NORTH ATLANTIC TREATY ORGANIZATION
ORGANISATION DU TRAITÉ DE L'ATLANTIQUE NORD

Fire Safety Requirements for Acoustic Materials: EN 13501-1 Classification and Principles of Key Calorimetric Test Methods

MYP G6006: "Acoustic Multi-Functional Composites for Environmental Risks and Health Hazards Reduction"

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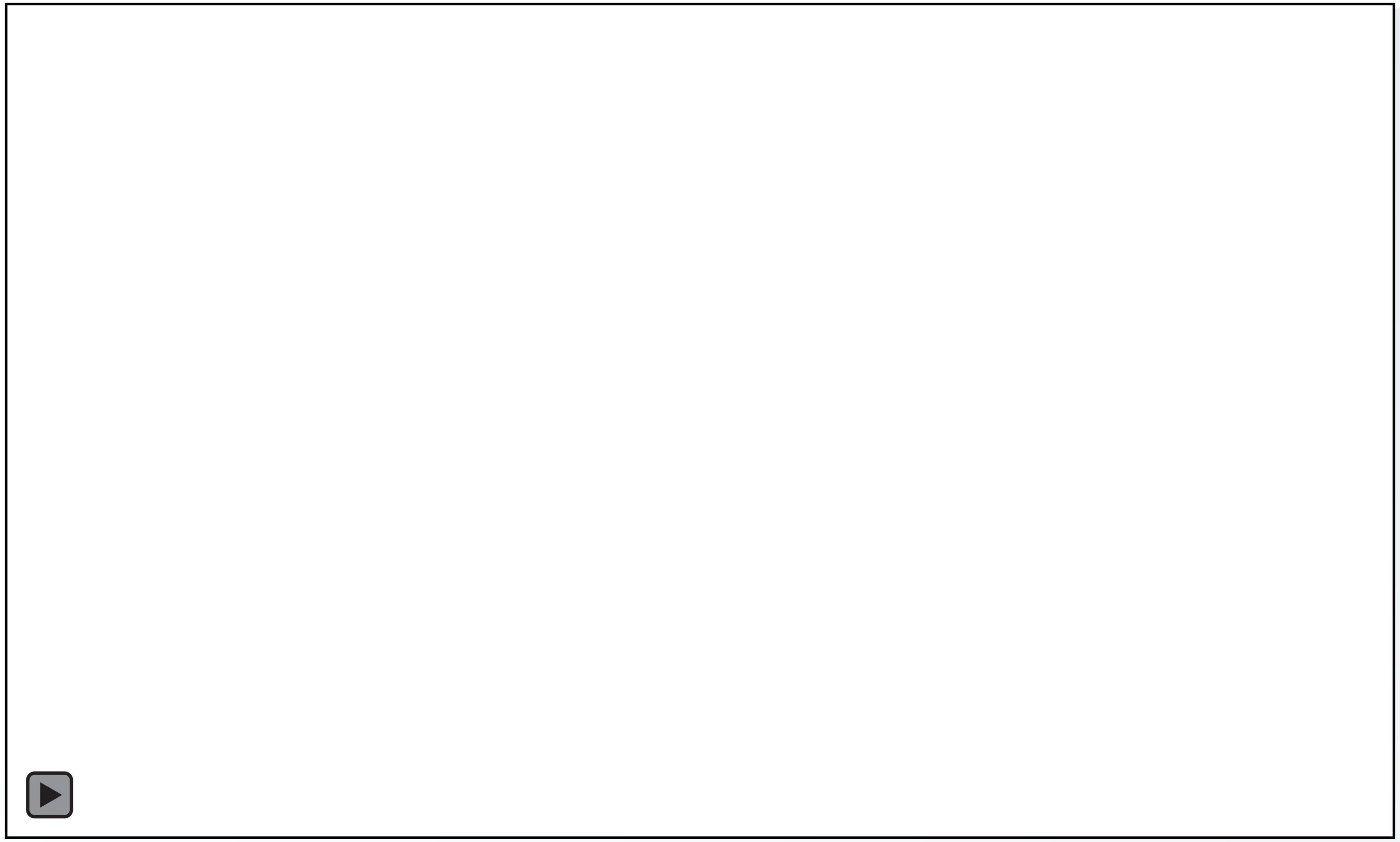
PUBLIC

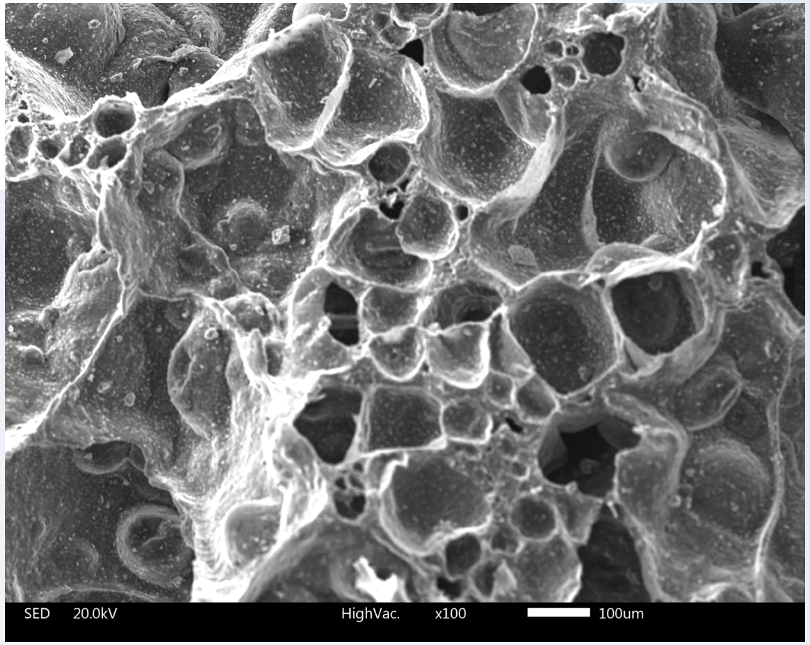
The Primary Focus of Acoustic Design

- **Main Objective:** Maximizing sound absorption, noise reduction, and acoustic comfort in enclosed spaces.



The Inherent Contradiction (Acoustics vs. Flammability)

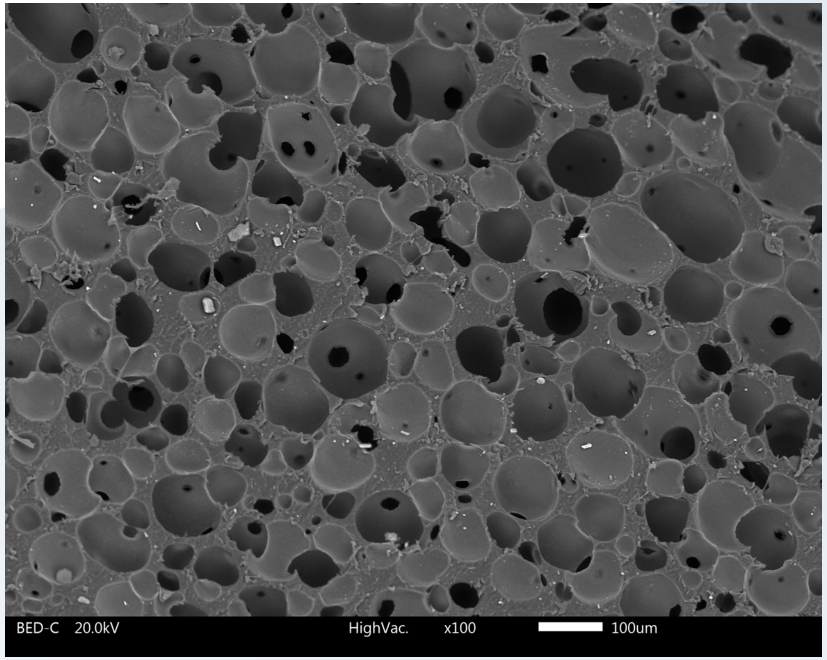
- **The Paradox:** The exact physical and structural properties that make a material an excellent sound absorber also make it a severe fire hazard.
- **High Porosity = Oxygen Supply:** Open-cell networks that allow sound waves to enter also allow a continuous, unrestricted flow of oxygen to feed a fire.
- **Large Active Surface Area:** Fibrous and porous structures expose a massive surface area to heat, accelerating the rate of pyrolysis and ignition.



SEM image – own materials

Thermal and Chemical Vulnerabilities

- **Low Thermal Inertia:** Acoustic materials (like foams and mineral wools) are lightweight and have low density. They cannot absorb or dissipate heat effectively, meaning their surface reaches ignition temperature extremely fast.
- **Chemical Composition:** The most common and cost-effective acoustic absorbers are synthetic polymers (e.g., Polyurethane/ PU foams). These are organic, carbon-based materials with extremely high calorific values (excellent fuel sources).
- **Conclusion:** Superior acoustic performance naturally invites rapid fire spread unless specifically engineered with flame retardants.



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Real-World Consequences: Tragic Case Studies
The Fatal Combination: Many severe fires in public spaces share a common, deadly trio:
Ignition source (often indoor pyrotechnics).
Highly flammable acoustic treatment (untreated polymer foams).
Rapid fire spread accompanied by highly toxic smoke.
The Core Issue:
Cost-effective “egg-crate” polyurethane (PU) foams used for soundproofing without proper fire-retardant treatments.

The Station Nightclub Fire (Rhode Island, USA, 2003)

- **Casualties:** 100 fatalities, over 200 injured.
- **The Catalyst:** Tour manager set off pyrotechnics (gerbs) during a concert.
- **The Acoustic Culprit:** Sparks ignited flammable, non-fire-retardant PU acoustic foam installed around the stage for sound dampening.
- **Fire Dynamics:** Flashover occurred in less than 2 minutes. Rapid generation of heavy, toxic smoke containing hydrogen cyanide (HCN) and carbon monoxide (CO), which caused most fatalities before thermal burns.

Kiss Nightclub Fire (Santa Maria, Brazil, 2013)

- **Casualties:** 242 fatalities, over 600 injured.
- **The Catalyst:** Band member ignited an indoor flare.
- **The Acoustic Culprit:** Sparks ignited the acoustic polyurethane foam installed on the ceiling for sound insulation.
- **Key Failures:** The foam lacked fire-retardant properties (installed purely for acoustics and cost-saving). Burning droplets of polymer fell onto the crowd, spreading the fire to the floor. Massive release of asphyxiating cyanide gas.

Colectiv Nightclub Fire (Bucharest, Romania, 2015)

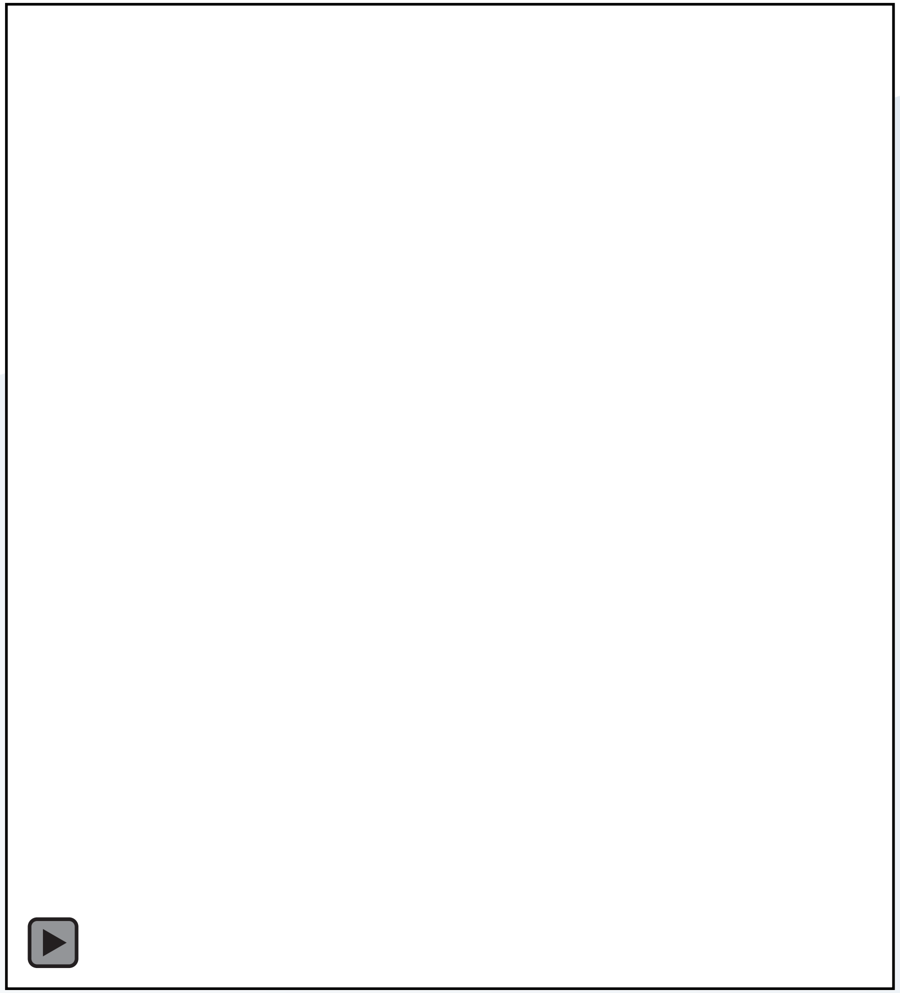
- **Casualties:** 64 fatalities (many died weeks later in hospitals due to severe burns and toxic exposure).
- **The Catalyst:** Sparkler fountains ignited a foam-covered pillar.
- **The Acoustic Culprit:** The club was lined with cheap, highly flammable PU acoustic foam.
- **The Consequence:** The fire spread across the ceiling at extreme speeds. **The incident highlighted massive regulatory failures in enforcing fire safety standards for acoustic materials.**

Regional Warning: The Kočani Nightclub Fire (North Macedonia, March 2025)

- **The Incident:** A catastrophic fire at the "Pulse" nightclub in Kočani, resulting in over 60 fatalities and more than 200 injuries.
- **The Acoustic & Insulation Failure:** Sparks reached the low ceiling, instantly igniting highly flammable insulation and ceiling linings. The fire spread rapidly across the roof structure, causing burning debris to rain down on the crowd.
- **Aggravating Factors:** Massive and rapid emission of dense, toxic smoke caused severe inhalation injuries. The venue operated without proper fire safety protocols, lacking non-combustible interior finishes and adequate emergency exits.

The Most Recent Warning: Crans-Montana (Swiss Alps, Jan 1, 2026)

- **The Incident:** A devastating fire at the Le Constellation bar in the Crans-Montana ski resort during New Year's Eve celebrations.
- **Casualties:** 41 fatalities, over 115 injured (many severe burns and toxic inhalation).
- **The Catalyst:** Wait staff carrying champagne bottles with lit sparklers ("fountain candles") too close to a low ceiling in the basement level.
- **The Acoustic Failure:** The ceiling was heavily clad in synthetic acoustic foam (likely non-retardant).
- **Fire Dynamics in Action:** Ignition of the foam occurred almost instantly upon contact with sparks. Rapid flame spread across the ceiling led to a catastrophic **flashover within seconds.** Pyrolysis of the foam released deadly gases, while the single staircase acted as a chimney, trapping patrons.
- **The Lesson:** Even in modern, highly regulated environments (like Switzerland), the fundamental contradiction between cheap acoustics and fire safety remains a lethal blind spot if regulations are ignored.



The Crucial Question: Why Did these Disasters Happen?

- **A Pattern of Failures:** Analyzing these case studies reveals systemic issues rather than isolated accidents:
  - **Cost over Safety:** Cheap, highly flammable packaging foams were frequently mistaken for, or used in place of, specialized fire-retardant acoustic materials.
  - **Lack of Awareness:** Ignorance regarding the **explosive fire growth rate (HRR) and toxicity of untreated polymers.**
- **The Regulatory Void:** Historically, there was a lack of unified, strictly enforced standards for interior finishes in many regions.
- **The Conclusion:** A mandatory, scientifically backed classification system for all construction products became an absolute necessity to prevent future mass-casualty events.

The European Response: CE Marking and the CPR

- **The Construction Products Regulation (CPR):** The EU regulation mandating that all products permanently incorporated into building works must ensure fire safety.
- **The CE Mark:** It is not a mere quality logo, but a strict "regulatory passport." It legally declares that the product meets essential European safety requirements.
- **Inclusion of Acoustic Materials: Acoustic panels, foams, and insulation are legally classified as construction products. Therefore, they cannot be sold or installed legally without a CE mark.**

The Path to CE Marking (Where Fire Safety Fits In)

- **Declaration of Performance (DoP):** To apply the CE mark, the manufacturer must draw up a DoP, detailing the product's **essential characteristics**.
- **Essential characteristics** for acoustic construction materials (Acoustic Absorption, Release of Dangerous Substances, Durability, Thermal Resistance and Safety in Case of Fire)
- **Safety in Case of Fire:** This is one of the mandatory "Essential Requirements" under the CPR.
- **The Prerequisite:** A manufacturer cannot issue a DoP or attach a CE mark to an acoustic lining without first subjecting it **to standardized, third-party Fire Testing by a Notified Body**.

Safety in Case of Fire: Two Different Paths

- Basic Requirement for Construction Works (BR2): According to the CPR, "Safety in case of fire" is a mandatory requirement, but it is evaluated through two fundamentally different testing philosophies.
- The Choice of Test: Depends on the function of the product in the building.
- **1. Reaction to Fire (Focus: Materials) → The Growth Phase**
  - **Purpose:** To evaluate how a material contributes to the fire's growth and spread in its early stages.
  - **Applicable to:** Surface linings, insulation, acoustic panels, floorings, and cables.
- **2. Fire Resistance (Focus: Elements/Systems) → The Fully Developed Phase**
  - **Purpose:** To evaluate the ability of a construction element to prevent fire from spreading between compartments and to maintain structural stability.
  - **Applicable to:** Fire doors, load-bearing walls, floors, and fire dampers.

Why Acoustic Materials = Reaction to Fire?

- **Surface Exposure:** Acoustic materials are typically the "visible" layer of walls or ceilings. They are the first to be "attacked" by a flame or heat source.
- **Fire Contribution:** Since they cover large areas, their ability to ignite, spread flame, and release heat (HRR) determines whether a small fire will turn into a catastrophic flashover.
- **Summary:** For an acoustic engineer, "Fire Safety" almost always means "Reaction to Fire" performance.

From Concept to Regulation: EN 13501-1

- **The Need for a Common Language:** Historically, every European country had its own "Reaction to Fire" tests and scales, causing confusion and compromising safety.
- **The Harmonized Solution:** EN 13501-1 (Fire classification of construction products and building elements).
- **What it does:** It does not describe a single test. Instead, it provides the strict classification criteria based on a specific set of standardized calorimetric and fire tests.
- **The Output:** It translates complex laboratory data (ignition time, heat release rate, flame spread) into a simple, legally binding alphanumeric code: The Euroclass System.

The Euroclass System (The Main Scale)

- The Principle: A continuous grading scale based on the material's energy contribution to a growing fire.
- **The 7 Main Classes:**
  - **A1 & A2:** Non-combustible materials (No or negligible contribution to fire).
  - **B, C, D:** Combustible materials (Ranging from very limited to medium contribution).
  - **E:** Combustible with high contribution (Easily ignitable).
  - **F:** Unclassified / Highly Flammable (Fails to meet Class E criteria).
- **The Acoustic Challenge:** Most untreated acoustic foams fall into Class E or F, making them illegal for exposed use in public spaces.

Beyond the Main Class: The "Silent Killers"

- For acoustic polymers (like polyurethane), heat and flame are only part of the hazard. EN 13501-1 introduces two mandatory sub-classifications for classes A2 through D.
- 1. **Smoke Production ("s"):** Evaluates opacity and toxicity.
  - s1: Strict limit (Very little smoke - Safest).
  - s2: Medium smoke production.
  - s3: No limitation (Heavy, dense smoke).
- 2. **Flaming Droplets/Particles ("d"):** Evaluates melting plastics that can spread fire downwards.
  - d0: No flaming droplets.
  - d1: Droplets extinguish quickly (within 10 seconds).
  - d2: No limitation.

Decoding an Acoustic Product's "Reaction to Fire"

- Example of a high-quality acoustic panel rating:

B - s1, d0

- Translation for the Fire Engineer:
- B: Combustible, but very limited contribution to fire growth (likely treated with fire retardants).
- s1: Will not blind occupants or fill the room with dense smoke during evacuation.
- d0: Will not melt and drop burning polymer onto people or the floor below.

The Engineering Question: How is the Class Determined?

- **The Challenge:** We have the legal framework (CPR) and the classification system (EN 13501-1). But fire behavior is highly complex. How do we objectively assign an acoustic material to a specific Euroclass?
- **The Answer:** Standardized Laboratory Testing.
- **The Rule of EN 13501-1:** This standard does not contain a single, universal test. Instead, it relies on a specific suite of interconnected EN and ISO testing standards to evaluate different stages and severities of fire exposure.
- **The Objective:** To measure precise physical and chemical properties: heat release, flame spread, ignitability, and smoke generation.

The Testing Suite (Methods of EN 13501-1)

- Depending on the expected classification (from A1 down to F), acoustic materials are subjected to one or more of the following standardized tests:
- **For Non-Combustible Classes (A1, A2)**
  - EN ISO 1182: Non-combustibility test (Cylindrical furnace at 750°C).
  - EN ISO 1716: Determination of the gross heat of combustion (Bomb Calorimeter).
- **For Combustible Classes (A2, B, C, D)**
  - EN 13823: Single Burning Item (SBI) test. (The cornerstone of the Euroclass system for acoustic linings, utilizing the principles of Oxygen Depletion Calorimetry).
- **For Lower Classes (B, C, D, E)**
  - EN ISO 11925-2: Ignitability of products subjected to direct impingement of flame - Single-flame source test

Defining the Classes: What Do the Grades Actually Mean?

Class	Test method(s)	Classification criteria	Additional classification
A1	EN ISO 1182 [a] and	$\Delta T \leq 30$ °C; and $\Delta m \leq 50$ %; and $t_f = 0$ s (i.e. no sustained flaming)	-
	EN ISO 1716	$PCS \leq 2{,}0$ MJ/kg [a] and $PCS \leq 2{,}0$ MJ/kg [b] [c] and $PCS \leq 1{,}4$ MJ/m² [d] and $PCS \leq 2{,}0$ MJ/kg [e]	-
A2	EN ISO 1182 [a] or	$\Delta T \leq 50$ °C; and $\Delta m \leq 50$ %; and $t_f \leq 20$ s	-
	EN ISO 1716 and	$PCS \leq 3{,}0$ MJ/kg [a] and $PCS \leq 4{,}0$ MJ/m² [b] and $PCS \leq 4{,}0$ MJ/m² [d] and $PCS \leq 3{,}0$ MJ/kg [e]	-
	EN 13823	$FIGRA_{0,2\,MJ} \leq 120$ W/s and LFS < edge of specimen and $THR_{600s} \leq 7{,}5$ MJ	Smoke production [f] and Flaming droplets/particles [g]

Defining the Classes: What Do the Grades Actually Mean?

Class	Test method(s)	Classification criteria	Additional classification
B	EN 13823 and	$FIGRA_{0,2\ MJ} \leq 120$ W/s and LFS < edge of specimen and $THR_{600s} \leq 7,5$ MJ	Smoke production [f] and Flaming droplets/particles [g]
	EN ISO 11925-2 [i]: Exposure = 30 s	$F_s \leq 150$ mm within 60 s	
C	EN 13823 and	$FIGRA_{0,4\ MJ} \leq 250$ W/s and LFS < edge of specimen and $THR_{600s} \leq 15$ MJ	Smoke production [f] and Flaming droplets/particles [g]
	EN ISO 11925-2 [i]: Exposure = 30 s	$F_s \leq 150$mm within 60 s	
D	EN 13823 and	$FIGRA_{0,4\ MJ} \leq 750$ W/s	Smoke production [f] and Flaming droplets/particles [g]
	EN ISO 11925-2 [i]: Exposure = 30 s	$F_s \leq 150$ mm within 60 s	
E	EN ISO 11925-2 [i]: Exposure = 15 s	$F_s \leq 150$ mm within 20 s	Flaming droplets/particles [h]
F	EN ISO 11925-2 [i]: Exposure = 15 s	$F_s > 150$ mm within 20 s	

The Laboratory Workflow: How are Tests Chosen?

- Not a Random Process: Laboratories do not apply every ISO test to every sample. The testing regime is strictly dictated by the manufacturer's Target Classification and the physical nature of the material.
- Material Profiling (The "Eye Test"):
  - Inorganic materials (e.g., mineral wool, metal panels) have zero or low carbon content. They aim for Class A1 or A2.
  - Organic/Synthetic materials (e.g., PU acoustic foams, timber, polyesters) inherently contain fuel. They can never physically achieve Class A, so they aim for Class B, C, or D.
- The Decision Matrix:
  - Aiming for A1: Laboratory runs only ISO 1182 (Non-combustibility) and ISO 1716 (Bomb Calorimeter).
  - Aiming for B, C, or D: Laboratory skips high-temp furnaces and goes straight to the SBI Test (EN 13823) and Single-flame source test (ISO 11925-2).

The "Waterfall" Effect in Classification

- What happens if an acoustic material fails to meet its target class during the test?
- **Data-Driven Downgrading:** If an acoustic foam aims for Class B (using the SBI test) but its Heat Release Rate (HRR) is too high, the lab does not start over. The product is simply downgraded to Class C or D based on the recorded SBI data.
- **The Baseline (Classes E and F):** If a material performs terribly in the SBI test (or isn't meant for high-risk areas), it is evaluated only with the Single-flame source test (ISO 11925-2).
  - Passing the small flame test = Class E.
  - Failing the small flame test = Class F (Highly flammable / Unclassified).

Who Sets the Rules? (Testing vs. Legislation)

- **The Common Misconception:** Many assume that EN 13501-1 dictates where materials can be installed. It does not.
- **The Division of Labor:**
  - **EN 13501-1:** Provides the language and the classification (e.g., this foam is Class C).
  - **National Building Codes:** Dictate the law and application (e.g., you cannot use Class C in an escape route).
- **The Guiding Principle:** The required Euroclass is strictly determined by the **occupancy profile** and the **fire risk** of the specific room.

Occupancy Types and Required Euroclasses

- Regulations vary by country, but the engineering logic remains universal across Europe:
- **1. Escape Routes (Staircases, Main Corridors)**
  - Risk: Must remain tenable and smoke-free for safe evacuation.
  - **Typical Requirement: A1, A2, or B - s1, d0.** (Zero or very limited contribution).
- **2. Assembly Spaces (Discotheques, Amphitheaters, Theaters)**
  - Risk: High occupant load, low lighting, potential for panic, loud noise delaying alarms.
  - **Typical Requirement:** Strict control. **Usually Class B** (or sometimes C if active fire suppression like sprinklers is present). Classes E and F are strictly illegal.
- **3. Standard Rooms (Offices, Small Classrooms)**
  - Risk: Familiar surroundings, lower occupant density, easy evacuation.
  - **Typical Requirement:** Lower restrictions. **Class C or D** is often permissible for acoustic wall panels.

Local Legislation: Where is the "Building Code"? (The Case of Serbia)

- **No Single "Code Book":** Unlike the US or UK, fire safety in building design is governed by a hierarchy of national laws and specific rulebooks.
- **The Umbrella Law:** The Law on Fire Protection (Zakon o zaštiti od požara) defines the legal obligation for fire safety and material classification.
- **The Specific Rulebook:** The exact Euroclasses for public spaces are dictated by the Rulebook on technical norms for fire protection of residential, commercial, and public buildings.
- **How it works in practice:** The Rulebook explicitly links the space's occupancy risk to the EN 13501-1 standard.
  - **Example:** For a large amphitheater or a nightclub, the rulebook mandates highly restrictive classes (e.g., B-s1, d0) for acoustic wall and ceiling linings, strictly prohibiting untreated Class E/F polymers.
- **The Authority:** Enforcement, project approval, and technical inspection are managed by the Sector for Emergency Management (Ministry of Interior).

The "Sprinkler Trade-Off"

- **Active vs. Passive Fire Protection:** Fire safety engineering works as a holistic system.
- **The Concession:** Many national codes allow a relaxation of the "Reaction to Fire" requirement if the building is fully protected by an automatic sprinkler system.
- **Example:** An acoustic wood panel rated **Class C** might be illegal in a large amphitheater. However, if the room is fitted with a fast-response sprinkler system, the code may legally allow that Class C material to be installed.

Once again…The Testing Suite: Four Pillars of Classification

- **EN ISO 1182:** Non-combustibility test (Applied for Classes: A1, A2)
- **EN ISO 1716:** Determination of the gross heat of combustion / Bomb Calorimeter (Applied for Classes: A1, A2)
- **EN 13823:** Single Burning Item (SBI) test (Applied for Classes: A2, B, C, D)
- **EN ISO 11925-2:** Ignitability of products subjected to direct impingement of flame - Single-Flame Source Test (Applied for Classes: B, C, D, E)

EN ISO 1182: Non-combustibility test (Applied for Classes: A1, A2)

- **The Objective:** To strictly identify materials that will not burn or contribute any heat to a fully developed fire (Targeting Euroclasses A1 and A2).
- **Sample Preparation**
- **Shape & Size:** The manufacturer must machine the material into exact cylinders (Ø 45 mm, height 50 mm).
- **Conditioning:** Samples are oven-dried to remove ambient moisture (ensuring mass loss is due to combustion, not water evaporation).

EN ISO 1182: Non-combustibility test (Applied for Classes: A1, A2)

- **The Procedure:** The cylinder is lowered into a vertical tube furnace pre-heated to an extreme baseline of 750°C (simulating post-flashover conditions).The sample remains inside for a standard duration (typically 30 minutes).
- What is Continuously Measured:
- **1. Temperature Rise (ΔT):** Thermocouples measure if the sample's internal chemical reaction heats the furnace above the 750°C baseline.
- **2. Mass Loss (Δm):** The cylinder is weighed before and after to see how much material was vaporized or burned away.
- **3. Sustained Flaming (t_f):** Visual and sensor observation of any flames emerging from the sample, measured in seconds.

EN ISO 1716: Determination of the gross heat of combustion / Bomb Calorimeter (Applied for Classes: A1, A2)

- **The Objective:** To determine the absolute maximum energy potential of a material when completely combusted (Gross Calorific Value – PCS – Pouvoir Calorifique Supérieur).
- **Sample Preparation**
- The acoustic material cannot be tested in its raw form. It must be ground into a very fine powder. A tiny, precise amount (approximately 1 gram) is pressed into a pellet and placed into a crucible.

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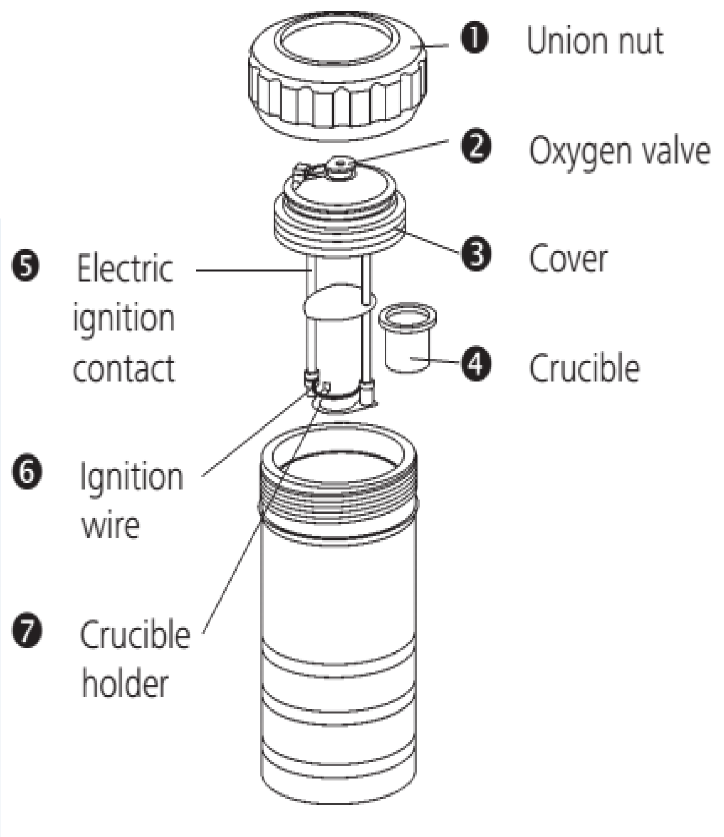

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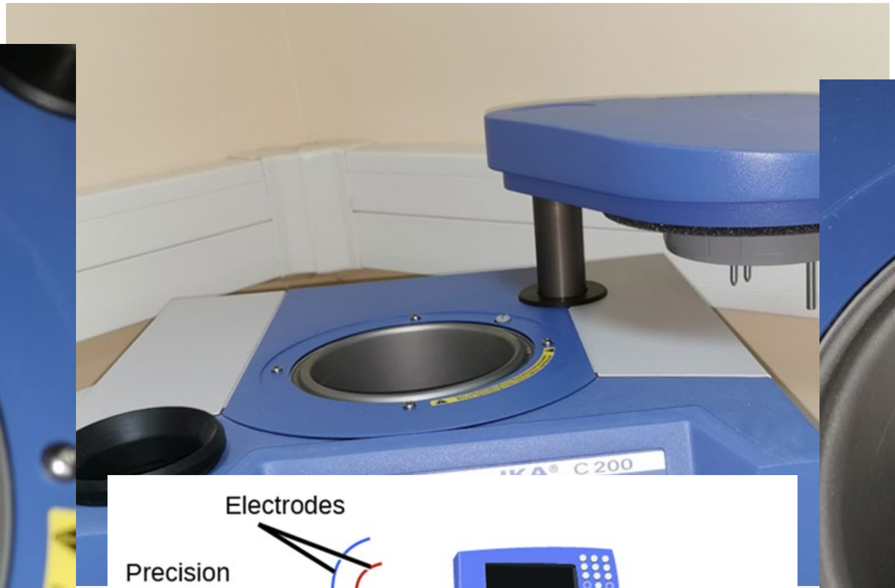
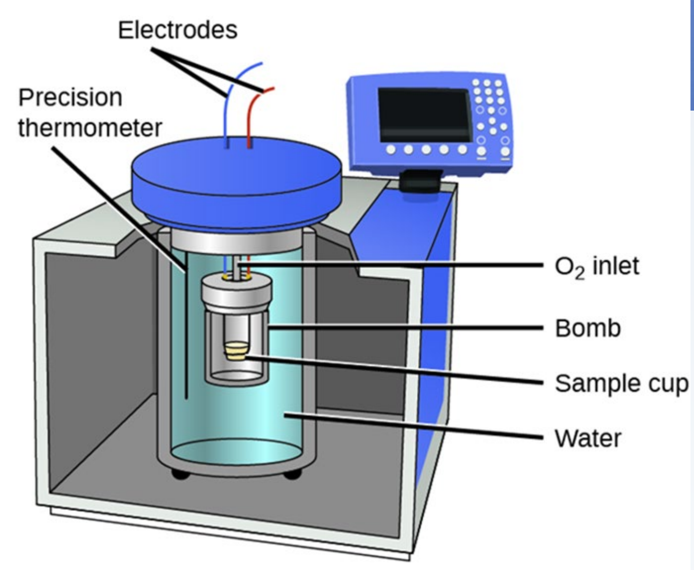




EN ISO 11925-2: Ignitability of products subjected to direct impingement of flame - Single-flame source test (Applied for Classes: B, C, D, E)

- **The Objective:** To determine the ignitability of a vertically mounted material when exposed to a small, localized flame.
- **Sample Preparation**
- The acoustic material is cut into rectangular specimens (250 mm x 90 mm). A standard piece of filter paper is placed exactly below the specimen to catch any falling debris.
- **Thickness is crucial!!!!!!**

EN ISO 11925-2: Ignitability of products subjected to direct impingement of flame - Single-flame source test (Applied for Classes: B, C, D, E)

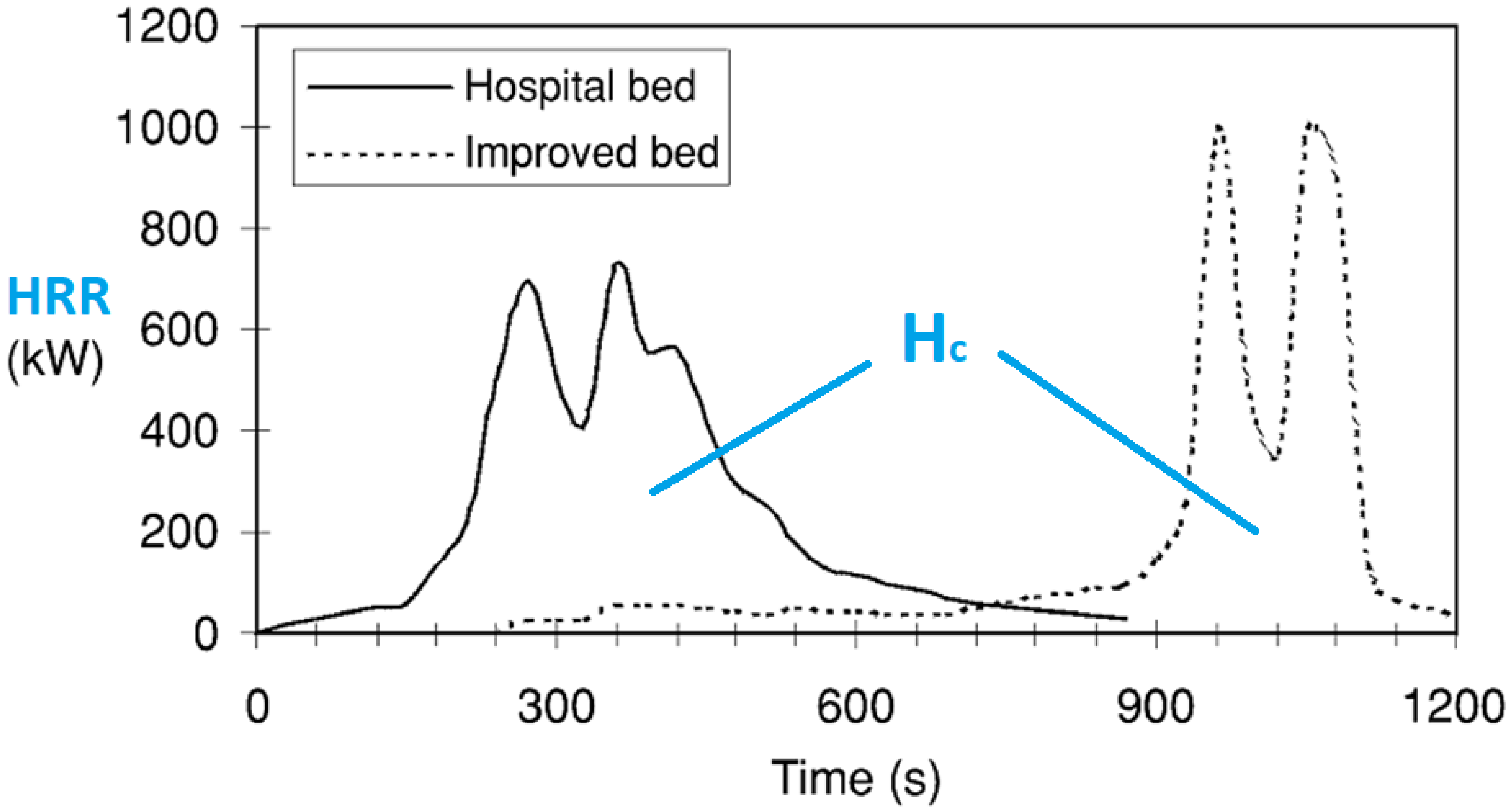
- **The Procedure:** A small propane gas flame (equivalent to a match or a lighter, about 20 mm high) is applied directly to the surface or the edge of the specimen at a 45-degree angle.
- **Exposure Time:** The flame is applied for **15 seconds** (if aiming for Class E) or **30 seconds** (if aiming for Classes B, C, or D).
- **What is Measured:**
- **1. Vertical Flame Spread (F_s):** The operator observes if the flame tip reaches the 150 mm mark on the specimen within a strict time limit (20s or 60s).
- **2. Flaming Droplets:** If the acoustic polymer melts, drips, and ignites the filter paper below, the material automatically receives a d2 (highly hazardous droplets) classification

EN 13823: Single Burning Item (SBI) test (Applied for Classes: A2, B, C, D)

- **The Objective:** To evaluate the potential of a material to contribute to a fire's growth when exposed to a thermal attack in a room corner.
- **Physical Setup & Specimen Dimensions:** Two rectangular panels of the acoustic material are assembled to form a 90-degree corner.
- **Long wing:** 1.5 m high X 1.0 m wide.
- **Short wing:** 1.5 m high X 0.495 m wide.
- (Thickness is determined by the "End-Use" application).
- **The Ignition Source:** A triangular propane sandbox burner is placed at the base of the corner, outputting exactly 30 kW of heat (simulating a burning wastebasket).

EN 13823: Single Burning Item (SBI) test (Applied for Classes: A2, B, C, D)

Why Heat of combustion is not sufficient?



Heat release rate is the single most important variable in fire hazard

Why HRR can't by measured by thermocouples?

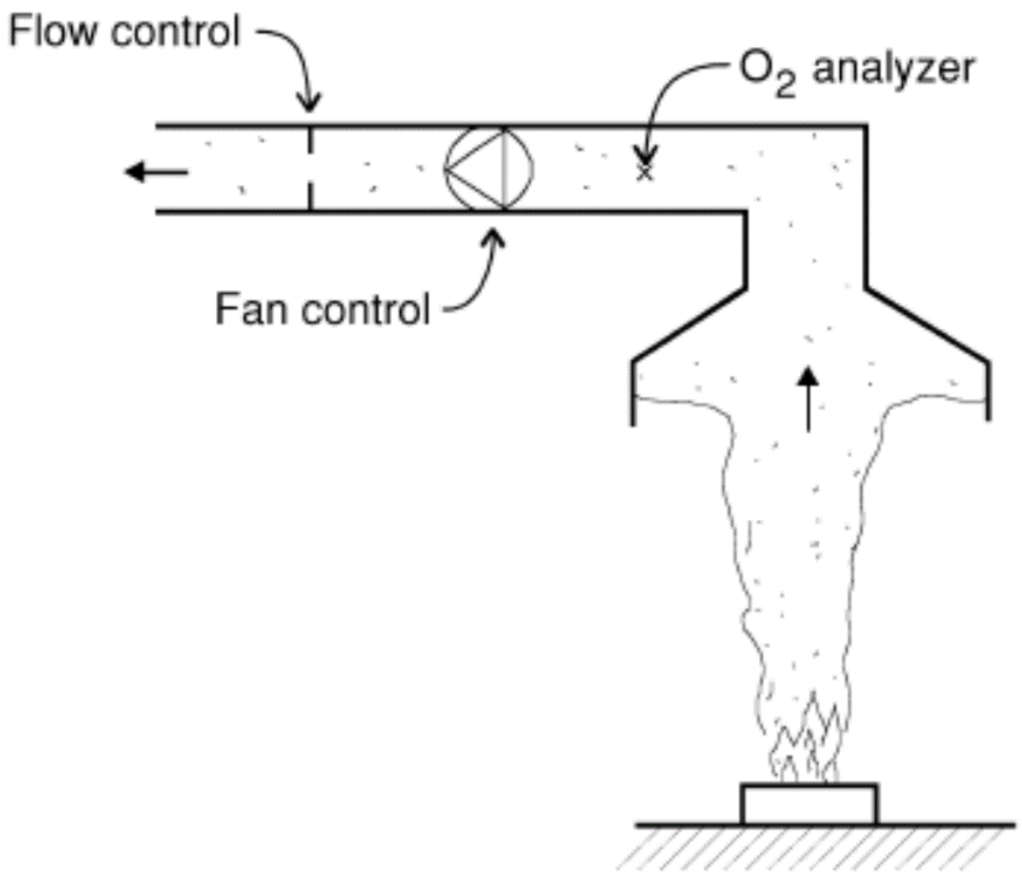
- **The Engineering Problem:**
- In an open room or a large test rig, you cannot accurately measure the total heat released just by placing thermometers, because heat escapes in all directions and measurement highly fluctuate.

Measurement of HRR - Oxygen depletion principle

- Two scientists, Thornton and Huggett, discovered a close correlation between the content of oxygen in flue gases and the heat released during a fire. They found that this correlation is **13.1 MJ of heat per kg of consumed O_2**
- Janssens of NIST laid out the theoretical/mathematical basis for calculation
- In the 1980s, Babrauskas developed the first device for Heat Release Rate (HRR) measurement based on oxygen depletion principle – the cone calorimeter

Category	E (kJ/g O_2)
Fuels containing C and H	
Normal alkanes	12.7
Substituted alkanes	12.6
Cyclic alkanes	12.7
Normal alkenes	13.2
Cyclic alkenes	13.0
Dienes	13.5
Normal alkynes	13.3
Arenes	13.0
Fuels containing C, H and O	
Alcohols	13.3
Aldehydes	14.2
Ketones	13.2
Acids	14.2
Esters	13.0
Others	13.9
Fuels containing C, H, N and S	
C-H-N fuels	11.5
C-H-S fuels	11.3
Polymeric materials	
C and H in the structure	12.5
C, H, O and N in the structure	12.5
C, H and Cl in the structure	12.8
C, H and F in the structure	11.3
C, H and Si in the structure	13.7

Principle – No. temp. measurement!



Oxygen Consumption Calorimetry

$$\dot{q} = (13.1 \times 10^3)\ 1.10C \sqrt{\frac{\Delta P}{T_e}} \frac{(X^0_{O_2} - X_{O_2})}{(1.105 - 1.5\, X_{O_2})}$$

Where:

- $\dot{q}$ = Rate of heat release (kW)
- **C** = Orifice plate coefficient ($kg^{1/2} \cdot m^{1/2} \cdot K^{1/2}$)
- ΔP = Pressure drop across the orifice plate (Pa)
- T_e = Gas temperature at the orifice plate (K)
- X_{O_2} = Measure mole fraction of O_2 in the exhaust air
- $X^0_{O_2}$ = Initial mole fraction of O_2 in the exhaust air

GOAL: Correlate HRR and measured oxygen concentration in flue gases

Measurement of HRR - Oxygen depletion principle

The Golden Rule of Classification: A Euroclass certificate is strictly tied to the tested thickness

- **The Mass/Fuel Paradox:** A 10 mm acoustic foam might achieve **Class B** because its total available fuel mass is low.
- The exact same chemical foam at 100 mm thickness contains 10x more fuel, generates a much higher Heat Release Rate (HRR), and could easily drop to Class D or E.
- **The Engineering Trap:** You cannot legally apply a certificate for a thin acoustic panel to a thicker version of the same product. To cover different products, manufacturers must use Extended Application (EXAP) rules (testing both the minimum and maximum thicknesses of their product range).