duration and high concentrations to HCN.

3.2.3 Limited visibility

Reduced visibility due to smoke will hinder efficient escape. This may cause people to be exposed to high concentrations of hot and toxic smoke. Reduced visibility in smoke is the effect that will first lead to critical conditions during fire in buildings, which is why low smoke production of materials is an important requirement in many different applications.

The visibility should be around 4-10 meters if people shall be able to escape without great difficulties. The required visibility will be dependent on how well the individuals evacuating know the building.

3.3 Fire in living quarters

Loose fittings, especially upholstered furniture and mattresses, can have large impact on the fire development during fire in a living quarter because they tend to consist of relatively large amounts of combustible material and often

- Ignite relatively easily
- Release large amounts of heat
- Burn quickly
- Release large amount of dark and toxic smoke

Tests performed at SP Fire Research have shown that upholstered furniture and mattresses can release heat above 1 MW. This can be achieved within 2-3 minutes after ignition and will in itself be sufficient to cause flashover in a cabin.

The selection of fire safe materials for furniture is an example of passive fire safety measures that will increase the fire safety in rooms. Fire alarms and automatic extinguishing systems would be the most relevant active fire safety measures in these areas. Alarms will mainly affect the available escape time. Automatic water-based extinguishing systems will, however, directly influence the fire development. A correctly functioning sprinkler system will most likely control the fire within the room of origin, preventing further fire spread.

Lately the application areas of water mist extinguishing systems have increased. SP Fire Research has worked extensively with the application of water mist in offshore turbine rooms and machine rooms on board ships. Several suppliers of water mist systems have completed testing for these areas of applications. There are also ongoing work related to the efficiency of water mist systems in buildings onshore.

4 Documentation of fire safety

Documentation of fire safe materials for offshore applications can be prepared in several ways. Results from fire testing according to a standardized method are a commonly used starting point. The documentation can be in the form of a report in which methods and results are described, or it can be designed as an assessment on the basis of test results. Such assessments can be made in relation to a recognized classification system, or it may be assessed with respect to the product's usefulness in a given application.

Whatever the form of the documentation it is important that the fire safety documentation is proportionate to the area of application and relevant fire scenarios. If a product satisfies the requirements to resisting ignition when exposed to a match flame, it is not certain that it will resist a larger ignition source.

Different products are tested in different ways, and there are different requirements to the test results. The test methods for testing surface materials for walls and ceilings are for example often different from those that are used for testing floorings. Sometimes the method is the same, but the pass criteria are different. This is because the differences in the use of the product can cause differences in the levels of fire safety. The fire properties of walls and ceilings will for example be more critical than the properties of a flooring, both because of installation and the position in the room.

A principal rule is that the specimen shall be prepared to resemble the end use product as far as possible. This means that a surface material shall be tested on the same type of substrate as in the end use application, because the substrate very often is important to the overall test results. The same is true for joints, mounting details etc. A test report will generally only be valid for the product the way it is tested. For example, if a type of paint is tested on a non-combustible substrate, the test results are only valid for that specific application, and will not give any information about the properties of the paint on a combustible substrate.

Some methods are very specific for the product to be tested, e.g. the methods for mattresses or curtains. Other test methods are less product specific, such as methods for non-combustibility or heat of combustion.

A complicating factor is that there are many different test methods for the same product type. Traditionally each country has had their own system for testing and classification of the reaction-to-fire properties of construction products. There can be considerable differences between these different methods and classifications systems. Often it is not possible to compare the results from one method with the results from another. Fire test results are strongly connected to the method that has been used and to the test conditions during the specific test.

Generally, it is not possible to transfer a class designation from one system to a designation in another system. A harmonised system for test methods and class designations for construction products was introduced in Europe in 2002. However, test reports from the old national methods in Europe are still in circulation.

It is also worth noticing that some materials are not suited for testing according to existing methods. This can for example be because of the physical shape of the material or that it melts or swells when exposed to heat. Another factor is atypical areas of application. In such cases alternative means of documentation can be useful, e.g. calculations and analyses preferably based on test results. One example of this is calculation of properties in large scale based on test result in small scale [22,23,24,25,26].

5 Fire test methods

5.1 Properties to be documented

As mentioned previously the guidelines to the facilities regulations list a number of test methods that can be used for determining fire properties of materials. This chapter describes these and other test methods that, in our opinion, are suitable for use in documentation of the reaction-to-fire properties of materials used on offshore petroleum table 7-9industry facilities.

The principle reaction-to-fire properties that will be critical for fire development are

- heat release
- smoke production
- production of toxic smoke
- spread of flames
- production of burning droplets

Any requirements to the limitation of smoke production must be related to the application area of the product. If the application allows for smoke to be released to the open air and not posing a hazard to people, the level of smoke production is less relevant than when people can be exposed to the smoke. Documentation of low levels of smoke production will be more important for applications in living quarters and confined spaces, than for applications outdoors.

5.2 Applicable test methods

The evaluation of the appropriate test methods that are relevant and that will cover the properties that are regulated with regards to reaction-to-fire properties, are based on the following:

- The methods should preferably document more than one property.
- The specimen exposure must as far as possible resemble what would be the case in a real fire scenario.
- The results from the testing must be related to a set of criteria for classification or approval.
- The methods should be standardised, acknowledged test methods used in Europe.
- The test results should be applicable for use in fire safety engineering.

It may be difficult to conclude on methods that meet all these requirements. The test methods described below are, in our opinion, best suited to achieve documentation for the evaluation of fire safety of materials for use on offshore petroleum industry facilities.

The chapter is organised according to areas of application and some test methods are listed more than once. Later in this report it is described how these methods are applied in various classification systems. Finally, the methods are presented alphabetically in a list. This should be regarded as a list of reference and the list does also contain a limited amount of information about the different methods.

5.3 Test methods designations

When a national standardisation body (e.g. Standards Norway) publish the national version of a European standard (i.e. an EN standard), this standard is given a prefix to show that this is a national publication. In Norway the designation will then be NS-EN, in Sweden SS-EN, in the UK BS-EN, etc.

Correspondingly, a standard from ISO, when published by CEN, will be given the designation EN ISO. When this standard is then published by the national standardisation body, it is given a national prefix before EN ISO. In Norway this becomes NS-EN ISO, in Sweden SS-EN ISO, in the UK BS-EN ISO etc. In the table below the standards from CEN are designated NS-EN while the standards from ISO can be designated NS-EN ISO.

The different national standards will be identical as long as they have the same origin, i.e. the same edition of an ISO or CEN standard. For example, a test according to NS-EN ISO 1182 will equal tests according to both SS-EN ISO 1182, EN 1182 and ISO 1182. However these national standards may contain an annex, specific for the country in which the standard is published.

5.4 Classification of construction products

Traditionally, each country has had their own fire test methods and classification systems for construction products. This was costly for producers that exported their products. However, a harmonisations process has led to common test methods in all the European Economic Area (EEA), including the EU and EFTA. For constructions products within the EEA this classification standard is valid:

EN 13501-1:2007 + A1:2009 *Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests* [27].

This classification standard does not cover all material applications in buildings. The requirements on for example upholstered furniture, mattresses are published elsewhere. Some criteria are given in the actual test method (as for upholstered furniture and mattresses), while some criteria are given in separate publications.

Materials used on ships are governed by the IMO (International Maritime Organization) regulations published in:

2010 FTP Code. International Code for Application of Fire Test Procedures (IMO resolution MSC.307(88)) [14].

The 2010 IMO FTP Code describes the different test methods to be used for various areas of applications on board ships, and which criteria to apply for all the different methods. The 2010 IMO FTP Code was published in 2012 after a revision of IMO Resolution MSC.61(67), resulting in some new test method designations. For example, IMO Resolution A.653(16) *Recommendation on improved fire test procedures for surface flammability of bulkhead, ceiling and deck finish materials* [28] was replaced by IMO 2010 FTPC Part 5 *Test for surface flammability (test for surface materials and primary deck coverings)* [12].

As of July 1st 2012 testing has been conducted according to the new FTP code. New type approvals shall not be issued on the basis of test reports which are more than 5 years old when submitted [14].

5.5 Selection guidelines for test methods and criteria

It is very difficult to set general limits for acceptable heat release in number of kilowatts from a material. Equally it is almost impossible to set such limits for smoke production and for the production of toxic gases. Conditions that are defined as critical contribution in some circumstances may be harmless in others. This will be dependent on factors such as room size, if the room or nearby areas are staffed, whether there is an automatic extinguishment system in the room, where the escape routes are placed in relation to the fire compartment, etc.

We will, however, attempt to recommend the method of documentation of combustible materials for use on offshore petroleum industry facilities.

SP Fire Research is of the opinion that material documentation of fire safety, using other methods than those described in this report, should not be accepted without thorough evaluation unless the test method clearly represents a more severe fire exposure than those listed in the table below.

Guidelines for selection of test methods with accompanying pass criteria are organised according to area of application. The recommendations describe the classes necessary to reach in order to be deemed satisfactory for use for use on offshore petroleum industry facilities. Brackets behind the recommended class describe the relevant classification standard. If the criteria are given in the test standard it is stated in the brackets. If the requirements is connected to specific ignition sources there will be a reference to the chapter in the report describing relevant classification.

5.6 Documentation of the toxicity of smoke

Both the guidelines to the facilities regulations and NORSOK standard S-001 state that the toxicity of smoke shall be evaluated and documented. Most fire fatalities are caused by smoke poisoning, and this makes smoke toxicity a very important property of fire safety. A considerable problem is that smoke toxicity depends on a number of different factors, such as:

- The material's chemical composition
- Position and amount of the material
- Combination of several different materials
- Geometrical conditions
- Ventilation conditions
- Type of fire (smouldering, glowing or flaming combustion)
- Intensity of the fire exposure of the material

There are to date few simple methods measuring smoke toxicity, but one of these are IMO 2010 FTPC Part 2 [29]. According to this method the material is exposed to different test conditions in a chamber. The optical density of the smoke in the chamber is measured, and gas is sampled for analysis with an FTIR analyser (*FourierTransform Infra-Red –analyser),* according to ISO 19702 [30].

The usefulness of the results from different test methods of this type can be discussed, but they can act as screening methods in order to weed out materials that potentially may produce large amounts of toxic smoke in fires.

A more complete documentation of the smoke toxicity will involve a risk analysis of the particular area, and it must take the factors listed above into consideration. In addition, calculations of different probable fire scenarios, including smoke spread and human exposure and how people are affected physically and psychologically must be performed. However that is a very comprehensive work which cannot be expected when evaluating the toxicity of individual materials.

The toxicity of smoke is, however, a very important factor when it comes to personal risk during fire. Because of the complexity connected to the phenomena smoke production and the spreading of smoke, it is difficult to offer a final and conclusive evaluation of just how toxic the smoke from individual materials will be in a fire situation. It may, however, be possible to evaluate the toxicity based on results from simpler gas analyses and evaluate the effect taking factors like area of application, amount of material and possible fire scenarios into consideration.

6 Test methods for non-combustible materials and materials with low combustibility

Both the guidelines to the facilities regulations and NORSOK standard S-001 indicate that materials wherever possible should be *non-combustible*. The test method for documentation of non-combustibility, ISO 1182 [31], is used in many countries, and the same method is used for buildings, ships and offshore applications.

In maritime and offshore applications, it is distinguished between non-combustible and combustible materials. However, these are concepts related to the method ISO 1182.

Documentation of *low* combustibility primarily involves the determination of a material's calorific value or heat of combustion, i.e. the amount of energy released during complete combustion, presented in units of MJ/kg. Testing can be performed according to ISO 1716 [32].

Neither ISO 1182 nor ISO 1716 contain any criteria for the test results or recommendations for how the results should be assessed.

IMO 2010 FTPC Part 1 – *Non-combustibility test* [33] describes testing according to ISO 1182 and state the required results for a material to be regarded as non-combustible according to IMO.

According to the European classification standard EN 13501-1 [27] testing according to EN-ISO 1182 is the basis for the so called Euroclasses A1 and A2. The criteria for class A1 correspond to the criteria in IMO 2010 FTPC Part 1 (with some additional requirements in the latter). The Euroclasses A1 and A2 are in addition based on testing according to EN-ISO 1716. The requirement for class A1 is stricter than for class A2. According to Norwegian building regulations A2 is considered to be equivalent to non-combustible, therefore A2 should be regarded as sufficient when non-combustibility is required in living quarters. In process areas, however, A1 should be preferred.

The standard ISO 5660 (cone calorimeter) [13] can also be used to document the combustibility of different products, and is recommended in the guidance to the facilities regulation as a method to document heat emission and smoke development. Methods have been developed in order to assess test results from the cone calorimeter with respect to combustibility [33,34,35].

It is, however, problematic that there exists no recognized classification system for all types of products that can be tested in the cone calorimeter. Criteria for some products and some applications can be found (e.g. for small components in interior products for high-speed craft), but not a general classification system. This requires quite specific competence when assessing documentation based on tests in the cone calorimeter.

Therefore a literature review was performed to develop a set of criteria that could be used for different material applications in the offshore industry. The review comprised literature from several countries on assessment of materials for different applications [26,35,36,37,39,40,40,42,43,43,44].

7 Test methods and assessment guidelines for combustible materials

The use of combustible materials on offshore facilities can have several positive aspects for different applications. These advantages may include lower procurement costs, lower maintenance requirements, lower weight and easier installation. The use of combustible materials may also increase the safety in some cases (e.g. products forming a protective layer of char during combustion) [45]. When combustible materials are applied on offshore facilities, it is important to have control over which products are being used, what applications, and the quantities of products that can be permitted.

It is natural to set different requirements for combustible materials depending on the application on the petroleum offshore facility. Fire risk will be considerably different in living quarters as compared to areas near or in the process areas. Possible fire scenarios will be different both in terms of ignition sources, fire development, the spread of fire and smoke and possible consequences. We have therefore added the following philosophy as the basis for assessment of the requirements that should apply to combustible materials offshore:

Requirements for living quarters

- Combustible materials used in living quarters should be selected to ensure that a fire does not spread from the room of origin.
- A fire in a living quarter shall normally not be able to lead to flashover, and material properties should be of such a quality that the emergency response team will have a high probability of controlling the fire.

Requirements for process areas

- A fire shall not occur in combustible materials on offshore facilities without the contribution of fire in petroleum products.
- Combustible materials shall not contribute substantially to worsen the conditions during a fire in petroleum products.

7.1 Materials for thermal insulation and sound insulation

7.1.1 Test methods and criteria for materials used for thermal insulation and sound insulation products

Thermal insulation and sound insulation materials shall be non-combustible. Testing and documentation can be performed as described in chapter 6.

7.1.2 Guidelines for the selection of materials for thermal insulation and sound insulation products

Thermal insulation and sound insulation materials shall be non-combustible and shall be tested according to ISO 1182 and meet the criteria as described in IMO 2010 FTPC Part 1
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

or

Alternatively, the material can be tested according to ISO 5660-1, satisfying the following criteria:

Heat flux density level [kW/m^2]	Test duration [s]	t_{ign} [s]	$HRR_{avg,300s}$ [kW/m^2]	HRR_{max} [kW/m^2]	THR [MJ/m^2]	SPR_{avg} [s^{-1}]
50	900	≥ 150	-	≤ 10	≤ 10	≤ 0.17

7.2 Materials for passive fire protection for structures and equipment

7.2.1 Test methods and criteria for materials for passive fire protection for structures and equipment

Testing and documentation can be performed as described in chapter 6.

If combustible materials are selected, they shall have low flame-spread characteristics, low heat release rate and shall not produce excessive amounts of smoke and toxic gases. This can be documented as for surface materials for walls and ceilings, se section 7.3.

If the passive fire protection will only be used on horizontal surfaces on floor level, the criteria for floor and primary deck coverings can be considered, se section 7.6. These criteria can also be relevant if the passive fire material covers a small area or if it is placed in a location where the fire risk is regarded as moderate.

7.2.2 Guidelines for the selection of materials for passive fire protection for structures and equipment

Non-combustible materials shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

or

Combustible materials satisfying the criteria for surface materials in walls and ceiling linings[*)] according to IMO 2010 FTPC Part 5 and Part 2.
or
Combustible materials satisfying Euroclass B-s1,d0 (EN 13501-1)
or
Combustible materials satisfying the criteria for fire restricting materials according to IMO 2010 FTPC Part 10 (ISO 9705)

or

Alternatively, the material can be tested according to ISO 5660-1, satisfying the following criteria:

Heat flux density level [kW/m^2]	Test duration [s]	t_{ign} [s]	$HRR_{avg,300s}$ [kW/m^2]	HRR_{max} [kW/m^2]	THR [MJ/m^2]	SPR_{avg} [s^{-1}]
Either						
50	900	≥ 150	-	≤ 50	≤ 10	≤ 0.17
Or						
50	900	≥ 150	≤ 50	≤ 65	-	≤ 0.17
75	900	≥ 90	≤ 100	≤ 100	-	≤ 0.17

[*)] If the fire risk can be regarded as moderate because of factors like location, amount and geometry of the passive fire protection, combustible materials satisfying the criteria for floor and primary deck coverings according to IMO 2010 FTPC Part 5 and Part 2 can be considered.

In case the materials are used outdoors, in areas where the risk for exposure of people to smoke is small, lower requirements on smoke production may be considered. This must be assessed in each case.

7.3 Surface materials on wall and ceiling linings

Materials forming the surface layer on interior walls, ceilings and floors are discussed in this section. There are several acknowledged suitable test methods for this group of products.

7.3.1 Test methods for surface materials on walls and ceilings

There are a number of different methods in use to test surface materials. Within the European Economic Area the following methods are adopted as a part of the harmonised system:

- EN 13823 (Single Burning Item test) [46] for construction products, excluding floorings
- EN ISO 11925-2 (small flame test) [47] for construction products including floorings

IMO 2010 FTPC indicates that floor and primary deck coverings, and ceiling and wall linings shall be tested for the documentation of flame-spread and heat release:

- IMO 2010 FTPC Part 5 (wall and ceiling linings, floor and primary deck coverings). The criteria for wall and ceiling linings are stricter than those for floor and primary deck coverings.

According to IMO 2010 FTPC surface materials for wall and ceiling linings shall also be tested for the documentation of smoke production and toxicity:

- IMO 2010 FTPC Part 2

The criteria for smoke density are stricter for wall and ceiling linings than for floor and primary deck coverings, whereas the criteria for toxicity are the same for all product types.

ISO 5660-1 (the cone calorimeter test) can also be used to document the fire safety properties of surface materials. ISO 5660-1 describes determination of time to ignition, heat release and smoke production.

ISO 9705 (room corner test) is a method for testing of surface materials in relatively large scale. IMO requires surface materials used on high-speed craft to be tested according to ISO 9705 [11,14,47].

Most of the methods mentioned above are small scale test methods, except for EN 13823 which is regarded as medium scale, and ISO 9705 which is a large scale test.

7.3.2 Criteria for materials for surface materials on wall and ceiling linings

Different regulations for surface materials

This section describes the recommended criteria for surface materials tested and classified according to:

- The IMO regulations for passenger ships
- The IMO regulations for high-speed craft
- The CEN regulations – the European system connected to the construction products regulations

IMO – Surface materials with low flame-spread characteristics

Test method:
IMO 2010 FTPC Part 5 – *Test for surface flammability (test for surface materials and primary deck coverings)* [14], using the test standard ISO 5658-2 [49].

Criteria for classification:
The criteria for testing surface materials according to IMO 2010 FTPC Part 5 are stated in the published method, and are presented in the table below.

Table 7-1 Criteria for flame-spread characteristics of surface materials according to IMO 2010 FTPC Part 5.

	CFE [kW/m^2]	Q_{sb} [MJ/m^2]	Q_t [MJ]	q_p [kW]	Burning droplets
Criteria for bulkhead, wall and ceiling linings	≥ 20.0	≥ 1.5	≤ 0.7	≤ 4.0	Not produced

CFE = Critical flux at extinguishment
Q_{sb} = Heat for sustained burning
Q_t = Total heat released
q_p = Peak heat release rate

The material will either pass or fail this test. The criteria for surface materials on walls and ceilings are stricter than those for floor coverings.

What does the classification mean?
A surface material that satisfy the criteria of this test method can be considered a fire safe product with respect to flame-spread and heat release. The test conditions are relatively severe, and the criteria to the test results are relatively strict.

The IMO regulations require that a surface material shall also be tested for the production of smoke production and toxic products according to IMO 2010 FTPC Part 2.

IMO – Surface materials producing low quantities of smoke and toxic products

Test method:
FTPC Part 2 – *Smoke and toxicity test*, using the test standard ISO 5659-2 [50] and ISO 19702 [30].

Criteria for classification:
The criteria to results from testing of surface materials according to IMO 2010 FTPC Part 2 are stated in the published method, and are presented in the table below. The criteria shall be satisfied for all the three test modes as described in the method.

Table 7-2 Criteria for production of smoke and toxic products according to IMO 2010 FTPC Part 2.

	Smoke density D_m* [-]	**Toxicity, Gas concentrations in ppm****						
		CO	**HCl**	**HF**	**NO_x**	**HBr**	**HCN**	**SO_2**
Criteria for materials used as surfaces of bulkheads, linings or ceilings	≤ 200	≤ 1450	≤ 600	≤ 600	≤ 350	≤ 600	≤ 140	≤ 120

*D_m = the average of the maximum specific optical density of smoke, dimensionless unit
**ppm = concentration in parts per million

The material will either pass or fail this test.

When the test results from the three test modes meet all the criteria shown in Table 7-2 above, the product is considered not to be capable of producing excessive quantities of smoke and toxic products or not to give rise to toxic hazards at elevated temperatures.

The smoke density criteria for surface materials on walls and ceilings are stricter than for floor and primary deck coverings (see section 7.6) and plastic pipes (see 7.9.2). The criteria for the gas concentrations are the same for all these types of products.

What does the classification mean?
A surface material that satisfy the criteria of this test method can be considered a fire safe product with respect to production of smoke and toxic gases at those conditions that the method simulates.

IMO – Fire restricting surface material

Test method:
IMO 2010 FTPC Part 10 – *Test for fire-restricting materials for high-speed craft* [14] using the test standard ISO 9705 [11].

Criteria for classification:
The criteria for testing surface materials on bulkhead, wall and ceiling linings, including their supporting structure according to IMO 2010 FTPC Part 10 are stated in the published method, and are presented in the table below.

Table 7-3 Criteria for testing according to ISO 9705 as described in IMO 2010 FTPC Part 10.

HRR_{avg} [kW]	HRR_{max} [kW]	SPR_{avg} [m^2/s]	SPR_{max} [m^2/s]	Flame spread	Flaming drops/debris
≤ 100	≤ 500	≤ 1.4	≤ 8.3	Flame spread shall not reach any further down the walls of the test room than 0.5 m from the floor excluding the area which is within 1.2 m from the corner where the ignition source is located.	No flaming drops or debris of the test specimen may reach the floor of the test room outside the area which is within 1.2 m from the corner where the ignition source is located.

HRR_{avg} = the time average of heat release rate (HRR) excluding the HRR from the ignition source.
HRR_{max} = the maximum HRR averaged over any 30 s period of time during the test, excluding the HRR from the ignition source.
SPR_{avg} = the time average of the smoke production rate.
SPR_{max} = the maximum value of the smoke production rate averaged over any period of 60 s during the test.

The material will either pass or fail this test.

When the test results, after 20 minutes of test according to ISO 9705, meet all the criteria shown in Table 7-3 above, the product is considered to be *fire-restricting*.

What does the classification mean?
A surface material that satisfy the criteria of this test method can be considered a fire safe product with respect to heat release and production of smoke at those conditions that the method simulates. The test is large scale and the conditions are realistic and simulates a room fire starting in a waste basket, spreading to a furniture. The requirements of IMO 2010 FTPC Part 10 are relatively strict.

The Euroclasses for surface materials

The Euroclasses under the European Commission's Construction Products Regulations are given in the standard EN 13501-1 [27], see also section 5.4.

The classes A1, A2, B, C, D, E and F for construction products are defined in the standard. Other classes for floors are defined, and are described in section 7.7.2.

The relevant test methods to be used for classification are shown in

Table 7-4 and a brief description is shown in Table 7-5 below.

Table 7-4 Test methods for construction products except flooring within the Euroclass system [27].

Class	Methods
A1	EN-ISO 1182 and EN-ISO 1716
A2	EN-ISO 1182 and EN 13823 *or* EN-ISO 1716 and EN 13823
B	EN 13823 and EN-ISO 11925-2
C	EN 13823 and EN-ISO 11925-2
D	EN 13823 and EN-ISO 11925-2
E	EN-ISO 11925-2
F	No performance determined

Criteria for classification:
The criteria related to results from the different test methods are presented in EN 13501-1.

What does the classification mean?
The Euroclasses describe different levels of heat release and flame-spread (A1 to F), different levels of smoke production (s1, s2, s3), and different levels of production of flaming droplets and/or debris (d0, d1, d2). These terms are put together to describe the product's reaction-to-fire properties. A surface material that for example show low heat release and low flame-spread, produces little smoke and that does not produce any burning droplets would be given the class B-s1,d0. A brief description of the different designations are given in Table 7-5 below.

Table 7-5 Brief description of the different class designations for construction products (except flooring) within the Euroclass system [27].

Class		Description
Heat release, flame-spread, ignitability	**A1**	Products in class A1 will not contribute to any phase of the fire, including the fully developed fire. Therefore they are automatically considered to be able to meet all requirements of a lower class. These are materials such as rock, glass, metal, some mineral wools, etc.
	A2	Products in class A2 will not significantly contribute to the fire energy or to fire development during a fully developed fire. These are materials with very low combustibility, such as some mineral wools and plaster boards.
	B	Low flame-spread characteristics. Low heat release.
	C	Limited flame-spread characteristics. Moderate heat release.
	D	Normal flame-spread characteristics. Normal heat release (e.g. untreated wood).
	E	The product is only tested with exposure from a small flame, and will under those conditions show limited flame-spread characteristics. The class has lower requirements on the fire safety properties.
	F	No performance determined.
Smoke production	**s1**	Low smoke production.
	s2	Moderate smoke production.
	s3	No requirements for smoke production.
Burning droplets/particles	**d0**	No burning droplets/particles.
	d1	Only burning droplets/particles with short duration.
	d2	No requirements on burning droplets/particles.

7.3.3 Guidelines for selection of surface materials on walls and ceilings

Non-combustible materials shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

or

Combustible materials satisfying the criteria for surface materials in walls and ceiling linings[*)] according to IMO 2010 FTPC Part 5 and Part 2.
or
Combustible materials satisfying Euroclass B-s1,d0 (EN 13501-1)
or
Combustible materials satisfying the criteria for fire restricting materials according to IMO 2010 FTPC Part 10 (ISO 9705)

or

Alternatively, the material can be tested according to ISO 5660-1, satisfying the following criteria:

Heat flux density level [kW/m^2]	**Test duration [s]**	**t_{ign} [s]**	**$HRR_{avg,300s}$ [kW/m^2]**	**HRR_{max} [kW/m^2]**	**THR [MJ/m^2]**	**SPR_{avg} [s^{-1}]**
Either						
50	900	≥ 150	-	≤ 50	≤ 10	≤ 0.17
Or						
50	900	≥ 150	≤ 50	≤ 65	-	≤ 0.17
75	900	≥ 90	≤ 100	≤ 100	-	≤ 0.17

[*)] In case the materials are used outdoors, in areas where the risk for exposure of people to smoke is small, lower requirements on smoke production may be considered. This must be assessed in each case.

7.4 Tarpaulins

7.4.1 Test methods for tarpaulins

Large size tarpaulins should be documented with acceptable fire safety properties, both with regards to ignitability, flame-spread and heat release. The requirements must be assessed with basis in the area of application, see 5.1.

The European standards EN 13823 (Single Burning Item test) and EN ISO 11925-2 (small flame test) can be used for testing and classification of tarpaulins. The criteria to be met must be determined based on the application area and the size of the tarpaulin.

The large scale test ISO 9705 is in use today as documentation for fire safety of coated fabrics used as water and frost protection in road tunnels in Norway. The criteria for the test results are given in a manual issued by the Norwegian Public Roads Administration on protection of tunnels from water and frost [51]. Such documentation would also be relevant for tarpaulins to be used on offshore petroleum industry facilities.

7.4.2 Criteria for tarpaulins

Tarpaulins should be tested and assessed as surfaces on walls and ceilings, see 7.3.

7.4.3 Guidelines for selection of tarpaulins

Non-combustible materials shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

or

Combustible materials satisfying the criteria for surface materials in walls and ceiling linings[*)] according to IMO 2010 FTPC Part 5 and Part 2.
or
Combustible materials satisfying Euroclass B-s1,d0 (EN 13501-1)
or
Combustible materials satisfying the criteria for fire restricting materials according to IMO 2010 FTPC Part 10 (ISO 9705).

ISO 5660-1 is not suited for this type of product.

7.5 Noise reduction curtains

7.5.1 Test methods for noise reduction curtains

Acoustic insulating walls and noise reduction curtains form large vertical surfaces in process areas and should meet the criteria for surfaces on ceilings and walls, see section 7.3. The requirements must be assessed based on the area of application, see section 5.1.

The fire safety properties of noise reduction curtains should be documented by testing with relatively small ignition sources. This means fire exposure which is far lower than that of a fully developed fire in hydrocarbon fuel The properties that should be determined are heat release, flame-spread, formation of burning droplets or particles, optical smoke density and production of toxic gases.

If the noise reduction curtain will be free-hanging, and if front and back are not equal, both sides must be tested.

There are to alternative ways of documenting the fire safety properties of noise reduction curtains:

- EN 13823 (SBI) and EN ISO 11925 (small flame) with classification according to the classification standard EN 13501-1. Noise reduction curtains should satisfy class B-s1,d0.

or

- IMO FTPC Part 2 (smoke and toxicity) and IMO FTPC Part 5 (flame-spread). Noise reduction curtains should meet the requirements of both of these methods.

7.5.2 Criteria for noise reduction curtains

Noise reduction curtains should be assessed as surfaces on walls and ceilings, see 7.3.

7.5.3 Guidelines for selection of noise reduction curtains

Non-combustible materials shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

or

Combustible materials satisfying the criteria for surface materials in walls and ceiling linings according to IMO 2010 FTPC Part 5 and Part 2.
or
Combustible materials satisfying Euroclass B-s1,d0 (EN 13501-1)
or
Combustible materials satisfying the criteria for fire restricting materials according to IMO 2010 FTPC Part 10 (ISO 9705)

or

Alternatively, the material can be tested according to ISO 5660-1, satisfying the following criteria:

Heat flux density level [kW/m^2]	Test duration [s]	t_{ign} [s]	$HRR_{avg,300s}$ [kW/m^2]	HRR_{max} [kW/m^2]	THR [MJ/m^2]	SPR_{avg} [s^{-1}]
Either						
50	900	≥ 150	-	≤ 50	≤ 10	≤ 0.17
Or						
50	900	≥ 150	≤ 50	≤ 65	-	≤ 0.17
75	900	≥ 90	≤ 100	≤ 100	-	≤ 0.17

7.7 Floor and primary deck coverings

7.7.1 Test methods for floor and primary deck coverings

Within the European Economic Area the following methods for floors are adopted as a part of the harmonised system:

- EN ISO 11925-2 (small flame test) [47] for construction products generally, including floorings
- EN ISO 9239-1 (radiant panel test) [52] for floorings

IMO 2010 FTPC indicate that surfaces on floors shall be tested for documentation of flame-spread characteristics and heat release:

- IMO 2010 FTPC Part 5 (surface materials and primary deck coverings)

According to IMO 2010 FTPC surfaces on floors shall also be tested for the documentation of smoke and toxicity:

- IMO FTPC Part 2

The IMO requirements on optical density are stricter for walls and ceilings than for floor- and primary deck coverings, while the requirements on toxicity is the same for all product types.

ISO 5660-1 (the cone calorimeter test) can also be used for documenting the fire safety of floors.

7.7.2 Criteria for floor and primary deck coverings

IMO – floor coverings with low flame-spread characteristics

Test method:
IMO 2010 FTPC Part 5 – *Test for surface flammability (test for surface materials and primary deck coverings)* [14], using the test standard ISO 5658-2 [49].

If a floor covering consists of several layers, each layer, or a combination of some of the layers, may be required to meet the criteria for floor coverings with low flame-spread characteristics.

IMO makes a distinction between *floor covering* and *primary deck covering*. A *primary deck covering* is the first layer of a floor construction which is applied directly on top of the deck plating (including primary coat, anti-corrosive compounds and adhesives). Other layers in the floor construction above the deck plating is defined as *floor covering*. Products that are the first layer of a floor construction, applied directly on top of the deck plating, and is also the exposed surface, shall be regarded as *floor covering*.

Criteria for classification:
The criteria for testing floor and primary deck coverings according to IMO 2010 FTPC Part 5 are stated in the published method, and are presented in the table below.

Table 7-6 Criteria for flame-spread characteristics of floor- and primary deck according to IMO 2010 FTPC Part 5.

	CFE [kW/m^2]	Q_{sb} [MJ/m^2]	Q_t [MJ]	q_p [kW]	Burning droplets
Criteria for floor coverings	≥ 7.0	≥ 0.25	≤ 2.0	≤ 10.0	≤ 10
Criteria for primary deck coverings	≥ 7.0	≥ 0.25	≤ 2.0	≤ 10.0	Not produced

CFE = Critical flux at extinguishment
Q_{sb} = Heat for sustained burning
Q_t = Total heat released
q_p = Peak heat release rate

The material will either pass or fail this test. The criteria for floor and primary deck coverings are not as strict as for surfaces on walls and ceilings, see section 0.

What does the classification mean?
A floor or primary deck covering that satisfy the criteria of this test method can be considered a fire safe product with respect to flame-spread and heat release. The test conditions are relatively severe, and the criteria to the test results are relatively strict.

According to the IMO regulations floor- and primary deck coverings shall also be tested for the production of smoke production and toxic gases according to IMO 2010 FTPC Part 2.

IMO – floor coverings producing low quantities of smoke and toxic gases

Test method:
FTPC Part 2 – *Smoke and toxicity test*, using the test standard ISO 5659-2 and ISO 19702.

Criteria for classification:
The criteria for testing floor- and primary deck coverings according to IMO 2010 FTPC Part 2 are stated in the published method, and are presented in the table below. The criteria shall be satisfied for all the three test modes as described in the method.

Table 7-7 Criteria for production of smoke and toxic products according to IMO 2010 FTPC Part 2.

	Smoke density D_m * [-]	Toxicity, gas concentrations in ppm**						
		CO	HCl	HF	NO_x	HBr	HCN	SO_2
Criteria for floor coverings	≤ 500	≤ 1450	≤ 600	≤ 600	≤ 350	≤ 600	≤ 140	≤ 120
Criteria for primary deck covering	≤ 400	≤ 1450	≤ 600	≤ 600	≤ 350	≤ 600	≤ 140	≤ 120

* D_m = the average of the maximum specific optical density of smoke, dimensionless unit
** ppm = concentration in parts per million

The material will either pass or fail this test.

When the test results from the three test modes meet all the criteria shown in Table 7-7 above, the product is considered not to be capable of producing excessive quantities of smoke and toxic products or not to give rise to toxic hazards at elevated temperatures.

The smoke density criterion for floor and primary deck coverings are not as strict as for surfaces on walls and ceilings. The criteria for the gas concentrations are the same for both product types.

What does the classification mean?
A floor- or primary deck covering that satisfies the criteria of this test method can be considered a fire safe product with respect to production of smoke and toxic gases at the fire conditions that the method simulates.

The Euroclasses for floor coverings

The standard EN 13501-1 for the classification of construction products defines the classes $A1_{fl}$, $A2_{fl}$, B_{fl}, C_{fl}, D_{fl} og F_{fl} for flooring (fl stands for *flooring*). A brief summary of the classes and their corresponding test methods is shown in Table 7-8 below.

Table 7-8 Required test methods for floorings within the Euroclass system [27].

Class	Methods
$A1_{fl}$	EN ISO 1182 and EN ISO 1716
$A2_{fl}$	EN ISO 1182 and EN -ISO 9239-1 or EN ISO 1716 and EN -ISO 9239-1
B_{fl}	EN -ISO 9239-1 and EN ISO 11925-2
C_{fl}	EN -ISO 9239-1 and EN ISO 11925-2
D_{fl}	EN -ISO 9239-1 and EN ISO 11925-2
E_{fl}	EN ISO 11925-2
F_{fl}	No performance determined

Criteria for classification:
Class $A1_{fl}$ is the strictest class. The combustibility of materials in classes $A1_{fl}$ and $A2_{fl}$ is very low, while class B_{fl} includes products with limited flame spread characteristics and a low heat release. In addition to the main classes the additional classification s1 and s2 can be given for smoke production.

What does the classification mean?
The Euroclasses for floorings describe different levels of heat release and flame-spread ($A1_{fl}$ til F_{fl}) and two levels of smoke production (s1 and s2). These terms are put together to describe the product's reaction-to-fire properties. A flooring that for example show low heat release and low flame-spread, and produces little smoke would be given the class B_{fl}-s1. A brief description of the different designations are given in Table 7-9 below.

Table 7-9 Brief description of the different class designations for floorings within the Euroclass system [27].

Class		Description
Heat release, flame-spread, ignitability	**$A1_{fl}$**	Products in class $A1_{fl}$ will not contribute to any phase of the fire, including the fully developed fire. Therefor they are automatically considered to be able to meet all requirements of a lower class. These are materials such as rock, glass, metal, some mineral wools, etc.
	$A2_{fl}$	Products in class $A2_{fl}$ will not significantly contribute to the fire energy or to fire development during a fully developed fire. These are materials with very low combustibility, such as some mineral wools and plaster boards.
	B_{fl}	Low flame-spread characteristics and low heat release when exposed to heat radiation.
	C_{fl}	As for B_{fl}, but less strict criteria.
	D_{fl}	As for C_{fl}, but less strict criteria. Some parquet floors will meet the requirements of this class.
	E_{fl}	The product is only tested with exposure from a small flame, and will under those conditions show limited flame-spread characteristics. The class has lower requirements on the fire safety properties.
	F_{fl}	No performance determined.
Smoke production	**s1**	Low smoke production.
	s2	No requirements for smoke production.

7.7.3 Guidelines for selection of floor- and primary deck coverings

Non-combustible materials shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

or

Combustible materials satisfying the criteria for surface materials in floor and primary deck coverings according to IMO 2010 FTPC Part 5 and Part 2.
or
for *living quarters*, floorings can be acceptable if they satisfy Euroclass D_{fl}-s1 (EN 13501-1).

or

Alternatively, the material can be tested according to ISO 5660-1, satisfying the following criteria for *living quarters*:

Heat flux density level [kW/m^2]	Test duration [s]	t_{ign} [s]	$HRR_{avg,300s}$ [kW/m^2]	HRR_{max} [kW/m^2]	THR [MJ/m^2]	SPR_{avg} [s^{-1}]
50	900	≥ 150	-	≤ 100	≤ 25	≤ 0.17

Floorings in *process areas* should satisfy the following criteria when tested according to ISO 5660-1:

Heat flux density level [kW/m^2]	Test duration [s]	t_{ign} [s]	$HRR_{avg,300s}$ [kW/m^2]	HRR_{max} [kW/m^2]	THR [MJ/m^2]	SPR_{avg} [s^{-1}]
50	900	≥ 150	-	≤ 100	≤ 25	≤ 0.3

7.8 Gratings

7.8.1 Test methods for gratings

Combustible gratings used as floor and deck should satisfy the requirements as for flooring. When gratings are used in ceilings and on walls, they should meet the criteria for surface materials on ceilings and walls. This also applies if the gratings can be exposed from underneath.

The relevant criteria for smoke production must be assessed on the basis of its use, see section 5.1.

Relevant test methods:

- IMO 2010 FTPC Part 5 (flame-spread, criteria for flooring or ceilings and walls as applicable) **and** IMO 2010 FTPC Part 2 (smoke and toxicity, criteria for flooring or ceilings and walls as applicable), against criteria given in these for the relevant application.

or

- EN ISO 11925-2 (ignitability) and EN ISO 9239-1 (flame spread and smoke production, flooring), classification according to EN 13501-1

or

- EN ISO 11925-2 EN 13823 , classification according to EN 13501-1

7.8.2 Criteria for gratings

If the gratings are applied so that they can only be exposed to fire from above, they should be tested and assessed as flooring in process areas, see section 7.6.

If the gratings can be exposed for fire from underneath, they should be tested and assessed as wall and ceiling linings, see section 7.3.

7.8.3 Guidelines for selection of gratings

Non-combustible materials shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

or

Combustible materials satisfying the criteria for surface materials in walls and ceiling linings (or floor covering if the gratings can only be exposed from above) according to IMO 2010 FTPC Part 5 and Part 2.
or
Combustible materials satisfying Euroclass B-s1,d0 (EN 13501-1)
or
Combustible materials satisfying the criteria for fire restricting materials according to IMO 2010 FTPC Part 10 (ISO 9705)

or

Alternatively, the material can be tested according to ISO 5660-1, satisfying the following criteria:

Heat flux density level [kW/m^2]	Test duration [s]	t_{ign} [s]	$HRR_{avg,300s}$ [kW/m^2]	HRR_{max} [kW/m^2]	THR [MJ/m^2]	SPR_{avg} [s^{-1}]
50	900	≥ 150	-	≤ 100	≤ 25	≤ 0.3

7.9 Pipes and insulation for pipes and ducts

7.9.1 Test methods for pipes and insulation for pipes and ducts

Within the European Economic Area the following methods are adopted as a part of the harmonised system for linear pipe thermal insulation products:

- EN 13823 (Single Burning Item test) [46] for construction products
- EN ISO 11925-2 (small flame test) [47] for construction products

Testing of plastic pipes is also described in IMO Resolution A.753(18) Guidelines for the application of plastic pipes on ships [53], including requirement to test the material for flame-spread and smoke generation. When these guidelines, which are still valid and in use, were published, the flame-spread test method was called IMO Resolution A.653(16) [28] and the test method for smoke and toxicity was under development. The test for flame-spread has been replaced by IMO 2010 FTPC Part 5 and the test for smoke and toxicity has been published as IMO 2010 FTPC Part 2. The criteria for plastic pipes are equal to those for bulkhead, wall and ceiling linings.

The criteria for smoke production must be related to the area of application, see 5.1.

Materials used in ventilation ducts shall also be tested according to these methods, with pass criteria as for surface materials for wall and ceiling linings.

7.9.2 Criteria for pipes and ducts insulation

IMO – Surface materials with low flame-spread characteristics

Test method:
IMO 2010 FTPC Part 5 – *Test for surface flammability (test for surface materials and primary deck coverings)* [14], using the test configuration of appendix 3 of IMO Resolution A.753(18).

Criteria for classification:
The criteria for testing plastic pipes according to IMO 2010 FTPC Part 5 are the same as for bulkhead, wall and ceiling linings, and are presented in the table below.

Table 7-10 Criteria for flame-spread characteristics applicable for plastic pipes according to IMO 2010 FTPC Part 5.

	CFE [kW/m^2]	Q_{sb} [MJ/m^2]	Q_t [MJ]	q_p [kW]	Burning droplets
Criteria for bulkhead, wall and ceiling linings	≥ 20.0	≥ 1.5	≤ 0.7	≤ 4.0	Not produced

CFE = Critical flux at extinguishment
Q_{sb} = Heat for sustained burning
Q_t = Total heat released
q_p = Peak heat release rate

The material will either pass or fail this test. The criteria for surface materials on walls and ceilings are stricter than those for floor coverings.

What does the classification mean?
A plastic pipe that satisfies the criteria of this test method can be considered a fire safe product with respect to flame-spread and heat release. The test conditions are relatively severe, and the criteria to the test results are relatively strict.

IMO – Surface materials producing low quantities of smoke and toxic gases, as applicable for plastic pipes

When the plastic pipes are required to produce low quantities of smoke and toxic gases they shall meet the criteria for bulkhead, wall and ceiling linings.

Test method:
FTPC Part 2 – *Smoke and toxicity test*, using the test standard ISO 5659-2 and ISO 19702.

Criteria for classification:
The criteria for testing surface materials according to IMO 2010 FTPC Part 2 are stated in the published method, and are presented in the table below. The criteria shall be satisfied for all the three test modes as described in the method.

Table 7-11 Criteria for production of smoke and toxic gases according to IMO 2010 FTPC Part 2.

	Smoke density D_m * [-]	Toxicity, gas concentrations in ppm**						
		CO	HCl	HF	NO_x	HBr	HCN	SO_2
Criteria for materials used as surfaces of bulkheads, linings or ceilings	≤ 200	≤ 1450	≤ 600	≤ 600	≤ 350	≤ 600	≤ 140	≤ 120

* D_m = the average of the maximum specific optical density of smoke, dimensionless unit
** ppm = concentration in parts per million

The material will either pass or fail this test.

When the test results from the three test modes meet all the criteria shown in Table 7-11 above, the product is considered not to be capable of producing excessive quantities of smoke and toxic products or not to give rise to toxic hazards at elevated temperatures.

The smoke density criteria for surface materials on walls and ceilings are stricter than for floor and primary deck coverings, see section 7.6. The criteria for the gas concentrations are the same for both types of products.

What does the classification mean?
A plastic pipe that satisfies the criteria of this test method can be considered a fire safe product with respect to production of smoke and toxic products at those fire conditions that the method simulates.

The Euroclasses for linear pipe thermal insulation products

Tests are performed according to EN 13823, but with a specific configuration of the test specimens, and according to EN ISO 11925-2. The classes and their criteria are presented in EN 13501-1.

What does the classification mean?
The Euroclasses describe different levels of heat release and flame-spread ($A1_L$ to F_L), different levels of smoke production (s1, s2, s3), and different levels of production of flaming droplets and/or debris (d0, d1, d2). A brief description of the different designations are given in Table 7-12 below.

Table 7-12 Brief description of the different class designations for linear pipe thermal insulation products.

Class		Description
Heat release, flame-spread, ignitability	**$A1_L$**	Products in class $A1_L$ will not contribute to any phase of the fire, including the fully developed fire. Therefor they are automatically considered to be able to meet all requirements of a lower class. These are materials such as rock, glass, metal, some mineral wools, etc.
	$A2_L$	Products in class $A2_L$ will not significantly contribute to the fire energy or to fire development during a fully developed fire. These are materials with very low combustibility.
	B_L	Low flame-spread characteristics and low heat release when exposed to radiation.
	C_L	As for B_L, but less strict criteria.
	D_L	As for C_L, but less strict criteria.
	E_L	The product is only tested with exposure from a small flame, and will under those conditions show limited flame-spread characteristics. The class has lower requirements on the fire safety properties.
	F_L	No performance determined
Smoke production	**s1**	Low smoke production.
	s2	Moderate smoke production.
	s3	No requirements for smoke production.
Burning droplets/particles	**d0**	No burning droplets/particles
	d1	Only burning droplets/particles with short duration.
	d2	No requirements on burning droplets/particles.

Materials used in ventilation ducts: IMO 2010 FTPC Part 2 and Part 5

Test method:
IMO 2010 FTPC Part 2 og Part 5.

Criteria for classification:
The same criteria are used for materials for use in ventilation ducts as for bulkhead, wall and ceiling linings.

What does the classification mean?
Materials used in ventilation ducts that satisfy the criteria of this test method can be considered a fire safe product with respect to flame-spread and heat release. The test conditions are relatively severe, and the criteria to the test results are relatively strict.

7.9.3 Guidelines for selection of pipes and insulation for pipes and ducts

Non-combustible materials shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1.
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

or

Plastic pipes satisfying IMO Res. A.753(18).
or
Combustible insulation materials in pipes and ventilation ducts satisfying the criteria for surface materials in walls and ceiling linings according to IMO 2010 FTPC Part 5 and Part 2.
or
Combustible insulation materials in pipes and ventilation ducts satisfying the criteria for linear pipe thermal insulation for Euroclass BL-s1,d0 (EN 13501-1)

or

Alternatively, the material for pipes and insulation materials in pipes and ventilations ducts can be tested according to ISO 5660-1, satisfying the following criteria:

Heat flux density level [kW/m^2]	Test duration [s]	t_{ign} [s]	$HRR_{avg,300s}$ [kW/m^2]	HRR_{max} [kW/m^2]	THR [MJ/m^2]	SPR_{avg} [s^{-1}]
Either						
50	900	≥ 150	-	≤ 50	≤ 10	≤ 0.17
Or						
50	900	≥ 150	≤ 50	≤ 65	-	≤ 0.17
75	900	≥ 90	≤ 100	≤ 100	-	≤ 0.17

7.10 Electric cables

7.10.1 Test methods for electric cables

According to the guidelines to the facilities regulations, electrical installation should consist of "halon" free material, which must also be interpreted to include cable insulation. We assume that the requirement is meant to include halogens. The smoke from halogen containing materials is corrosive and can damage equipment in electrical installations. Halogen containing smoke is also very irritating for the mucous membrane, eyes and the upper respiratory tract.

A fire in a bundle of cables may be a great risk for flame spread. The amount of cables on the cable ladder and the position of the cables will be of great importance for the spread of fire. In rooms with large amounts of cables the heat release will be critical to the fire spread. In order to limit a fire in a cable tray flame retardants are often added to the cable sheathing.

As of 2014 there is an addition in the EN 13501 series with 13501-6 *Classification using data from reaction to fire tests on electric cables* [54]. EN 13501-6 is based on the following test methods:

- EN ISO 1716 Heat of combustion
- EN 60332-1-2 Vertical flame spread of single cable
- EN 50399 Burning behaviour and smoke production of bunched cables
- EN 61034-2 Smoke production of burning cables
- EN 50267-2-3 Acidity of gases produced by burning cables

Based on the results from these test methods cables can be classified with regards to flame spread, heat release, flaming droplets or particles, optical smoke production and smoke acidity.

7.10.2 Criteria for electric cables

The Euroclasses for electric cables

The European classes for electric cables are given in the harmonised standard EN 13501-6. A brief summary is shown in Table 7-14 below.

The relevant test methods to be used for classification are shown in Table 7-13.

Table 7-13 Test methods for electric cables within the Euroclass system [54].

Class	Methods
$\mathbf{A_{ca}}$	EN-ISO 1716
$\mathbf{B1_{ca}}$	EN 50399 and EN 60332-1-2
$\mathbf{B2_{ca}}$	EN 50399 and EN 60332-1-2
$\mathbf{C_{ca}}$	EN 50399 and EN 60332-1-2
$\mathbf{D_{ca}}$	EN 50399 and EN 60332-1-2
$\mathbf{E_{ca}}$	EN 60332-1-2
$\mathbf{F_{ca}}$	No performance determined

Criteria for classification:
Class A_{ca} is the strictest class. The combustibility of materials in class A_{ca} is very low, while class B_{ca} includes products with limited flame spread characteristics and a low heat release. In addition to the main classes the additional classification s1, s2 and s3 can be given for smoke production, d0, d1 and d2 for the production of flaming droplets and/or particles and a1, a2 and a3 for acidity.

What does the classification mean?
Class A_{ca} comprises non-combustible products, e.g. cables with ceramic sheathing. $B1_{ca}$ is the best class of the combustible products. Products in class D_{ca} will have the fire properties corresponding to ordinary wood, and E_{ca} comprises products that are difficult to ignite with a small ignition source (e.g. match flame equivalent), but where heat and smoke development properties are not documented.

A brief description of the different designations are given in Table 7-14 below.

Table 7-14 Brief description of the different class designations for flooring within the Euroclass system [27].

Class		Description
Heat release, flame-spread, ignitability	**A_{ca}**	Level of highest performance corresponding to products that practically cannot burn, i.e. ceramic products.
	$B1_{ca}$	Products that are combustible but show no or very little burning when exposed to the fire test scenario.
	$B2_{ca}$	Products that do not give a continuous flame spread, show a limited fire growth rate and show a limited heat release rate when exposed to the fire test scenario.
	C_{ca}	As for class $B2_{ca}$, but less strict criteria.
	D_{ca}	Products that show a fire performance approximately like wood.
	E_{ca}	Products where exposure to a small flame is not causing large flame spread.
	F_{ca}	No performance determined.
Smoke production (EN 50399)	**s1**	Best smoke class when tested according to EN 50399.
	s2	Less strict criteria than s1.
	s3	Not satisfying s1 or s2.
Smoke production (EN 61034-2)	**s1a**	s1 and transmittance in accordance with EN 61034–2 ≥ 80 %.
	s1b	s1 and transmittance in accordance with EN 61034–2 ≥ 60 % < 80 %.
Burning droplets/particles	**d0**	No burning droplets/particles
	d1	Only burning droplets/particles with short duration.
	d2	No performance declared, or lack of compliance with the d0 and d1 criteria.
Acidity	**a1**	Best acidity class.
	a2	Less strict criteria than a2.
	a3	No performance determined, or lack of compliance with the a1 and a2 criteria.

7.10.3 Guidelines for selection of electric cables

Selection of fire class shall be made with respect to area of application and other fire safety measures. I areas of high fire risk it will be natural to choose cables of class A_{ca} while classes $B1_{ca}$ and $B2_{ca}$ will normally be acceptable in living quarters.

Additional classifications:

- s1, s1a or s1b should be required for smoke production in areas where people can be exposed for smoke.
- d0 should be required for flaming droplets/particles.
- Acidity class a1 should be selected in areas where the corrosivity of the smoke will be of importance.

ISO 5660-1 is not suited for this type of product.

7.11 Materials for the construction of lifeboats

7.11.1 Test methods for the construction of lifeboats

According to IMO Life Saving Appliances (LSA) Code and its general requirements for lifeboats, the hull and canopy of lifeboats shall be fire retardant or non-combustible. Prototype tests for lifeboats are further described by stating that the hull and canopy should be tested for their fire retardant characteristics by placing the material in a flame. After removal from the flame the burning time and burning distances should be measured and "should be to the satisfaction of the Administration". Since the LSA Code does not define what "fire-retardant" is, the procedure for testing the hull and canopy material is published by IMO in IMO MSC/Circ.1006 *Guidelines on fire test procedures for acceptance of fire-retardant materials for the construction of lifeboats* [55]. The procedure is two-fold: a *fire-retardant* test and a *flame-resistant test*.

The fire-retardant test is actually a test of the ignitability, and the test is performed in the cone calorimeter (ISO 5660-1). 3 specimens are exposed to an irradiance of 50 kW/m^2.

In the flame-resistant test one specimen is exposed to a relatively large gas flame source of approximately 50 kW for 1 minute.

7.11.2 Criteria for the construction of lifeboats

IMO MSC/Circ.1006

Test method:
IMO MSC/Circ. 1006 *Guidelines on fire tests for acceptance of fire-retardant materials for the construction of lifeboats.*

- *ISO* 5660-*1 Reaction-to-fire tests – Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement).* Only time to ignition is measured, at irradiance 50 kW/m^2.
- Test with exposure to 50 kW gas flame for 1 minute.

Criteria for classification:

- When tested according to ISO 5660-1 the average time to ignition for three specimens should be greater than 40 seconds.
- When tested with the 50 kW gas burner, the flames in the specimen shall extinguish within 30 seconds after removal of the flame.

What does the classification mean?
Materials satisfying the criteria according to IMO MSC/Circ.1006 are considered difficult to ignite. If the material is ignited by a moderate ignition source, it will not continue to burn once the flame is removed.

7.11.3 Guidelines for selection of materials for the construction of lifeboats

Non-combustible materials shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1
or
Combustible materials satisfying the requirements of IMO MSC/Circ. 1006.

7.12 Draperies, curtains and other supported textiles in living quarters

7.12.1 Test methods for draperies, curtains and other supported textiles

Fire safety documentation of textiles in curtains and draperies are normally not required for use in buildings on land. However, if such textiles are ignited a fire can easily spread to walls and ceiling. Different characteristics of textiles (density, construction and chemical composition) will have importance for the heat release and smoke production as well as how the flame spreads through the fabric and at which speed.

The flame-spread resistance capabilities of *vertically supported textiles and films* on board ships must, however, be documented, using IMO 2010 FTPC Part 7 [14]. If a flame retardant is added to the textile, there is a washing procedure (described by IMO 2010 FTPC Part 7) required before the fire test is performed.

The Nordic NORDTEST method NT FIRE 043 [56] describes large scale testing of free-hanging curtain and drapery textiles. The method evaluate the contribution to fire growth and smoke production under a larger ignition source.

7.12.2 Criteria for draperies, curtains and other supported textiles

IMO – 2010 Fire Test Procedure Code Part 7

Test method:
IMO 2010 FTPC Part 7 – *Test for vertically supported textiles and films* [57].

The material shall be tested both in its lengthwise and crosswise direction. If the material is not inherently flame retardant the material shall be tested both as new and after an exposure procedure. The choice of exposure procedures is dependent on what is applicable to its intended use, but include accelerated dry-cleaning, laundering, water leaching and weathering, all described in more detail in IMO 2010 FTPC Part 7.

Criteria for classification:
The criteria for testing vertically supported textiles and films according to IMO 2010 FTPC Part 7 are stated in the published method and include after-flame time, the occurrence of surface flashes, scope of damage (burn-trough and char length) and the production of burning droplets/particles.

What does the classification mean?
Vertically supported textiles and films satisfying the criteria of the method are considered to be able to resist the propagation of a match-flame equivalent, as well as a woollen textile of mass 800 g/m^2. The classification does not give any information about the flame-spread characteristics, heat release or smoke production from the material when it is exposed to a larger ignition source.

NORDTEST method NT FIRE 043

Test method:
NT FIRE 043 – *Large, free-hanging curtain and drapery textiles: Heat release, fire spread and smoke production – full scale test* [56].

The test is performed with a 100 kW propane gas burner ignition source, and the test duration is 5 minutes.

Criteria for classification:
The method presents four classes with accompanying criteria, as presented in Table 7-15 below.

Table 7-15 Criteria for the assessment of large free-hanging curtain and drapery textiles according to NT FIRE 043.

Class	$HRR_{max,10s}$ [kW]	$SPR_{max,10s}$ [dBm^2/s]	Maximum mass loss [%]	Total flame-spread	Maximum flame height from burning material on the floor [m]
I	150	5	50	Not allowed	None
II	800	20	90	Not allowed	None
III	1300	-	-	Allowed	1.0
IV	-	-	-	Allowed	-

$HRR_{max,10s}$ = Peak heat release rate, 10 seconds sliding average
$SPR_{max,10s}$ = Peak smoke production rate, 10 seconds sliding average. (Calculated by using Brigg's logarithm and not the natural logarithm which is used in ISO 9705.)

What does the classification mean?
Large, free-hanging curtain and drapery textiles satisfying class I will be resistant to larger ignition sources (e.g. a burning wastepaper basket), and will only release little heat and produce small amounts of smoke during exposure. A higher class means a greater contribution to the fire growth.

7.12.3 Guidelines for selection of draperies, curtains and other supported textiles in living quarters

Combustible curtain/drapery materials satisfying class I when tested according to NT FIRE 043 are considered acceptable in all areas.
or
Combustible curtain/drapery materials satisfying the criteria for vertically supported textiles and films according to IMO FTPC Part 7 are acceptable in *living quarters*.

7.13 Upholstered furniture and mattresses

7.13.1 Test methods for upholstered furniture and mattresses

The test methods for upholstered furniture are not the same as for mattresses, however the ignition sources are generally the same. The list of available ignition sources is long and the ones that is in most frequent use in the Nordic countries are listed below, with a typical corresponding heat effect [58]:

- Smouldering cigarette (5 W)
- Match flame equivalent (100 W)
- Wooden crib[1] no. 4 (1 kW)
- Wooden crib no. 5 (1,9 kW)
- Wooden crib no. 6 (2,6 kW)
- Wooden crib no. 7 (6,4 kW)
- Propane gas burner (30 kW)

Figure 7-1 Varying sizes – a small box of matches alongside a wooden crib no. 5 and no. 7.

Upholstered furniture – resistance to ignition
Documentation of the resistance to ignition from smouldering cigarette and match-flame equivalent (i.e. "smokers material") is a common requirement for upholstered furniture.

Testing of upholstered furniture for use on-board ships is described in IMO 2010 FTPC Part 8, where both smouldering cigarette and the match flame equivalent are used.

EN 1021-1 (smouldering cigarette) [59] and EN 1021-2 (match-flame equivalent) [60] are corresponding test methods for upholstered furniture for use in land-based applications. The cigarette is not covered in any of these methods.

The resistance to ignition can be documented for upholstery filling and cover material separately. The upholstery filling will then be tested either in combination with a standard

[1] A wooden crib is a small standardized ignition source made of wood sticks. The cribs are ranked after number, a crib with a high number represents a larger ignition source than a crib with a low number.

textile (BS 5852) or exposing the foam directly (IMO 2010 FTPC Part 8), and the cover material would be tested in combination with a standard foam.

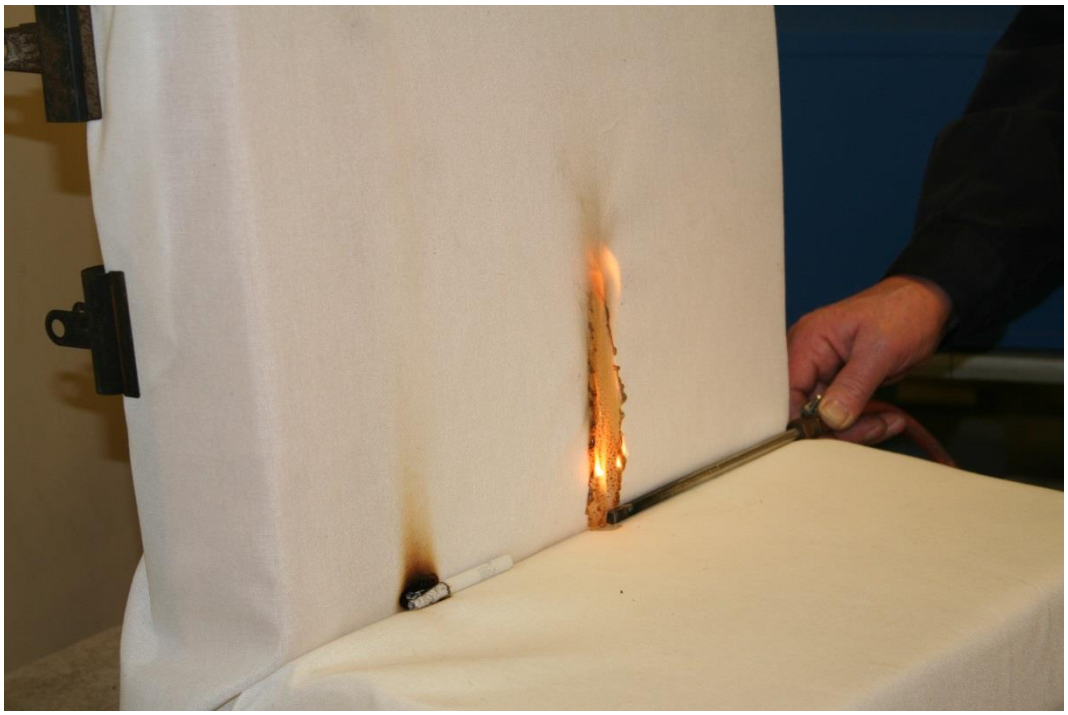

Figure 7-2 Demonstration – smouldering cigarette and match-flame equivalent on an IMO 2010 FTPC Part 8 upholstery material assembly.

Upholstered furniture – fire development

The NORDTEST method NT FIRE 032 [61] describes full scale testing of upholstered furniture and measurement of heat release and smoke production. The ignition source is wood crib no. 7 – i.e. much larger than a smouldering cigarette or match-flame equivalent. Pass or fail criteria are not defined in this method.

The British test standard BS 5852:2006 [62] describes testing of upholstered furniture, either as a chair mock-up or as a complete, full-size piece of furniture. Besides the smouldering cigarette (ignition source 0) and butane flame ignition sources in ascending order of severity (sources 1-3) BS 5852 also describes testing with the ignition sources 4 through 7. These are wooden cribs, much larger ignitions sources than a smouldering cigarette and a match-flame equivalent. This means that the upholstered furniture most probably will ignite, but the requirements are related to the allowed spread of fire in the seating. The criteria depend on the ignition source used in the test.

Mattresses – Resistance to ignition

It is also common to document that mattresses can resist ignition during exposure to the ignition sources smouldering cigarette and match-flame equivalent.

Testing of mattresses for use on-board ships is described in IMO 2010 FTPC Part 9, where both smouldering cigarette and the match flame equivalent are used.

EN 597-1 (smouldering cigarette) [63] and EN 597-2 (match-flame equivalent) [64] are corresponding test methods for mattresses for use in land-based applications.

The difference between IMO 2010 FTPC Part 9 and EN 597-1 is that the cigarette is covered with a cotton-wool pad in the IMO method, which causes the heat to accumulate. Hence the cigarette test according to IMO 2010 FTPC Part 9 is more severe than that of EN 597-1.

Mattresses – fire development
Documentation of fire development of mattresses is less common, but the British test standard BS 6807 [65] and the Swedish SS 876 00 10 [66] are two test methods that cover this aspect.

BS 6807 describes testing of bedding equipment using the wood cribs 4 to 7, which are much larger ignition sources than a smouldering cigarette or a small flame. This means that the mattress most probably will ignite, but the requirements are related to the allowed spread of fire in the mattress. The criteria depend on the ignition source used in the test.

The Swedish standard SS 876 00 10 is specifically developed for mattresses for certain areas of application (e.g. prisons and psychiatric institutions). This method uses a propane burner with a 30 kW flame exposure for two minutes, simulating fire in a duvet.

7.13.2 Criteria for upholstered furniture and mattresses

Upholstered furniture: IMO – 2010 Fire Test Procedure Code Part 8

Test method:
IMO 2010 FTPC Part 8 – *Test for upholstered furniture* [67].

The method states that the combination of materials used in the upholstered seating shall be tested for resistance to a smouldering cigarette and a lighted match.

Criteria for classification:
The specimen shall not show signs of progressive smouldering or flaming fire for the duration of one hour after the smouldering cigarette has been placed on the specimen. The specimen shall not show signs of progressive smouldering or flaming fire for more than 120 seconds after removing the propane flame from the specimen

If both of these criteria are satisfied, the material combination fulfils the requirements of IMO 2010 FTPC Part 8. The material will either pass or fail this test.

What does the classification mean?
A combination of upholstery materials satisfying the criteria will be able to resist ignition when exposed to smaller ignition sources (e.g. cigarettes and match flames) . The classification does not give any information about flame-spread characteristics, heat release or smoke production from the furniture when it is exposed to a larger ignition source.

Upholstered furniture: European norm EN 1021-1

Test method:
EN 1021-1 – *Furniture - Assessment of the ignitability of upholstered furniture - Part 1: Ignition source smouldering cigarette* [59].

Criteria for classification:
The specimen shall not display signs of progressive smouldering for the duration of one hour after the smouldering cigarette has been placed on the specimen. Flames initiated by the smouldering cigarette are not allowed.

The material assembly will either pass or fail this test.

What does the result from the testing mean?
A combination of upholstery materials satisfying the criteria will be able to resist ignition when exposed to a smouldering cigarette. The results do not give any information about flame-spread characteristics, heat release or smoke production from the furniture when it is exposed to a larger ignition source.

Upholstered furniture: European norm EN 1021-2

Test method:
EN 1021-2 Furniture - Assessment of the ignitability of upholstered furniture - Part 2: Ignition source match flame equivalent [60].

Criteria for classification:
The specimen shall not display signs of progressive smouldering for the duration of one hour after the smouldering cigarette has been placed on the specimen.

The test assembly shall not display flaming ignition, which include:

- escalating combustion behaviour
- test assembly burning until it is essentially consumed within the test duration
- flame front reaching the outer edges of the assembly
- flaming continuing for more than 120 seconds after removal of the flame.

The material assembly will either pass or fail this test.

What does the result from the testing mean?
A combination of upholstery materials satisfying the criteria will be able to resist ignition when exposed to a smaller ignition such as match flames. The results do not give any information about flame-spread characteristics, heat release or smoke production from the furniture when it is exposed to a larger ignition source.

Upholstered furniture: BS 5852

Test method:
BS 5852: 2006. Methods of test for assessment of the ignitability of upholstered seating by smouldering and flaming ignition sources.

Testing can be performed using different ignition sources from smouldering cigarette, to small butane flame sources to wooden cribs, in all 8 different ignition sources of increasing size. There are procedures for testing either upholstery composites or complete items of furniture.

Criteria for classification:
The test specimens are classified with a designation that indicates which ignition source is applied. *NI* stand for *No Ignition*, while *I* means *Ignition*. A class *NI/7* means that the product has passed a test where ignition source 7 has been applied.

- ***For testing with a small butane flame:***
  The specimen shall not display signs of smouldering within 15 minutes after removing the flame. Flaming in the specimen for more than 120 seconds after the removal of the flame is not allowed.

- ***For testing with wooden cribs:***
  The specimen shall not display signs of smouldering or flaming according to definitions in BS 5852:2006. The criteria cover scope of damage, burn-through, duration of flame and smoke production as well as the occurrence of fire in molten material underneath the specimen. The criteria are dependent on which crib that is used.

What does the classification mean?
A combination of upholstery materials satisfying the criteria will be able to resist ignition when exposed to a similar ignition sources as have been applied during test. A higher number of the ignition source indicates better fire properties. The classification does not give any information about heat release or smoke production rate from the furniture.

Upholstered furniture: Nordtest method NT FIRE 032

Test method:
NT FIRE 032. Upholstered furniture: Burning behaviour – full scale test

According to this method the testing shall be performed applying the wooden crib no. 7. However, any other ignitions sources can be applied if required.

Criteria for classification:
Pass or fail criteria are not defined in this method, hence a classification system is not available.

What does the result from the testing mean?
The method is very useful in combination with testing of upholstered furniture e.g. according to BS 5852:2006 or mattresses according to BS 6807:2006. Testing can then be

performed according to these standards while placing the specimen underneath the measurement equipment described in NT FIRE 032. With this procedure, testing will be supplemented with data on heat release, smoke production, release of toxic smoke as well as mass loss. Such information can be very useful for fire risk assessments.

Mattresses and bedding components: IMO – 2010 Fire Test Procedure Code Part 9

Test method:
IMO 2010 FTPC Part 9 – *Test for bedding components* [68].

The method states that bedding components (e.g. blankets, quilts, bedspreads, pillows and mattresses but excluding e.g. sheets, pillow cases, box springs, valances and bed curtains) shall be tested for resistance to a smouldering cigarette and a lighted match.

Criteria for classification:
The specimen shall not show signs of progressive smouldering or flaming fire for the duration of one hour after the smouldering cigarette has been placed on the specimen.
The specimen shall not show signs of progressive smouldering or flaming fire for more than 150 seconds after removing the propane flame from the specimen

If both of these criteria are satisfied, the material combination fulfils the requirements of IMO 2010 FTPC Part 9. The material will either pass or fail this test.

What does the classification mean?
Bedding components satisfying the criteria will be able to resist ignition when exposed to smaller ignition sources (e.g. cigarettes and match flames) . The classification does not give any information about flame-spread characteristics, heat release or smoke production from the product when it is exposed to a larger ignition source.

Mattresses: European norm EN 597-1

Test method:
EN 597-1 Furniture - Assessment of the ignitability of mattresses and upholstered bed bases - Part 1: Ignition source smouldering cigarette [63].

Criteria for classification:
The specimen shall not display signs of progressive smouldering for the duration of one hour after the smouldering cigarette has been placed on the specimen.

The material assembly will either pass or fail this test.

What does the result from the testing mean?
A mattress satisfying the criteria will be able to resist ignition when exposed to a smouldering cigarette. The results do not give any information about flame-spread characteristics, heat release or smoke production from the furniture when it is exposed to a larger ignition source.

Mattresses: European norm EN 597-2

Test method:
EN 597-2 Furniture - Assessment of the ignitability of mattresses and upholstered bed bases - Part 2: Ignition source: match flame equivalent [64].

Criteria for classification:

The specimen shall not display signs of progressive smouldering, which includes the following types of behaviour:

- escalating combustion behaviour
- test assembly smoulders until it is largely consumed within the test duration
- test assembly smoulders to its full thickness within the test duration
- test assembly that smoulders after one hour from the application of the ignition source
- test assembly that shows evidence of smouldering on final examination

The test assembly shall not display flaming ignition, which include:

- escalating combustion behaviour
- test assembly burning until it is essentially consumed within the test duration
- flame front reaching the outer edges of the assembly
- flaming continuing for more than 120 seconds after removal of the flame.

The material assembly will either pass or fail this test.

What do the results from the testing mean?
A mattress satisfying the criteria will be able to resist ignition when exposed to a smaller ignition such as match flames. The results does not give any information about flame-spread characteristics, heat release or smoke production from the mattress when it is exposed to a larger ignition source, or to a smouldering cigarette.

Mattresses: BS 6807

Test method:
BS 6807:2006 Assessment of the ignitability of mattresses, upholstered divans and upholstered bed bases with flaming types of primary and secondary sources of ignition.

Testing can be performed using different ignition sources from small butane flame sources to wooden cribs, in all 6 different ignition sources of increasing size. There are procedures for testing either upholstery composites or complete mattresses.

Criteria for classification:
The test specimen is classified with a designation that indicates which ignition source is applied and if has passed the test or not.

For testing with a small butane flame (ignition source 2 and 3):
The specimen shall not display signs of progressive smouldering, which includes the following types of behaviour:

- escalating combustion
- test specimen smoulders until it is essentially consumed within the test duration

- test specimen smoulders to its full thickness or to either side within the test duration
- the specimen shall not display signs of smoke, heat or glowing 15 minutes after removing the flame

The specimen shall not display signs of flaming ignition, which includes the following types of behaviour:

- escalating flaming combustion
- test specimen burns until it is essentially consumed within the test duration
- test specimen where the flame front reaches the extremities of the specimen or burns through its full thickness or to either side within the test duration
- flaming in the specimen for more than 120 seconds after the removal of the flame is not allowed
- debris causes an isolated floor fire

For testing with wooden cribs (ignition sources 4-7):

The specimen shall not display signs of progressive smouldering, which includes the following types of behaviour:

- escalating combustion
- test specimen smoulders until it is essentially consumed within the test duration
- test specimen smoulders to its full thickness or to either side within the test duration
- the specimen shall not display signs of smoke, heat or glowing 60 minutes after ignition of the crib

The specimen shall not display signs of flaming ignition, which includes the following types of behaviour:

- escalating flaming combustion
- test specimen burns until it is essentially consumed within the test duration
- test specimen where the flame front reaches the extremities of the specimen or burns through its full thickness or to either side within the test duration
- crib 4 and 5: Flaming in the specimen for more than 10 minutes after ignition of the crib
- crib 6 and 7: Flaming in the specimen for more than 13 minutes after ignition of the crib
- debris causes an isolated floor fire

<u>What does the classification mean?</u>

Mattresses satisfying the criteria will be able to resist ignition when exposed to a similar ignition source as have been applied during test. A higher number of the applied ignition source indicates better fire properties. The classification does not give any information about heat release or smoke production rate from the furniture.

Mattresses: SS 876 00 10

Test method:
SS 876 00 10 – *Healthcare textiles - Nursing beds - Burning requirements for mattresses to be used in high risk environment* [66].

According to this method a square propane gas burner is applied at the centre of a full size mattress, exposing the specimen to 30 kW for 2 minutes. The test procedure follows NT FIRE 055 [69].

Criteria for classification:
The criteria are given in the standard and are shown in Table 7-16 below.

Table 7-16 Criteria for mattresses tested according to SS 876 00 10.

Peak heat release (HRR_{smooth})	Total smoke production (TSP_{10})	Duration of flame after removing the burner
≤ 55 kW	≤ 50 m^2	≤ 3 minutes

What does the classification mean?
Mattresses satisfying the criteria will be able to resist ignition when exposed to a similar ignition sources as have been applied during test. A mattress that satisfies the criteria of SS 876 00 10 is considered fire safe.

7.13.3 Guidelines for selection of upholstered furniture in living quarters

Non-combustible materials, when required, shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

and

Combustible material assemblies passing test e.g. according to BS 5852 using crib no. 7 is considered acceptable for any application.
or
Combustible material assemblies passing test with smouldering cigarette and small flame, e.g. according to IMO 2010 FTPC Part 8, or BS 5851 using smaller ignition sources than crib 7, can be acceptable, but should be evaluated based on a risk assessment considering the area of application and passive and active fire safety measures.

7.13.4 Guidelines for selection of mattresses in living quarters

Non-combustible materials, when required, shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

and

Mattresses passing test e.g. according to BS 6807 using crib no. 7 or a 30 kW propane gas burner is considered acceptable for any application.
or
Mattresses passing test with smouldering cigarette and small flame, e.g. according to IMO 2010 FTPC Part 9 can be acceptable, but should be evaluated based on a risk assessment considering the area of application and passive and active fire safety measures.

7.14 Materials for furniture and fixtures in living quarters

7.14.1 Test methods for materials for furniture and fixtures in living quarters

Materials for furniture and fixtures in living quarters include materials used in tables, chairs, cupboards, etc., but exclude foam, cover and other materials that are part of a seating assembly or mattresses.

Fire safety documentation of materials used in furniture and fixtures are normally not required for use in buildings on land.

Materials used for furniture and other components in high-speed craft are required to satisfy the criteria of IMO 2010 FTPC Part 10, using the cone calorimeter test (ISO 5660-1) [48]. In order for the material to be *fire-restricting* it must meet requirements on ignitability, heat release and smoke production.

Other relevant test methods for documenting the fire properties of materials generally are those used for documenting non-combustibility (see section 5.1), and the methods for documenting surface materials on wall and ceiling linings (see section 7.3).

7.14.2 Criteria for furniture and fixtures in living quarters

Fire restricting materials used for furniture and other components: IMO – 2010 Fire Test Procedure Code Part 10

Test method:
IMO 2010 FTPC Part 10 – *Test for fire-restricting materials for high-speed craft* using the test standard ISO 5660-1 [14]. According to this test method the specimens are exposed to a heat flux of 50 kW/m^2 for 20 minutes according to ISO 5660-1.

Criteria for classification:
The criteria for testing materials used for furniture and other components for high-speed craft according to IMO 2010 FTPC Part 10 are stated in the published method, and are presented in Table 7-17 below.

Table 7-17 Criteria for testing according to ISO 5660-1 as described in IMO 2010 FTPC Part 10.

t_{ign} [s]	$HRR_{30,max}$ [kW/m^2]	THR [MJ/m^2]	SPR_{avg} [m^2/s]
≥ 20	≤ 60	≤ 20	≤ 0.005

t_{ign} = time to ignition
$HRR_{30,max}$ = maximum 30-second sliding average heat release rate.
THR = total heat release
SPR_{avg} = average smoke production rate

All criteria must be satisfied and the material will either pass or fail this test. A product satisfying the criteria is considered *fire-restricting* as required in certain applications according to paragraph 7.4.3.3 in *International Code of Safety for High-Speed Craft, 2000 (2000 HSC Code)* [70].

What does the classification mean?
A material classified as fire-restricting is considered to have satisfactory fire safety properties regarding flame-spread, heat release and smoke production. The test conditions are relatively severe, and the criteria to the test results are relatively strict.

Other criteria

Material components (excluding seating materials) in furniture and fittings can be tested and assessed as surface materials for wall and ceiling linings, see section 7.3.

7.14.3 Guidelines for materials for furniture and fixtures in living quarters

Non-combustible materials, shall be tested according to ISO 1182 and meet the criteria described in IMO 2010 FTPC Part 1.
or
satisfy Euroclass A1 or A2-s1,d0 (EN 13501-1).

or

Combustible materials satisfying the criteria for surface materials in walls and ceiling linings according to IMO 2010 FTPC Part 5 and Part 2.
or
Combustible materials satisfying Euroclass B-s1,d0 (EN 13501-1).
or
Combustible materials satisfying the criteria for fire restricting materials according to IMO 2010 FTPC Part 10 (ISO 5660-1).

8 Summary

Documentation of fire safe materials for offshore applications can be prepared in several ways. The documentation can be in the form of a report in which methods and results are described, or it can be designed as an assessment on the basis of test results. Such assessments can be made in relation to a recognized classification system or it may be assessed with respect to the product's usefulness in a given application.

Both the guidelines to the Facilities Regulations and NORSOK S-001N indicate that materials primarily should be non-combustible, however combustible materials can be allowed for different reasons and subject to a risk assessment.

If, for technical and practical reasons, combustible materials are selected, they should show properties of limited flame spread, low heat release, low levels of smoke production, and the smoke shall be of low toxicity. Non-combustible materials will fulfil these requirements, but other materials must be tested with the relevant test methods.

IMO 2010 FTPC Part 5 Test for surface flammability, IMO 2010 FTPC Part 2 Smoke and toxicity test and test and classification according to EN 13501-1 are suitable for documentation for most surface applications.

A list of reaction-to-fire test methods for materials in alphabetical order is presented below. These methods are often used for documentation of different products intended for use in onshore- or maritime- applications and on offshore installations. Several of the test methods are in principle quite similar but because they may be used in connection with different regulations the designations may differ.

The list contains only test methods that SP Fire Research has had sufficient information and experience to assess today. Other relevant and recognized test methods do exist in other parts of the world, and may very well be used for documentation of materials in the Norwegian offshore petroleum industry. Documentation from other tests than those listed below must, however, be carefully evaluated to assess if the tested product satisfy fire safety requirements in the application area in question.

BS 5852:2006 (upholstered furniture)	– Small scale test for combination of materials in upholstered furniture. – Test of ignition by exposure to different ignition sources; butane gas flame 1, 2 and 3, wood cribs 4, 5, 6 and 7. – Classification depends on the ignition source applied. – Classification criteria are related to fire development and damage. – The method can be combined with test method NT FIRE 032 to measure heat release and smoke production.
BS 6807:1996 (mattresses)	– Small scale test for mattresses. – Test of ignition by exposure to different ignition sources; butane gas flame 2 and 3, wood cribs 4, 5, 6 and 7. – Classification depends on the ignition source applied. – Classification criteria are related to fire development and damage. – The method can be combined with test method NT FIRE 032 to measure heat release and smoke production.
EN 597-1 and -2 (mattresses)	– Small scale test for mattresses. – Testing of ignitability with smouldering cigarette (part 1) and small flame (part 2). – States pass/fail criteria. – Similar to IMO 2010 FTPC Part 9.
EN 1021-1 and -2 (upholstered furniture)	– Small scale test for upholstered furniture. – Testing of ignitability with smouldering cigarette (part 1) and small flame (part 2). – States pass/fail criteria. – Equal to IMO 2010 FTPC Part 8.
EN 13823 (Single Burning Item test, SBI)	– Medium scale test for various materials. – Testing of flame-spread, heat release, smoke production and burning droplets/debris during exposure to a propane flame of 30 kW for 20 minutes. – Used for classification of materials with Euroclasses A2, B, C, D, $A2_{L,}B_L$, C_L, D_L (L= *linear pipe thermal insulation products*). – The pass/fail criteria vary depending on classification. – Criteria are given in EN 13501-1.
EN 50267-2-3 (electrical cables)	– Small scale test for electrical cables. – Test of the production of acidic gases. – Test criteria are given in EN 13501-6.

EN 50399 (electrical cables)	– Medium scale test for electrical cables. – Test of flame spread, heat release and smoke production. – Used for classification of cables according to the Euroclasses $B1_{ca}$, $B2_{ca}$, C_{ca} and D_{ca} (ca= *cable*). – Test criteria are given in EN 13501-6.
EN 60332-1-2 (electrical cables)	– Small scale test for electrical cables. – Test of vertical flame spread . – Used for classification of cables according to the Euroclasses $B1_{ca}$, $B2_{ca}$, C_{ca}, D_{ca} and E_{ca} (ca= *cable*). – Test criteria are given in EN 13501-6.
EN 61034-2 (electrical cables)	– Medium scale test for electrical cables. – Test of contribution to smoke obscuration. – Test criteria are given in EN 13501-6.
IMO 2010 FTPC Part 1 (non-combustibility)	– Test according to ISO 1182. – States pass/fail criteria for heat release, mass loss and visible flames.
IMO 2010 FTPC Part 2 (smoke and toxicity)	– Test according to ISO 5659-2, and states testing conditions. Also describes testing for toxic gases (with reference to ISO 19702). – States pass/fail criteria for smoke production and production of toxic gases.
IMO 2010 FTPC Part 5 (flame-spread)	– Small scale test of surface materials, floorings and deck coverings. – Testing of flame-spread characteristics, heat release, formation of burning droplets during exposure to radiation and a small flame. – Test according to ISO 5658-2. – States pass/fail criteria.
IMO 2010 FTPC Part 7 (textiles)	– Small scale test for curtain and draperies. – Testing of ignitability and flame-spread, small flame exposure. – Test is described in the method. – States pass/fail criteria .
IMO 2010 FTPC Part 8 (upholstered furniture)	– Small scale test for seating assemblies. – Testing of ignitability with small flame and smouldering cigarette. – States pass/fail criteria. – Equal to EN 1021-1 and -2.
IMO 2010 FTPC Part 9 (bedding components)	– Small scale test for bedding components (mattresses etc.). – Testing of ignitability with small flame and smouldering cigarette. – States pass/fail criteria . – Similar to EN 597-1 and 2, but a little more severe.
IMO 2010 FTPC Part 10 (fire restricting materials)	– Testing of products used on high-speed craft. – Uses either ISO 9705 or ISO 5660-1, depending of application. – States pass/fail criteria.

IMO MSC/Circ. 1006 (life boats)	– Small scale test for materials for life boats. – Testing ignitability and resistance to flame. – States pass/fail criteria.
IMO Res. MSC.61(67)	– IMO-resolution that approves FTPC (*the international code for fire test procedures*).
ISO 1182 (EN ISO 1182) (non-combustibility test)	– Small scale test for various materials. – Testing of the contribution to fire during exposure from 750 ^{o}C for appr. 30 minutes. – Method used in IMO 2010 FTPC Part 1. – Used for classification of materials with Euroclasses A1, A2, $A1_{fl}$, $A2_{fl}$, $A1_{L}$ and $A2_{L.}$ Criteria are given in EN 13501-1. – Any pass/fail criteria will depend on approval system or classification system.
ISO 1716 (EN ISO 1716) (calorific potential test)	– Small scale test for various materials. – Determines the heat of combustion from the tested material. – Method also mentioned in IMO 2010 FTPC Part 5. – Used for classification of materials with Euroclasses A1, A2, $A1_{fl}$, $A2_{fl}$, $A1_{L}$ and $A2_{L.}$ Criteria are given in EN 13501-1. – Any pass/fail criteria will depend on approval system or classification system.
ISO 5658-2 (flame-spread)	– Small scale test of surface materials oriented in the vertical position. – Testing of flame-spread characteristics and formation of burning droplets during exposure to radiation and a small flame. – Method used in IMO 2010 FTPC Part 5.
ISO 5659-2 (smoke chamber)	– Small scale test for various materials. – Test of smoke production during exposure to radiation, with and without pilot flame. – Method used in IMO 2010 FTPC Part 2. – Any pass/fail criteria will depend on approval system or classification system.
ISO 5660-1 (cone calorimeter)	– Small scale test for various materials. – Testing of ignitability, heat release, smoke production and production of toxic smoke during exposure to radiation and a spark ignition source. – Method used in IMO 2010 FTPC Part 10. – Any pass/fail criteria will depend on approval system or classification system .
ISO 9239-1 (EN ISO 9239-1) (floorings)	– Small scale testing for floorings. – Testing of flame-spread and smoke production during exposure to radiation and flame. – Used for classification of materials with Euroclasses $A2_{fl}$, B_{fl}, C_{fl} and D_{fl}. Criteria are given in EN 13501-1.

ISO 9705 (room corner test)	– Large scale test for surface materials in ceilings and walls. – Testing of flame spread, heat release, time to flash-over, smoke production and burning droplets/debris during exposure to a propane burner with 100 kW for 10 minutes plus 300 kW for 10 minutes. – Method used in IMO 2010 FTPC Part 10. – Any pass/fail criteria will depend on approval system or classification system.
ISO 11925-2 (EN ISO 11925-2) (small flame test)	– Small scale test for various materials. – Testing of ignitability, flame-spread and burning droplets/debris during exposure to a small flame. – Used for classification of materials with Euroclasses B, C , D, E, B_{fl}, C_{fl}, D_{fl}, E_{fl} , B_L, C_L, D_L, E_L (fl = *floorings*, L= *linear pipe thermal insulation products*). – Different test procedures and different pass/fail criteria depending on the product and the application.
ISO 19702 (smoke gas analysis)	– Guidance for analysis of gases and vapours in fire effluents using FTIR technology. – Method used in IMO 2010 FTPC Part 2.
NT FIRE 032 (upholstered furniture)	– Large scale test for upholstered furniture and other objects. Uses the same apparatus as described in ISO 9705. – Testing of heat release and smoke production during exposure to a small wooden crib ignition source. – A classification system has not been developed for this method. – Used for testing and approval if mattresses according to SS 876 00 10.
NT FIRE 043 (curtains and draperies)	– Large scale test for curtains and draperies. Uses the same apparatus as described in ISO 9705. – Testing of flame-spread, heat release, smoke production and burning droplets/debris during exposure to a propane burning of 100 kW for 5 minutes. – Used for classification of curtains and draperies, using the classes I-IV. – Criteria stated in the method.
SS 876 00 10 (mattresses)	– Full scale test for mattresses. – Testing of heat release and smoke production during exposure to a propane burner of 30 kW for 2 minutes. – Criteria for heat release and smoke production are given in the method.

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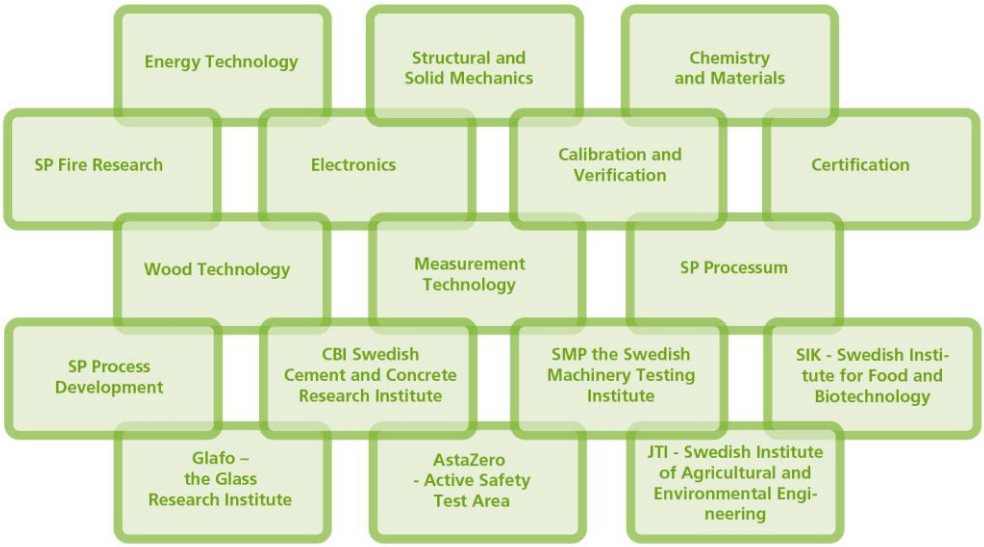

SP Fire Research AS

Box 4767 Sluppen, N-7465 Trondheim, NORWAY

Telephone: +47 464 18 000

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