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Lund 2026

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Report 3280
ISRN: LUTVDG/TVBB--3280--SE

Number of pages: 35 (without appendix)

Keywords: fire-retardant-treated wood, facades, equilibrium moisture content, fire testing

Abstract:

This study presents a cost-efficient method to assess the condition of fire-retardant treatments on existing wooden façades. The method is based on measuring changes in Equilibrium Moisture Content (EMC), linked to the hygroscopic salts used in fire-retardant systems on the Swedish market. These salts increase wood moisture uptake, which can cause leaching and reduced fire performance over time.

Samples from two buildings and previous projects at Lund University were examined after periods of 11 weeks to 3 years of weather exposure. Both exposed and protected materials were analysed using controlled climate conditioning. Fire performance was evaluated with Microscale Combustion Calorimeter, Cone Calorimetry, and Single Burning Item tests. Results show reduced EMC after ageing, indicating loss of fire-retardant chemicals. Pure salt-based systems showed significant reductions in EMC, while polymer-bound systems showed less EMC change. However, all systems exhibited decreased fire performance, with measurable decline already after only short periods of exposure. All samples tested according to the Single Buring Item- method, both from weather exposed and protected areas of the façade, showed FIGRA- results corresponding to Euroclass D.

Despite measurement uncertainties related to the material’s nature, correlations between EMC and fire performance were identified. The findings indicate that no general EMC threshold that covers all different systems can be established as acceptance criteria for the fire-retardant treatments, and system-specific acceptance criteria must be established through further targeted studies.

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Acknowledgements

This project has been financed by Brandforsk and Länsförsäkringars Forskningsstiftelse and we are grateful for the opportunity and support they have provided through their funding.

The support of the project from the owner of the burned building NW Stockholm, Heimstaden, and the owners of the house in Southern Sweden are kindly acknowledged.

Summary

A cost-efficient method for assessing the condition of fire-retardant treatments on existing façades has been developed and evaluated. The method is based on the hygroscopic properties of the salts used as fire retardants in all systems currently available on the Swedish market. These salts increase the wood's Equilibrium Moisture Content (EMC), which can lead to moisture accumulation, leaching of fire-retardant compounds, and a consequent reduction in fire protection performance.

Samples collected from two buildings and from earlier conducted research projects at Lunds University have been studied. The samples have been collected from fully weather exposed material and from material not exposed to precipitation. Weather exposure of the samples varied between 11 weeks and 3 years.

Samples have been conditioned in climate cabinets and influence of weathering on EMC established. Comparative samples have been tested for fire performance according to Microscale Combustion Calorimeter, Cone Calorimetry and Single Burning Item (SBI).

The results show that all groups of samples have a reduced average EMC after ageing, indicating loss of fire retardants. The differences are significant for treatments using pure salt-based chemicals, but not significant for the system using polymer binders to reduce leakage. One of the pure salt-based systems shows migration of salts during conditioning, a clear sign that high air humidity is sufficient for migration and subsequent loss of fire retardants in the system.

Fire testing shows a reduction in fire performance after ageing for all sample groups, including both the pure salt-based systems and the system containing a polymer binder. A decline in fire performance is evident after only 11 weeks of weather exposure. Changes in fire behaviour are observed consistently across all testing scales, including Microscale Combustion Calorimeter, Cone Calorimetry, and SBI. All samples tested according to SBI, samples from both fully weather exposed areas and from covered or less exposed areas show FIGRA values corresponding to Euroclass D in EN 13501-1:2019 Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests. With the more highly exposed samples showing worse performance than the protected samples.

Correlations between EMC of the test samples and their fire performance have been investigated. The variation in results is high for both EMC and fire properties making it difficult to establish acceptance criteria, and no universal EMC threshold can define acceptable fire performance for all systems. System-specific acceptance criteria must be established through further studies.

A suggestion for an initial testing and evaluation procedure is presented to allow for systematic collection of data and experience to determine future more reliable acceptance criteria.

Sammanfattning

En kostnadseffektiv metod för att utvärdera statusen hos brandskyddsbehandlingar på befintliga fasader har utvärderats. Metoden baseras på hygroskopiciteten hos salter som används som brandskyddsmedel i alla system som för närvarande finns på den svenska marknaden, vilket leder till både en ökning av träets jämviktsfukthalt och risk för urlakning av brandskyddsmedel och förlust av brandskydd om virket utsätts för fukt.

Prover hämtade från två byggnader och från tidigare genomförda forskningsprojekt vid Lunds Tekniska Högskola har studerats. Proverna täcker en skala från kraftigt väderexponerat material till material som skyddats från nederbörd till prover som lagrats helt skyddat inomhus. Väderexponeringen har varierat mellan 11 veckor och 3 år.

Inverkan av väderpåverkan på jämviktsfuktkvot har fastställts genom att proverna har konditionerats i klimatskåp. Jämförande prover har testats för brandreaktion enligt mikrokalorimetri, konkalorimetri och i Single Burning Item-test (SBI).

Alla grupper av prover uppvisar minskad genomsnittlig jämviktsfuktkvot av hela tvärsnitt efter åldring, vilket indikerar förlust av brandskyddsmedel. Skillnaderna är statistiskt signifikanta för behandlingar med rena saltbaserade kemikalier men inte signifikanta för system som använder polymera bindemedel för att minska urlakning. Ett av de rena saltbaserade systemen visar migration av salter redan under konditionering, ett tydligt tecken på att hög luftfuktighet kan vara tillräcklig för migration och efterföljande förlust av brandskyddsmedel i systemet.

Brandtesterna visar en försämring av prestanda efter åldring för alla grupper av prover, både för de rena saltbaserade systemen och systemet som innehåller polymerbindemedel. Försämrade brandprestanda kan ses redan efter 11 veckors väderexponering. Reducerad brandprestanda ses i alla testskalor, i mikrokalorimetri, i konkalorimetri och i SBI. Alla prover som testats enligt SBI, prover från både helt väderexponerade områden och från täckta eller mindre exponerade områden, visar FIGRA-värden motsvarande Euroklass D i EN 13501-1:2019 Brandklassificering av byggprodukter och byggnadselement, att jämföra med förväntade klassen B. Exponerade provkroppar uppvisar sämre brandtekniskaegenskaper än de skyddade proverna.

Trots mätosäkerheter relaterade till materialets natur identifierades korrelationer mellan jämviktsfuktkvot och brandprestanda. Spridningen i mätresultat är hög för både jämviktsfuktkvot och brandegenskaper, vilket gör det svårt att i dagsläget fastställa acceptanskriterier. Samtidigt skiljer sambanden avsevärt mellan de olika systemen som studerats varför det inte är möjligt att definiera ett generellt tröskelvärde för acceptabla brandprestanda för alla system. Systemspecifika acceptanskriterier måste fastställas genom ytterligare studier.

Ett förslag på en initial test- och utvärderingsprocedur presenteras för att möjliggöra systematisk insamling av data och erfarenheter för att fastställa framtida mer tillförlitliga acceptanskriterier.

List of abbreviations

DBI – Danish Institute of Fire and Security Technology

EMC – Equilibrium Moisture Content

FIGRA – Fire Growth Rate Index

FR – Fire Retardant

MCC – Microscale Combustion Calorimeter

SBI – Single Burning Item

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1 Introduction

Wood is a climate-smart building material and increased use of wood in the built environment has the potential to reduce global carbon dioxide emissions compared to the use of building materials. A major problem, however, is that wood is combustible and fires in timber buildings cause major property losses. As the use of timber in buildings increases, new requirements are also being placed on fire safety, as established standards for, for example, fire load may need to be revised [1] while the wood industry needs to protect itself against the risk of drastic restrictions in regulations, such as the ban on combustible materials in external walls that was introduced in the UK after Grenfell [2].

Fire-retardant (FR) impregnated wood is essential for the continued development of timber construction. Fire-protection treatments enhance building safety by reducing flame spread across both interior and exterior wooden surfaces. When properly tested and classified in accordance with the Euroclass system (EN 13501-1 [3]), such treatments can improve the reaction-to-fire classification of the surface (e.g., achieving Class B instead of untreated Class D). This improved Euroclass rating can permit larger areas of exposed timber in buildings while maintaining compliance with fire safety requirements.

Despite many years of experience, significant knowledge gaps remain regarding the long-term durability of fire-retardant treatments in outdoor applications and the leaching of active substances. Previous studies have demonstrated substantial variation in performance between different systems [3-6]. In addition, the correlation between accelerated ageing methods and natural weathering has been shown to be inadequate [7, 8].

Evaluation of ageing properties of fire-retardant treated products is currently done according to EN 16755 Durability of reaction to fire performance – Classes of fire-retardant treated wood products in interior and exterior end use. The standard compares reaction to fire results of samples treated with fire retardants prior to and after accelerated or natural ageing as well as resulting EMC and leakage after conditioning in climate 90 % RH / 27 °C. The tests specified in the standard can be expected to detect products with extremely poor resistance to humidity but does not address the issue of service life prediction of products exposed to weather [27]. The standard is currently under revision.

At the same time, there is a lack of effective methods to verify the performance of treated products once they have been installed in a façade, as well as reliable procedures for delivery/quality control. Unlike other fire safety systems (such as detectors or fire dampers) there are currently no established inspection or maintenance methods to assess and ensure the continued fire performance of FR façades. Today, destructive fire testing is required to determine the status of the fire protection or to verify product quality upon delivery [9]. As a result, many existing buildings have façades where the status of the fire protection treatment is unknown.

The knowledge gaps regarding the durability of fire protection treatments and the lack of effective methods for delivery control and to determine the fire protection status of existing buildings have led to fire protection treatment as such being questioned.

Most fire protection impregnation systems currently on the market are based on hygroscopic chemicals. The hygroscopic chemicals lead to an increase in the equilibrium moisture content (EMC) of the wood material treated with fire retardants compared to untreated wood. If chemicals are leached from the material, the equilibrium moisture content decreases. If all chemicals have been leached out, the equilibrium moisture content of the wood will return to approximately the same level as before the impregnation. It is therefore reasonable to assume that FR impregnated wood exposed to weathering, where some of the FR leaches out, will exhibit a lower EMC and consequently, reduced fire performance compared to materials that have been better protected from weather exposure.

Still, it has been seen that the equilibrium moisture content is affected by several factors. The decrease in the EMC of heat-treated wood (Thermowood) can be reduced after repeated drying and rewetting of the material [10, 11]

Determination of the EMC of FR wood products has previously been proposed, for example in *Nordtest NT Build 505* [12]. The Nordtest method is intended to assess whether treated wood products exhibit elevated EMC levels, which may increase the risk of moisture-related damage and leaching after treatment. However, the method does not address the performance of the fire-retardant treatment itself or potential changes in fire performance over the service life of the building. An increased study of the area is therefore needed to see how it can be used as an indicator of relative fire performance.

Ongoing research into the durability of systems currently on the market improves the state of knowledge but does not address questions regarding the status of existing older FR facades. A cost-effective and reliable method for assessing the fire protection status of existing façades would significantly reduce uncertainty and thereby strengthen confidence in, and the credibility of, fire-retardant treatments. It will also enable property owners to know if any measures need to be implemented and thus be able to carry out systematic fire protection work regarding the building facade.

1.1 Research objective

The objective of this work is to develop a cost-effective and time-saving method for assessing the relative fire protection status of existing FR wooden facades with minimal impact on the building. By determining the equilibrium moisture content in small samples of the facade material, the amount of remaining fire protection chemicals can be assessed and provide a basis for decisions on the need for more extensive investigations of the façade's fire protection status.

The following research questions are addressed to achieve the overall research objective:

- What is the relationship between equilibrium moisture content and fire performance for different types of FR wood products for exterior use?
- How does specimen size influence the results of the assessment method? What is the minimum representative sample size, and how many specimens are required to obtain reliable results?
- How does the concentration gradient of fire-retardant chemicals within a specimen affect the outcome of the proposed assessment method?
- Does the relationship between EMC and fire performance differ between wood with a high chemical concentration gradient and wood with a more uniform (low gradient) distribution?

1.2 Method

The work conducted in this research is primarily experimental and consists of measuring the equilibrium moisture content and evaluating the fire performance of fire-retardant–impregnated wood. The investigated materials include specimens exposed to direct weathering and specimens protected from direct weather exposure, collected from several different buildings.

The degree of weather exposure varied between the different samples. The controlled research studies at LTH compared properties of fully weather exposed samples to unexposed samples that had been stored indoors. The samples collected from the building northwest of Stockholm were taken from areas of the façade fully exposed to weather and from areas protected from sun and precipitation. The samples from the house in Southern Sweden were taken from the highly exposed southern façade of the building and compared to samples from the less exposed northern façade. The material is described in more detail in Chapter 2.

The aim is to include different types of impregnation systems in the evaluation of the assessment method. An important part of the project implementation is the identification of suitable buildings from which representative test specimens can be retrieved.

Fire performance is then evaluated at three different scales: micro-scale using Microscale Combustion Calorimetry, intermediate scale using the cone calorimeter, and large scale using the Single Burning Item test (refer Section 4)

1.3 Limitations and delimitations

The project is exploratory in nature and does not aim to develop a complete assessment method. Instead, its purpose is to examine the feasibility of a potential approach for evaluating exposed, fire-treated wooden façades.

Due to the relatively short project timeframe, only a limited number of samples could be studied. Furthermore, the systems tested were restricted to a small selection of products that currently dominate the Swedish market.

It shall also be noted that the study covers weather exposure periods of maximum three years. No data is available covering older facades. This means that there is a possibility that the idea of comparing samples from protected areas of a façade with fully weather exposed areas may not work on a building where most of or all fire retardants have leached out, leading to no difference between the EMC of the sampled areas. This aspect will be further discussed in the description of the suggested method.

2 Description of the sample material

The study was conducted on material collected from existing buildings as well as material used in previous academic studies at Lund University

Facade material has been collected from two buildings, a multi-storey building in northwest of Stockholm and a coastal multi-storey building in Southern Sweden. In addition to material from the buildings, test material from two studies at Lund University has been used.

The samples in the study were treated with three different systems, Material A, Material B and Material C. A fourth material called NN-wood is also included in the study, this material is not a product presently on the market.

Materials A and B (treated with Woodsafe WFX) as well as Material D (NN-Wood) were tested without surface coating to protect against impact of precipitation and leakage of fire retardants. Material C (Burnblock) had been coated with a system designed to break down in a relatively short time, Masquelack Cozy Vintage. No tests were conducted on material with efficient coatings protecting the wood against precipitation.

2.1 Material A

Material A is assumed to consist of Thermowood boards treated to Woodsafe WFX. To improve durability and reduce leaching in outdoor conditions, the formulation includes a polymer-based binder system. Material A was placed with a 10° angle on the roof of a building at Lund University for weather exposure (see Figure 1).

Material A has been a part of a master's thesis at LTH, and the samples were exposed to outdoor conditions for 4–11 weeks [6]. The fire performance of the material was tested with the Cone Calorimeter.

Figure 1: View of Material A when placed for weather exposure.

2.2 Material B

Material B consisted of cladding from a three-year-old façade of a fire-damaged building. The material was in this case also Thermowood treated with Woodsafe WFX, like Material A.

To investigate the difference between directly weather-exposed material and protected material, samples were taken from two different areas of the building in question (see Figure 2). Six sets of specimens were cut to a length of 1.5 meters for fire testing at the Danish Institute of Fire and Security Technology (DBI), three sets from heavily weather-exposed boards located at the southwestern corner of the building (see Figure 3), and three sets from a protected location beneath a covered entrance walkway on the northern side (see Figure 4 and Figure 5). In addition to the six sets prepared for testing at DBI, three further sets of weather-exposed specimens were collected for testing at LTH. These three sets were not cut to a length of 1.5 meters.

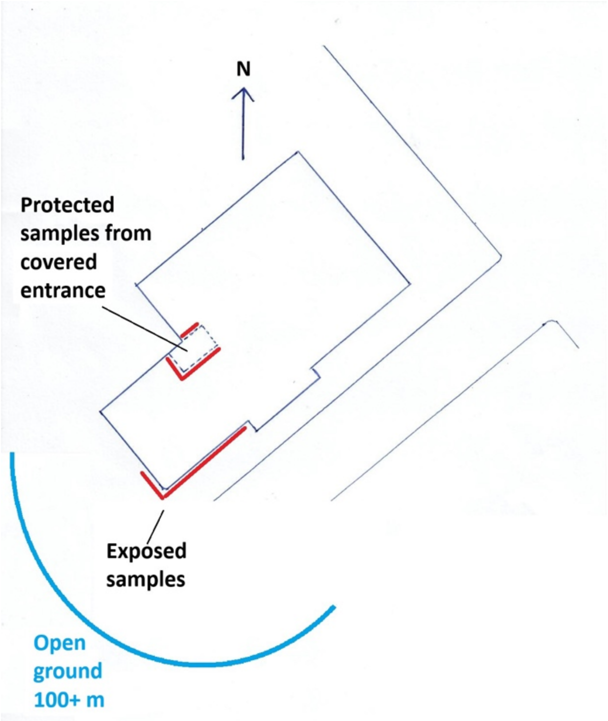

Figure 2: Schematic overview of building and areas where material was collected.

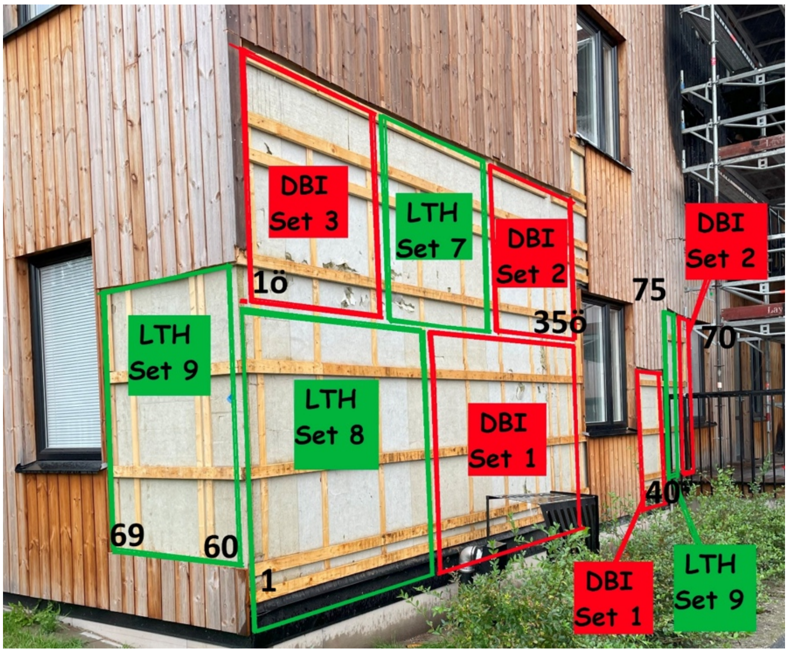

Figure 3: Exposed boards on the south-west side of the building. The shows what samples that were taken for tests at DBI for and for tests at LTH.

Figure 4: "Protected" boards from the north side of the building. The pictures show what samples that were taken for testing at DBI.

Figure 5: "Protected" boards from the north side of the building. The pictures show what samples that were taken for testing at DBI.

2.3 Material C

Material C was Thermowood treated with Burnblock. In contrast to Materials A and B, Material C did not include any polymer-based binder.

The material was sourced from a two-year-old façade of a coastal building in southern Sweden. The building was very close to the beach with the east façade facing the sea.

The material had been painted with Masquelack Cozy Vintage. The coating is designed to break down and disappear in a relatively short time while the facade wood builds up a naturally grey colour [13].

2.4 NN-wood

The product has been studied at Lund University but is not yet on the market. Samples were used in the study of EMC but not fire tested with in this project.

3 The assessment method

In this chapter the assessment method is introduced and explained.

3.1 Fundamental principles of the assessment method

The assessment method that is evaluated and tested in this study is based on the fact that most fire-retardant impregnation systems for wood currently available on the Swedish market are based on salts, relying on hygroscopic chemicals. The active substances are highly hygroscopic resulting in an increase in the EMC of the treated wood as humidity is absorbed from the surrounding air. If salts are leached out, the EMC decreases (see Figure 6). If all salts are removed, the EMC should correspond to something like that of untreated wood.

The proposed assessment criterion is therefore to measure the difference in moisture content between protected or unexposed boards and boards exposed to weathering, where the difference provides an indication of the extent of leaching.

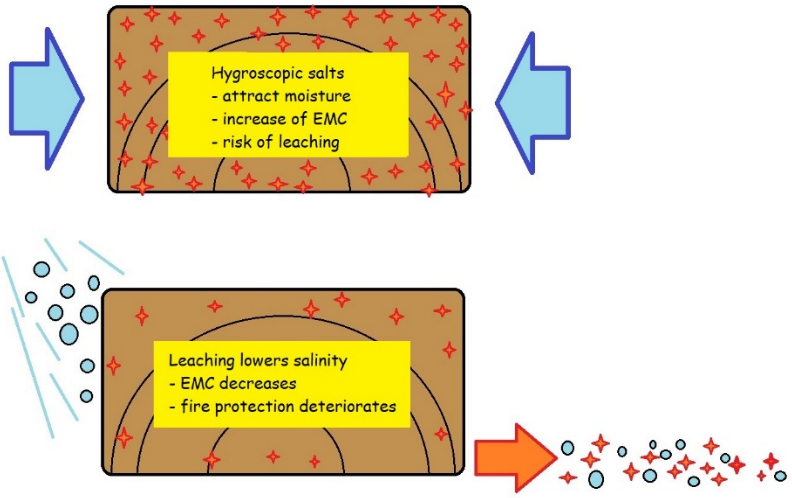

Figure 6: Schematic drawing of the hygroscopic salts being impregnated into the wood (top) and leaching out (bottom).

The advantages of this assessment method are that it can be done on rather small samples and is technically non-destructive, which means that the impact on the building will be limited. The EMC of the samples is then determined by storing them in a climate cabinet until a stable weight is reached, after which the moisture content is determined by the dry weight method (see Section 3.2). The method is robust and allows the samples to be sent to a laboratory for analysis after sampling from the building. The availability of laboratories around the country that can do this is good and is not considered to be a limitation for future use of the control method.

3.2 Measuring equilibrium moisture content

In the project the determination of EMC was carried out using the gravimetric oven drying method according to European standard EN 13183-1. The moisture content of a specimen is determined by observing when equilibrium is reached. The procedure consists of the following steps:

1. The specimen is conditioned at 23 °C and RH 85 % to obtain its initial mass (wet mass), see Figure 7, left.
2. The specimen is then dried in an oven at 103 +/- 2 °C until a constant mass is achieved (dry mass), see Figure 7, right.

3. The moisture content is calculated as:

$$\text{Moisture content (\%)} = \frac{\text{wet mass} - \text{dry mass}}{\text{dry mass}} \times 100$$

4. When the moisture content remains unchanged over repeated measurements under the same climatic conditions, the material is considered to have reached its equilibrium moisture content.

Figure 7: Cabinets used for conditioning of the specimens and oven drying of specimens.

3.2.1 Equilibrium Moisture Content of cross sections

An optimal specimen size was sought by evaluating the time required to reach constant mass for each dimension and assessing how specimen size influenced conditioning behaviour and weighing accuracy. Additional observations were recorded during the process, including signs of biological growth and the occurrence of substances migrating to the surface.

Equilibrium moisture content was determined on cross-sections cut from weather exposed and unexposed boards. The boards (see Chapter 2) were cut into specimens of different lengths in order to determine the minimum initial board size required to obtain a reliable value of the EMC. Nominal lengths of the cross-sections cut from each board were 10 mm, 50 mm and 100 mm. Knots in the test samples were avoided when possible. See Figure 8.

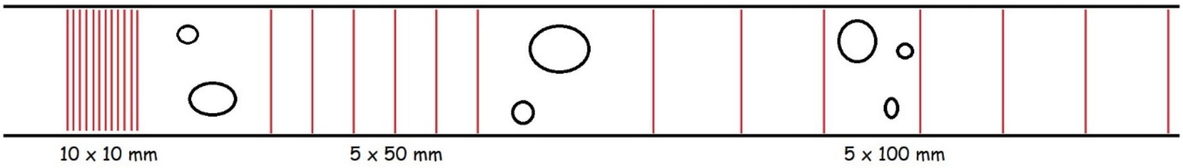

Figure 8: Cutting cross-section samples for determination of equilibrium moisture content.

Conditioning of the cross-section samples was done in a climate of 23 °C / 85 % RH. The samples were weighed before conditioning and regularly during conditioning until constant weight was reached, after which moisture content was determined according to the dry weight method (see Section 3.2).

3.2.2 Equilibrium Moisture Content gradient

Measurements of the EMC gradient through the cross-section were made in addition to determining the EMC of the entire cross-section. Gradient in equilibrium moisture content was determined on thin layers cut parallel to the flat surfaces of the boards. The thin layers were split with a knife from cross-sections of about 20 mm in length to minimize the influence of grain angle on the thickness of the layers. Thickness of the façade boards varied between approximately 20 mm and 22 mm, leading to approximately 2 mm average layer thickness (see Figure 9). The samples were conditioned for a minimum of 100 hours and moisture content determined by dry weight measurement (see Section 3.2). To obtain enough material for moisture content determination, layers from four or five cross-sections were weighed together (see Figure 10).

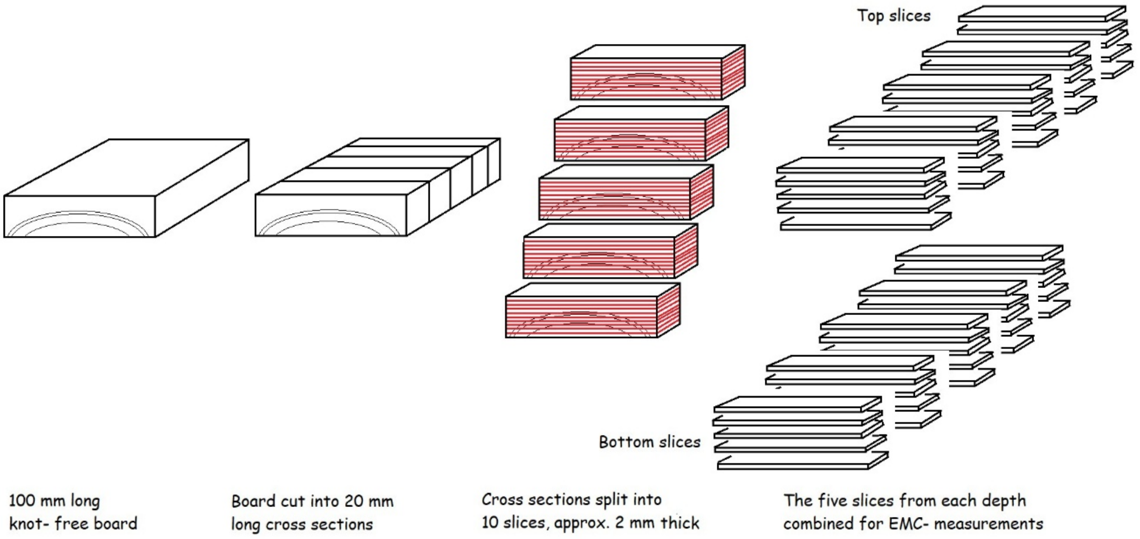

Figure 9: Method used to split boards for determination of EMC gradient.

Figure 10: Samples used to determine EMC gradient.

4 Fire performance tests

The different fire tests used in the project and how they were executed are presented in this chapter.

4.1 Fire test methods

The three main fire test methods applied in the project have been the Micro-scale Combustion Calorimeter, Cone Calorimeter and the Single Burning Item.

4.1.1 Micro Combustion Calorimeter

Experiments in this study were conducted using a micro-scale combustion calorimeter (MCC), developed by the US Federal Aviation Administration [14]. The MCC operates according to the principles of pyrolysis–combustion flow calorimetry (PCFC), in which the two primary stages of flaming combustion, solid-phase pyrolysis and gas-phase combustion, are physically separated. This separation is achieved using a two-stage reactor system. In the first chamber (yellow in Figure 11, left), the specimen undergoes controlled pyrolysis under a prescribed heating rate and atmosphere. The resulting pyrolysis gases are then transported to a second high-temperature furnace (red in Figure 11, left), where they are mixed with oxygen and completely combusted. The MCC determines the rate of oxygen consumption during combustion, which is subsequently converted into heat release rate (HRR) using the principles of oxygen consumption calorimetry (blue in Figure 11, left). Material samples are typically on the order of milligrams. Samples can be pyrolysed in inert or oxidative conditions. For this study oxidative conditions were chosen to look at secondary solid phase oxidation reactions as well as pyrolysis gas combustion.

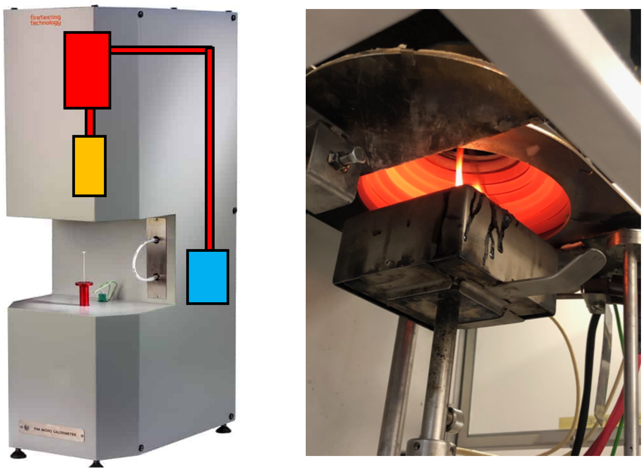

Figure 11: MCC (left) and Cone Calorimeter (right).

4.1.2 Cone Calorimeter

The cone calorimeter is often considered the most important bench-scale instrument in fire testing (see Figure 11, right). A sample with a size of 0.1×0.1 m^2 is exposed to thermal radiation from a cone-shaped heater. The incident heat flux can be varied within the range of 10–75 kW/m^2. The sample is ignited with an electric spark that is position from the start of the test and remains in place until the sample ignites. The gases emitted during the test are collected and analysed [15]. In the cone calorimeter different entities of fire performance, like heat release rate and time to ignition, are measured. The cone calorimeter has been widely used to study the fire behaviour of various materials, including wood and wood-based products [16-18].

4.1.3 Single Burning Item

The SBI test is a larger-scale method than the Cone Calorimeter for assessing reaction-to-fire performance [19]. The test specimen is mounted in a corner configuration consisting of a main wing measuring 1.0 m in width and 1.5 m in height, and a secondary, shorter wing measuring 0.5 m in width and 1.5 m in height. The specimen is exposed to a corner-mounted gas burner with an output of 30 kW for 20 minutes. During the test, the following parameters are measured: heat release rate, smoke production, flame spread, and the occurrence of flaming droplets or particles. The test results are used to determine the surface classification, known as the Euroclass (e.g., B-s1,d0), which is referenced in the Swedish building regulations.

An important parameter in the classification of reaction-to-fire performance for surface linings is the FIGRA value. FIGRA (Fire Growth Rate Index) is the maximum value of the quotient of the heat release rate from the specimen and the time at which it occurs, determined using a threshold of either 0.2 MJ or 0.4 MJ for the total heat release (THR). In simpler terms, FIGRA (expressed in W/s) can be seen as a measure of the initial fire growth during the test. The FIGRA value is used in the classification of building products in surface classes A2-D according to EN 13501-1 [3], in combination with results from additional tests. This so-called Euroclass system has been used in Swedish building regulations for more than 20 years to specify performance requirements for surface materials.

4.2 Execution of fire tests

Cone Calorimeter tests of Materials A, B, and C were conducted at the Fire Laboratory of Lund University. Although the laboratory is not an accredited testing institute, both the equipment and the test procedures comply with the relevant standards associated with each method. Before the tests in the Cone Calorimeters, test specimens of the wooden panel were placed in a climate chamber where they remained for approximately 1 week. During the tests, the façade panel was exposed to a heat flux of 50 kW/m^2.

Single Burning Item tests were performed on Materials B and C at DBI. The tests on Material B were carried out within the project timeframe and were supervised by the project group. DBI is an accredited testing institute, and the tests of Material B were carried out according to the same standards and procedures as in certified testing. The façade panel that was removed from the building was mounted, as good as possible, in the same way as it was originally mounted on the building. This means that the mounting with battens (see Figure 3), nailing in the same nail holes and the mutual positioning of the panel were recreated in accordance with the original installation.

The tests on Material C were conducted prior to the start of the project in connection to a damage investigation after which permission was granted for the project to use the resulting data. The fire tests of the different materials are summarised in Table 1.

Table 1: Summary of the conducted fire tests.

Material	MCC	Cone Calorimeter	SBI
A	-	LU	-
B	LU	LU	DBI
C	-	LU	DBI

5 Results

The result from the EMC measurement and fire tests of the different materials are presented in this chapter as well as the correlation between EMC and fire performance.

5.1 Equilibrium moisture content

The measurements of Equilibrium Moisture Content EMC of the cross sections generally showed high variation between samples. The different materials showed a principally different behaviour as the materials without polymer-based binder; Material C and N-Wood, showed significant reduction in EMC after exposure whilst EMC values before and after exposure of the material with polymer-binder, Material A and B, did not show statistically significant difference.

5.1.1 Measurements of EMC of cross sections

The average equilibrium moisture content EMC of all groups of exposed samples was lower than the average EMC of the corresponding not exposed samples. However, the variation is high and not all the differences are statistically significant. Table 2 and Figure 12 summarize the results of EMC measurements on cross samples in the study.

Table 2: Summary of EMC data on cross sections.

Sample	**Ageing**	**EMC average (%)**	**EMC stand. deviation (%)**	**Number of samples (N)**	**Significant difference after exposure**
Material A	Protected	14.6	0.31	10	No
	Exposed	13.8	1.06	10	
Material B	Protected	13.5	1.48	20	No
	Exposed	13.3	1.70	20	
Material C	Protected	19.2	2.50	10	Yes
	Exposed	15.7	0.79	59	
N-Wood LTH study	Protected	23.9	0.56	10	Yes
	Exposed	22.3	0.28	10	

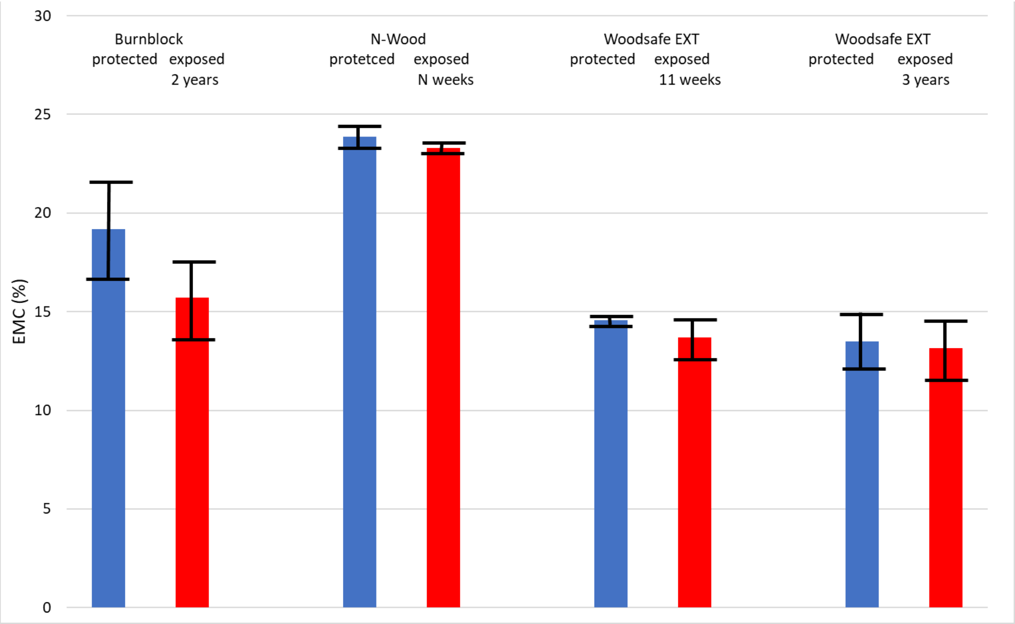

Figure 12: EMC data of protected and exposed cross sections. Average +/- 1 standard deviation.

5.1.2 Measurements of EMC gradient

Due to the low number of samples tested for EMC- gradient, statistical significance of the difference between samples groups could not be determined. As for the cross sections, the average EMC of all groups of samples was reduced after weather exposure. Table 3 summarizes the results from EMC gradient measurements in the study.

Table 3: Summary of EMC gradient measurements.

Sample	Ageing	Average EMC of exposed surface (%)	Average EMC of interior (%)	Average diff. EMC (interior) EMC (exposed) (%)	St.dev. difference EMC (%)	Number of samples (N)
Material A	Protected	16.7	12.6	4.1	--	1
	Exposed	16.5	13.3	3.2	--	1
Material B	Protected	16.5	13.5	-3.0	0.31	4
	Exposed	15.8	13.3	-2.5	0,43	4
Material C	Protected	19.4	24.6	5.3	3.98	4
	Exposed	16.2	19.5	3.4	2.79	5
N-Wood LTH study	Protected	37.7	28.6	1.1	--	1
	Exposed	23.0	22.8	-0.1	--	1

Figure 13 shows the individual EMC gradient values determined on samples treated with Burnblock taken from the house in Southern Sweden (Material C) and Figure 14 the average values from the same measurements. The EMC distributions of both the protected samples and the weather exposed samples show significantly lower EMC on the outer surface layers as compared to the layers towards the inside.

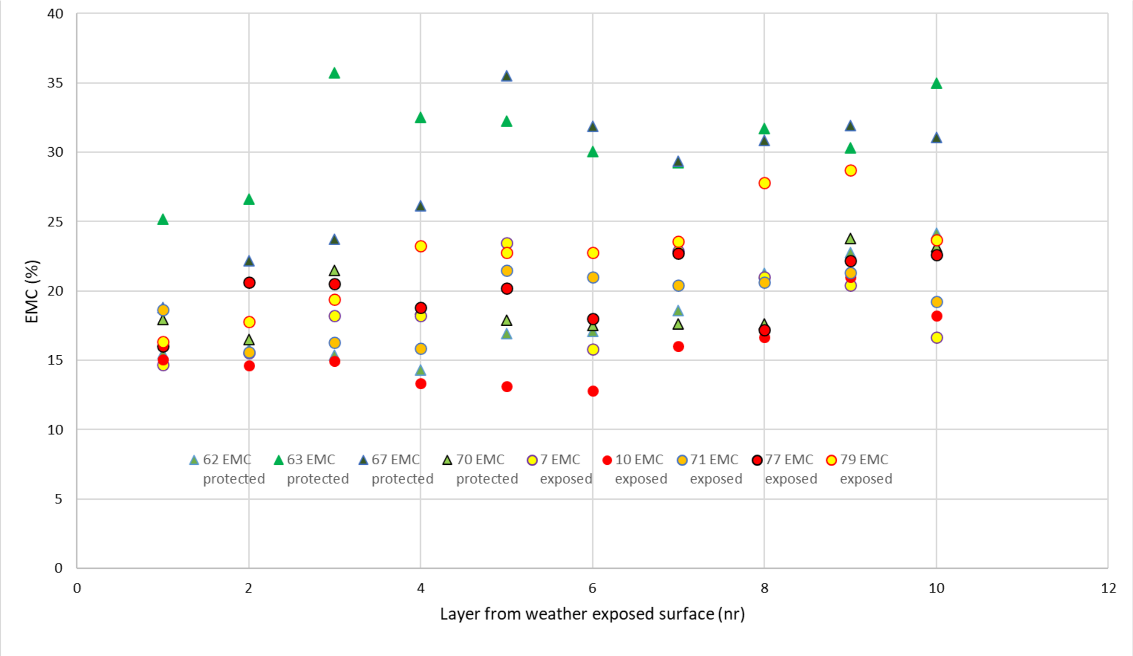

Figure 13: Individual EMC-gradient values Material C samples.

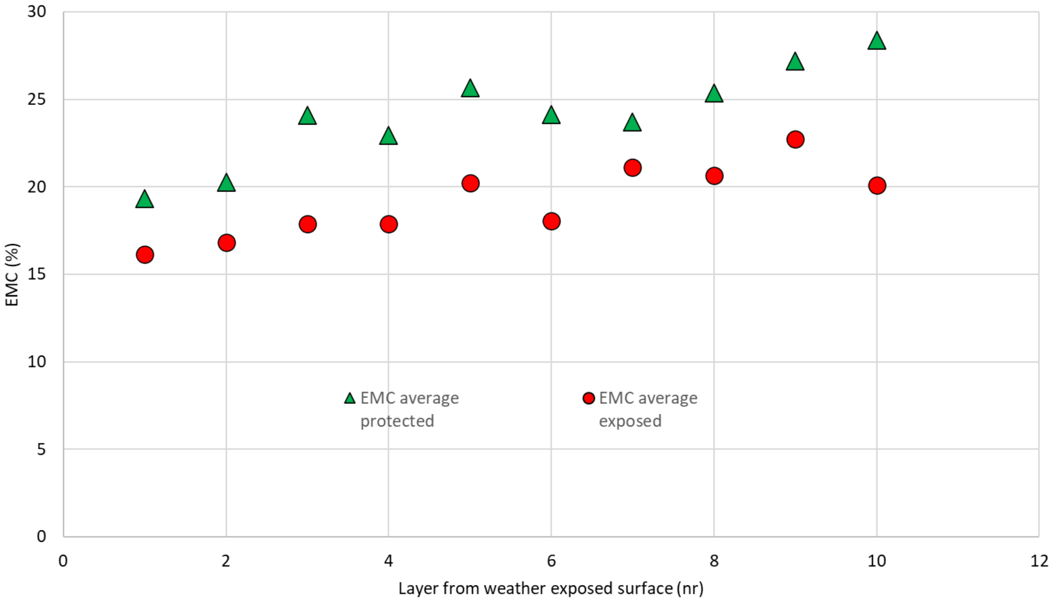

Figure 14: Average EMC-gradient for each layer in Material C samples.

The EMC pattern is principally different in the Material B (Woodsafe WFX) samples treated with polymer binder taken from the house NW Stockholm. Instead of a gradient through the cross section from the inside to the outside, the boards show a pattern with lower EMC in the core compared to both the inner and outer surfaces.

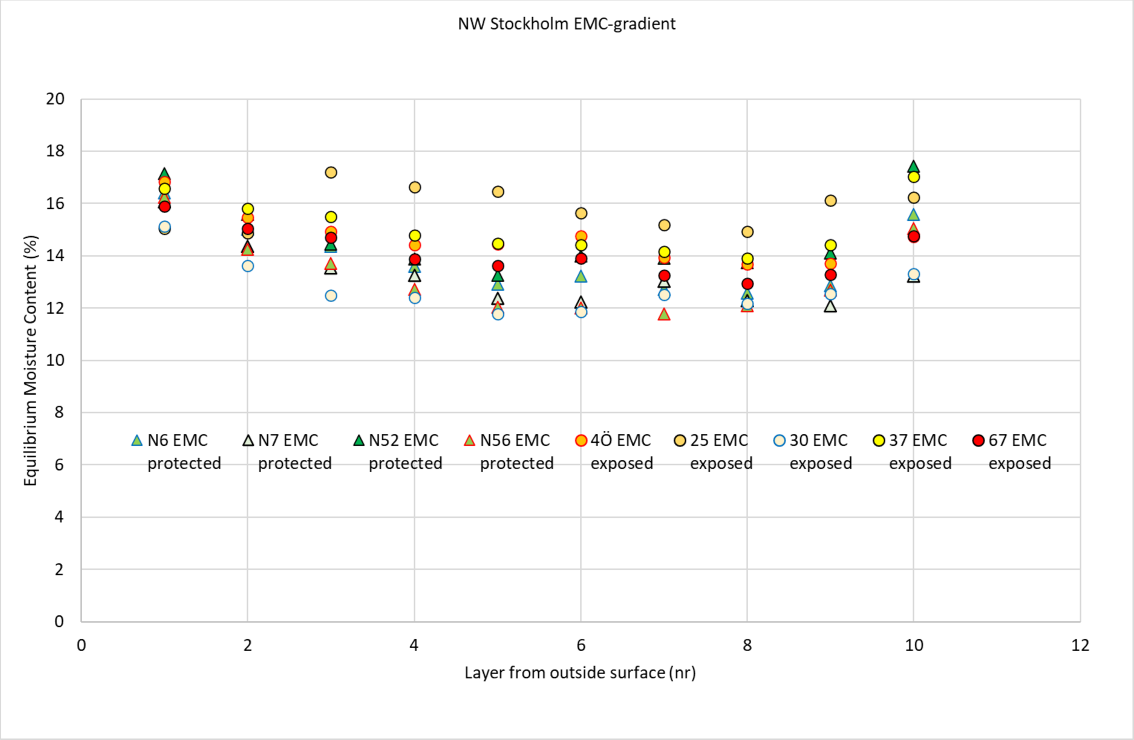

Figure 15: Individual EMC values for Material B samples.

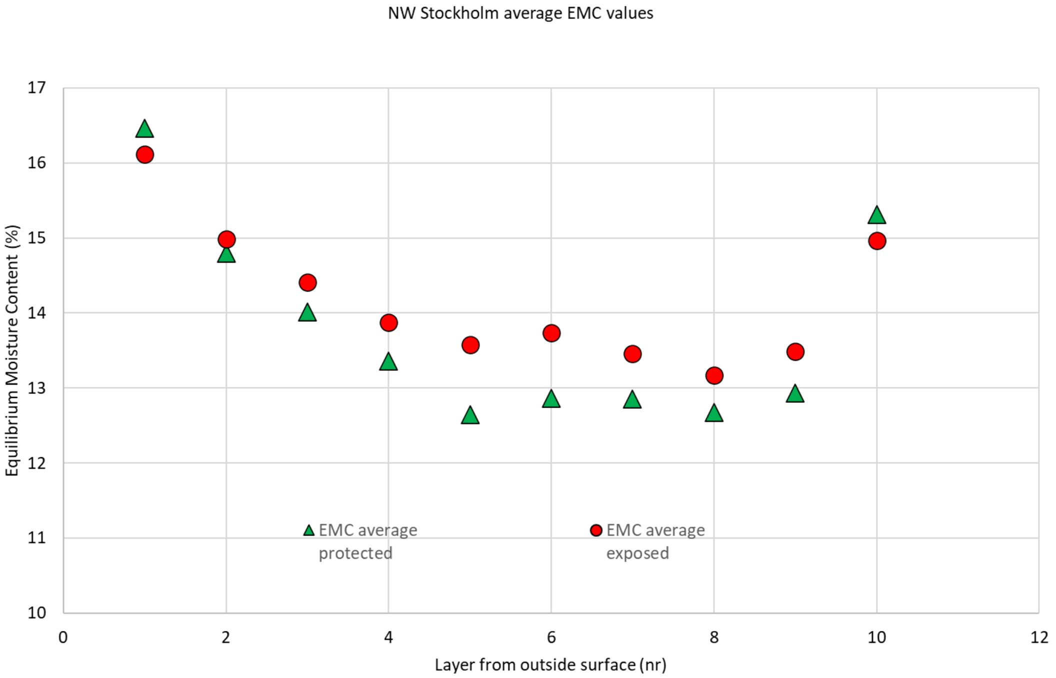

Figure 16: Average EMC-gradient for each layer in Material B samples.

5.1.3 Observations during conditioning and dry weight measurements

Salt crystals appeared during conditioning on the samples treated with Burnblock that were taken from the house in Southern Sweden (Material C). The crystals formed primarily on the end surfaces of the test samples is a clear sign that the high Relative Humidity during conditioning has been sufficient to initiate salt migration through the wood, showing that externally added free water not is necessary for leakage, see Figure 17.

Figure 17: Salt crystals formed during conditioning on end surfaces and interior surfaces of samples protected from precipitation treated with Burnblock (Material C).

Mould growth occurred during conditioning on 50 mm long samples treated with N-Wood and on 100 mm long samples with all treatments. The growth was most severe on N-Wood samples and least severe on samples treated with Burnblock. Figure 18 shows 100 mm samples treated with N-Wood.

Figure 18: Severe mould growth on 100 mm samples after conditioning of NN-wood.

Yellow drops formed on the surfaces of some of the Woodsafe WFX samples (Material A and B) during drying in 103 °C for dry weight measurement, see Figure 19. The chemical content of the drops has not been determined.

Figure 19: Yellow droplets formed on surface of Woodsafe WFX samples during drying at 103 °C.

5.2 Fire performance

Result from the fire tests in the Microscale Combustion Calorimeter, Cone Calorimetry and Single Burning Item are presented in this chapter.

5.2.1 Micro Combustion Calorimeter (MCC)

The results from the MCC testing are summarised in Table 4. All the MCC tests were performed at a heating rate of 1K/s and pyrolysed in an oxidative (80%N_2 20%O_2) environment. No repeat tests have been performed on these samples, hence results from this section should be considered qualitative and exploratory only.

The MCC was used to look at potential FR gradients through the material cross-section, testing slices of approx. 2.5mm from the exposed surface through the entire cross section of the wood panel samples. Only Material B from one exposed panel (ID: 68) was tested.

Table 4: MCC results summary of Material B.

Sample location (approx. depth in mm from exposed surface)	**HRC (J/gK)**	**Peak HRR (W/g)**	**Total HR (kJ/g)**	**Temp at Peak (°C)**
Exposed surface	144.11	138.63	17.02	307.76
2.5	123.36	111.71	17.11	300.69
5	115.87	113.27	17.20	304.03
7.5	111.55	101.19	17.30	314.30
10	164.72	149.92	18.07	346.52
12.5	136.30	122.98	17.31	336.10
15	103.25	93.73	16.80	296.22
17.5	133.88	120.06	15.98	295.54

Plotting some of the results (peakHRR and the temperature when the peakHRR occurs) from Table 4 in Figure 20, some differences can be noted going through the cross-section of the panel. Higher peakHRR values are observed at the exposed surface and in the centre of the panel. While considering these as indicative results only, this does indicate some change in performance, at the surface until approx. 2.5mm depth, a higher peakHRR may be an indication of leaching, with the peakHRR values lowering as we go deeper into the sample. The high values in the middle may be indications of the FR impregnation not penetrating through the full cross section of the panels (i.e. not reaching the middle). However, at this stage, these are just indications, and further testing is recommended to verify any of the above suppositions.

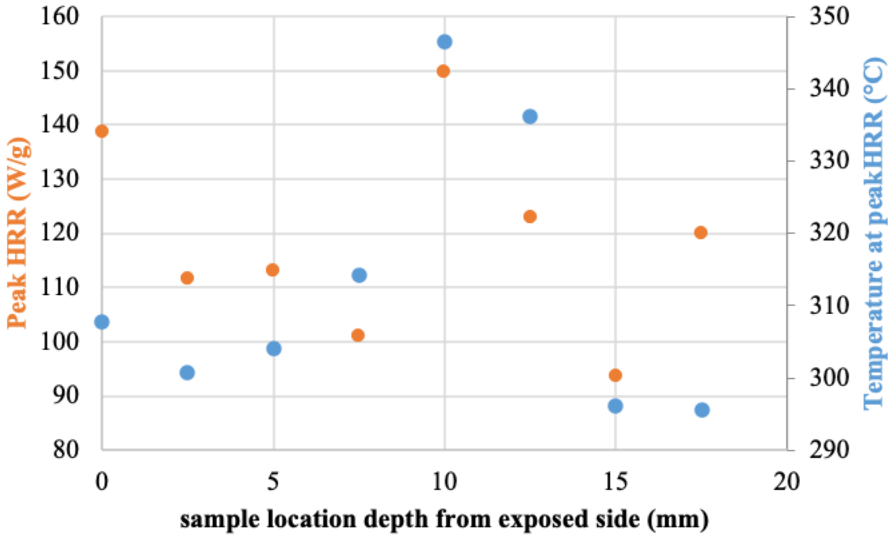

Figure 20: PeakHRR and temperature at peakHRR at different depths into the sample

5.2.2 Cone Calorimeter

The results from the cone calorimeter test are presented in Table 5. All tests presented in Table 5 have been performed with a heat flux of 50 kW/m^2. It can be observed that the exposed (unprotected) material exhibits a higher maximum heat release rate compared to the protected material. However, no consistent overall trend is evident regarding time to ignition. For Materials A (excluding the outlier), B and C, the exposed/unprotected specimens show a longer time to ignition than the protected ones.

Table 5: Data on maximum heat release rate (HRR$_{max}$) and time to ignition (t$_{ig}$) from the Cone Calorimeter tests.

Material		**Number of tests**	**Mean value**	
			Peak HRR (kW/m^2)	**t$_{ig}$ (s)**
A	Unexposed	7	124.1	22.3 (16.7*)
	Exposed	9	175.3	18.0
B	Unexposed	9	131.7	12.1
	Protected	26	148.6	12.6
	Exposed	37	193.6	14.7
C	Protected	7	139.5	8.4
	Exposed	9	173.9	9.9

* If an outlier (t$_{ig}$ = 56 s) is removed.

Due to the large number of tests conducted on Material B it is possible to present a distribution of the results (see Figure 21). From Figure 21 it is possible to see that there is a clear difference in the fire performance of the protected and exposed samples. A t-test also reveals that there is a significant difference ($p < 0.01$) between the means of the two groups for both peakHRR and time to ignition.

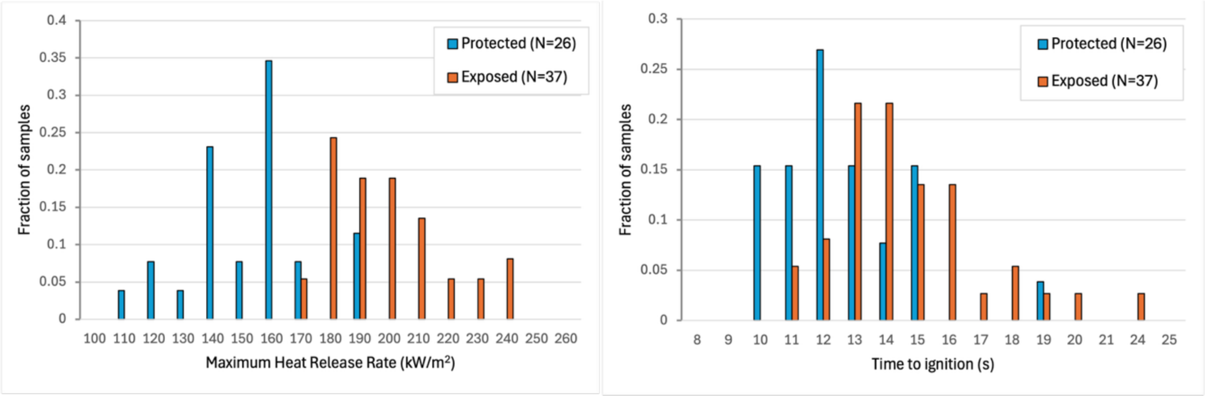

Figure 21: Results from Cone Calorimeter tests of Material B, peakHRR (left) and time to ignition (right).

5.2.3 Single Burning Item

A total of six SBI tests have been conducted on Material B and two tests on Material C. For Material B three tests were performed on protected material (North in Figure 2) and three tests were performed on exposed material (South in Figure 2). The test reports for Material B are included in the Appendix. An overview of the results is presented in Table 6, while Figure 22 presents the time-dependent development of the HRR and FIGRA.

Table 6: Overview of the results from the SBI tests of Material B.

Parameter	**Protected**					**Exposed**				
	Test 1	**Test 2**	**Test 3**	**St.dev**	**Mean**	**Test 1**	**Test 2**	**Test 3**	**St.dev**	**Mean**
$\text{FIGRA}_{02\text{MJ}}$	273.4	370.5	331.0	48.8	325.0	544	629.1	609.4	44.5	594.2
$\text{FIGRA}_{04\text{MJ}}$	263.3	370.5	330.2	54.1	321.3	544	629.1	609.4	44.5	594.2
$\text{THR}_{600\text{s}}$	7.4	14.3	10.0	3.5	10.6	13.15	15.4	11.6	1.9	13.4
SMOGRA	6.9	2.2	6.4	2.6	5.2	10.4	2.5	5.9	4.0	6.3
$\text{TSP}_{600\text{s}}$	45.3	45.6	51.1	3.3	47.3	57.4	43.3	50.3	7.1	50.3

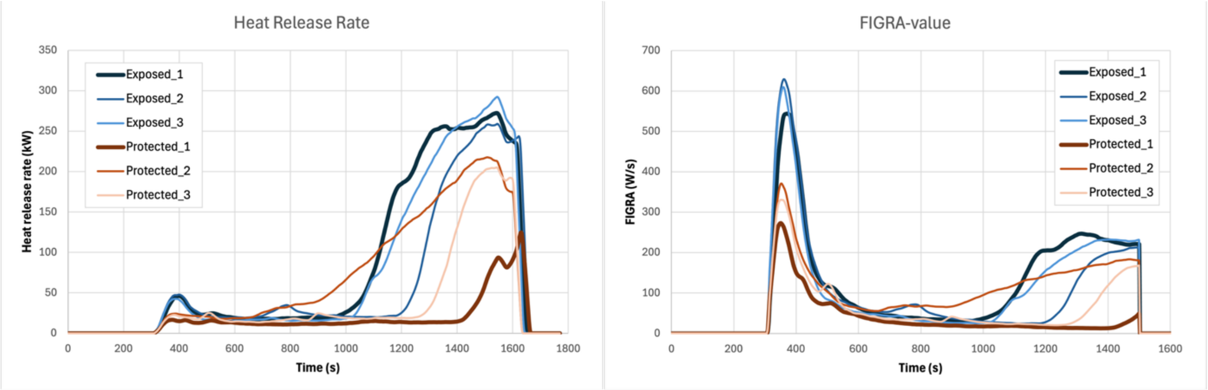

Figure 22: Results from SBI tests of Material B, heat release rate (left) and FIGRA (right).

Material C tests were performed on material from the north side (facing another house) and from the south facade (directly exposed to the weather), see Table 7.

Table 7: Results from the SBI tests of Material C.

Parameter	**North**	**South**
FIGRA$_{02MJ}$	280.7	652.0
FIGRA$_{04MJ}$	273.7	652.0
THR$_{600s}$	6.68	9.43
SMOGRA	2.2	4.8
TSP$_{600s}$	45.8	29.8

All the sample groups show FIGRA values corresponding to Euroclass D in EN 13501- 1 [3]. However, the FIGRA of the exposed samples are also considerably higher than the FIGRA of the protected samples. This is consistent with other fire tests performed.

5.3 Correlation between EMC and fire performance

Based on the EMC and fire performance results, the relationship between moisture behaviour and fire properties can be examined. The correlation between EMC (Table 3) and Cone Calorimeter data (Table 5), specifically peakHRR and time to ignition, is presented in Figure 23.

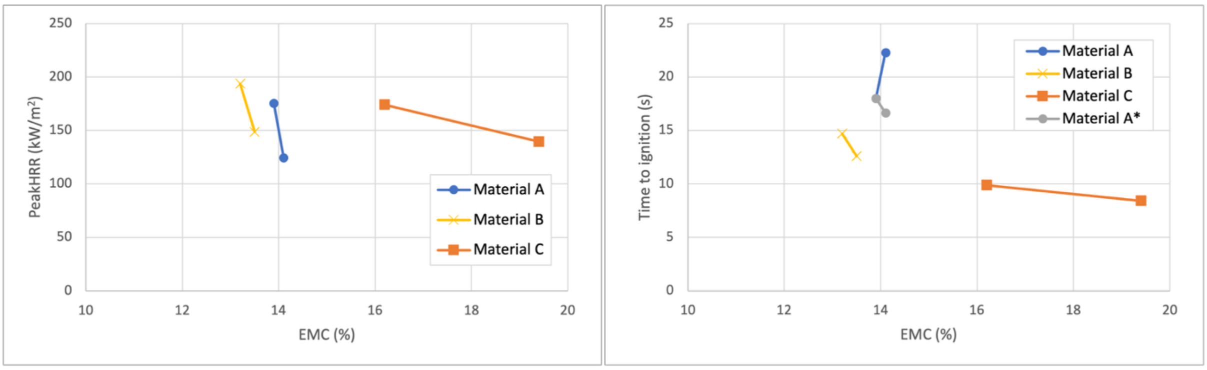

Figure 23: Correlation between EMC and peakHRR (left) and EMC and time to ignition (right).

For the Woodsafe WFX materials (Materials A and B), the correlation patterns for peakHRR are similar, with the regression lines located close to one another. In these systems, a small decrease in EMC corresponds to a relatively large increase in peakHRR.

In contrast, Burnblock (Material C) shows a different trend. A substantially larger reduction in EMC is correlated to a change in peakHRR comparable to that observed for Materials A and B. This suggests a different moisture–fire performance relationship for the polymer system.

Regarding time to ignition, Materials A and B again exhibit similar trends, provided that the outlier in Material A (see Table 5) is excluded from the analysis (see data for Material A* in Figure 23).

For Materials B and C tested using the Single Burning Item (SBI) method, the EMC correlation with FIGRA is presented in Figure 24. The overall trend resembles that observed for peakHRR in the Cone Calorimeter tests. Burnblock (Material C) displays a larger change in EMC to achieve a change in FIGRA like that of Material B, further supporting the conclusion that the systems respond differently to ageing and moisture loss.

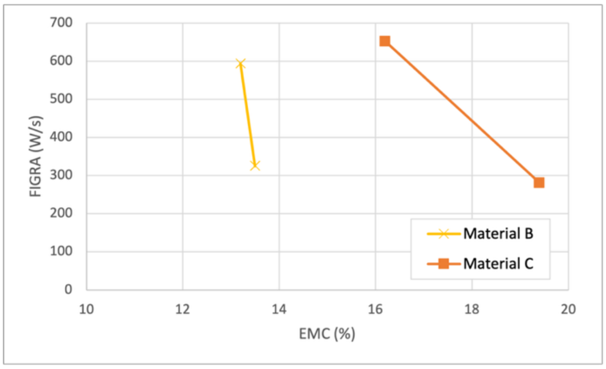

Figure 24: Correlation between EMC and FIGRA from SBI-tests.

6 Discussion

The aim of the study has been to present a first “beta-version” of a cost-efficient test procedure to estimate the properties of fire-retardant treated facades on existing buildings to check if the fire-protective properties of the treatments still are acceptable. The methodology shall be described and a suggestion for acceptance criteria presented. As the method is applied and experience from testing and different systems of fire retardants is gathered, more precise acceptance criteria can hopefully be determined.

It needs to be stressed that the method aims to provide a rough estimation of the status of the fire protective properties to function as guidance to whether more advanced tests are needed or not. It has not been the intention to provide an ultimate answer regarding the status of the fire-retardant treatment.

The number of test samples in this study has been relatively low which can have contributed to the fact that statistically significant differences between groups of samples could not always be established. However, even though the results one by one do not show significance, the different measurements show the same tendencies of reduced average EMC and reduced fire performance after weather exposure. The general tendencies support a conclusion that there is clear indication that EMC reflects loss of retardants and the fire performance of the material.

It is also important to note that the present study was designed to evaluate a test method, it was not designed to evaluate the performance of the different treatments. Studies specifically aimed at the long-term performance of fire retardants should be carried out before broader conclusions regarding the impact of weather exposure on the treated material is made.

The research questions studied to achieve the overall research objective of this project have been:

- What is the relationship between equilibrium moisture content and fire performance for different types of FR wood products for exterior use?
- How does specimen size influence the results of the assessment method? What is the minimum representative sample size, and how many specimens are required to obtain reliable results?
- How does the concentration gradient of fire-retardant chemicals within a specimen affect the outcome of the proposed assessment method?
- Does the relationship between EMC and fire performance differ between wood with a high chemical concentration gradient and wood with a more uniform (low gradient) distribution?

6.1 Results from EMC measurements

The EMC values show a high variation between samples. The main reason for the variation is most likely the heartwood content of the boards, influencing both the initial penetration and retention of fire retardants in the wood as well as hygroscopic properties of the treated wood influencing possible leakage.

6.1.1 EMC reduction of cross sections after weather exposure

The results are different between the systems with and without polymer binders. The two tested systems without polymer binder both show significantly reduced EMC of cross sections after ageing whilst the system with polymer show a reduction in average EMC, but not on a significant level. The significant decrease in EMC of the cross sections after exposure is a clear indication that leaching of fire retardants has occurred.

Regarding the systems without polymer, both the initial EMC level of the material not exposed to weather as well as the reduction of EMC are considerably different between the two systems. This shows that it will be necessary to establish individual acceptance criteria for each treatment system to make the screening test relevant.

The system with polymer binder does not show significant EMC-reduction of the whole cross sections after weather exposure, showing a clear positive effect of the polymers on reduction of leakage.

6.1.2 EMC gradient before and after weather exposure

The low number of samples from each system tested for EMC gradient makes it difficult to draw strict conclusions and inhibits determining significance of statistical differences. Further measurements of EMC gradients are planned and will be included in a planned scientific paper but will not be finished within the time frame of this project.

The results presented in Figure 14 indicate that the Burnblock system (Material C), without polymer binder, show a gradient through the cross section from the inside of the boards to the outside, where the EMC of the wood close to the external surface is significantly lower than the EMC at the interior surface. This gradient is seen for both the protected and fully weather exposed samples. The EMC values also seem to be lower for the weather exposed material compared to the protected, as was seen in the cross sections. The gradient is a strong indication of migration of retardants from the interior of the façade towards the outside. Migration and consequently leakage have occurred both in the weather exposed boards and the boards protected against precipitation.

The results for the Woodsafe WFX samples with polymer binder (Material A and B) show a different pattern than the samples without polymer, as can be seen in Figure 16. For both fully weather exposed boards and boards taken from a position protected against precipitation and sunshine, the samples show a higher average EMC close to the surfaces than in the interior.

The higher EMC values close to the surfaces indicate a higher concentration of fire retardants, which most likely reflects the penetration and retention of the impregnation liquid.

6.1.3 Impact of heartwood and sapwood on the measurements

Heartwood content influences initial penetration and retention of fire retardants as well as the hygroscopic properties of the material. The heartwood content will be different both between boards and between the top end and root end of each board due to the growth characteristics of the trees and the production process.

The growth ring orientation of the panel boards in the study is most likely a result of the production method. The façade boards are produced from planks that are split before heat treatment and profiling, leading to roughly half of the boards having the sapwood surface outwards, and half the heartwood side outwards.

Both buildings from which samples were collected show a pattern where approximately half of the external surfaces of the boards are cut with higher heartwood content and half of the boards having more sapwood on the outside. Since the sapwood can be expected to show a considerably higher penetration and retention of chemicals during impregnation, the boards with sapwood on the outside will have a greater initial content of fire retardants on the critical exposed than the boards with heartwood on the outside (see Figure 25).

The diameter of the logs and the position of the planks in the sawing pattern will thus impact the sapwood content on the surfaces of the boards as the heartwood in located in the centre of the three. Generally, a board cut farther from the centre of the log will show higher sapwood ratio, and the board will show higher sapwood content in the top end as compared to the bottom end due to the conicity of the three. Pure sapwood surfaces cannot be expected on panel boards made from Nordic Scots Pine due to the relatively thin sapwood layer in the trees; all panel boards will show a mixture of sapwood and heartwood on the surfaces.

Figure 25: Boards with higher sapwood ratio on the external surface to the left and with higher heartwood ratio on the right. Picture from building where Material B was collected.

6.1.4 Fire retardants migrating also without exposure to external water

Salt crystals were seen on the wood surfaces of the samples treated with Burnblock during conditioning, both on end surfaces and flat surfaces. Since the end surfaces of the boards were cut immediately prior to conditioning, the salt crystals are proof of migration of fire retardants, showing that high humidity is sufficient to initiate diffusion of the Burnblock (Material C) fire retardants, also without the wood being exposed to free water.

This conclusion can also be supported by the results from EMC gradient measurements where both the weather exposed samples and the samples protected from precipitation showed lower average EMC on the outside surface as compared to the inside, despite the expected higher initial penetration and retention at the surfaces with higher sapwood content. The gradient is a clear indication that migration has occurred.

6.2 Results from fire performance tests

As with the EMC results, fire performance shows considerable variability between individual samples. Despite this variation, clear and consistent differences are observed between weather-exposed and protected materials.

Weather-exposed samples generally exhibited higher peak HRR than both unexposed reference samples and samples taken from sheltered façade locations. This trend is evident across all three fire testing scales used in this study, Microscale Combustion Calorimetry, Cone Calorimetry, and Single Burning Item. The same pattern is observed for all three fire-retardant systems investigated, clearly indicating degradation of fire protection following weather exposure. It was also seen that the time to ignition increase slightly for all three materials when exposed to weather.

In terms of the Cone Calorimetry a large number of tests were performed on Woodsafe WFX (Material B) at 50 kW/m^2. This allowed to demonstrate a statistically significant higher peakHRR and longer time to ignition for exposed samples compared to protected.

None of the SBI tests performed on building-derived samples met the requirements for Euroclass B classification but instead showed FIGRA-values corresponding to Euroclass D, which is comparable with natural wood without fire-retardant treatment. This applies to samples from fully exposed as well as more protected locations, including boards treated with Woodsafe WFX (Material B) and Burnblock (Material C).

Both Woodsafe WFX and Burnblock samples demonstrated a marked reduction in fire-retardant properties after ageing, despite relatively short façade exposure times, two years for Burnblock-treated boards and three years for Woodsafe WFX-treated boards.

Although the overall reaction-to-fire performance and the indications of relatively rapid degradation are concerning, and it should be noted that none of the aged samples demonstrated the fire performance expected of these products when tested, it is important to emphasize that this study was designed to evaluate a test method rather than the durability or long-term performance of specific treatments. Hence, definitive conclusions regarding product performance require dedicated studies specifically designed for that purpose.

6.3 Correlation between EMC and fire performance

Based on the correlation analysis between EMC and the various fire tests performed, consistent trends can be identified: reduced EMC is associated with increased peak HRR and higher FIGRA values but at the same time longer time to ignition. The increase in peak HRR and FIGRA-values indicate that loss of fire-retardant content corresponding to a measurable reduction in fire performance. The longer time to ignition observed after weather exposure may be attributed to that the type of FR used in these systems (ammonium-phosphorus based) tends to reduce ignition times due to the designed early activation of the char forming abilities of these chemicals [20], which is a main FR mechanism of these retardant systems. Longer times to ignition can also be an effect of aging-related changes in the wood itself, a phenomenon that has also been documented in experimental studies across different wood species [21].

The observation of very similar relationships between EMC, peak HRR, and time to ignition for materials of the same type but originating from different buildings (Materials A and B, both treated with Woodsafe WFX) supports the reliability of the methodology and testing procedures applied in the project. The consistency across independent sample sets strengthens confidence in the robustness of the approach.

The concentration gradient of fire-retardant chemicals within a specimen will likely affect the correlation between EMC and fire performance, since fire performance is governed by the surface characteristics of the material. When the EMC near the external surface is significantly lower than at the interior (as in Material C), it indicates surface leaching and reduced fire performance. In such cases, measuring EMC over the entire cross-section is problematic because the resulting average does not represent the surface. When comparing EMC from exposed and protected material in a building, differences may still appear, but they may be less distinct when evaluating the full cross-section than when examining surface slices.

The apparent differences between Materials A and B compared with Material C (treated with Burnblock) are not unexpected, given the differences in chemical composition and formulation between polymer-bound systems and pure salt-based systems. However, these differences highlight an important limitation, that it is not feasible to define a universal EMC threshold that corresponds to a specific level of fire performance for all fire-retardant systems. Instead, system-specific acceptance criteria will likely need to be established for each individual product.

7 Suggested test procedure and temporary acceptance criteria

An initial or temporary test procedure is proposed where relatively short cross section samples are used in order both to limit damage to the building and reduce conditioning time.

Due to the high variation in EMC values between individual boards, it is suggested to cut cross section samples from 20 boards each from areas of the facades that are protected against direct precipitation and from areas directly exposed to weather. The EMC determination can be done on short samples (typically 10 mm to 20 mm in length).

If the façade boards are 140 mm wide, this would require a total of 2.8 m strips cut from protected and exposed areas of the building respectively. This reduces the damage to the façade and should allow repairing the façade by relatively simple and low-cost means.

With a sample length of 10-20 mm, a conditioning time of 150 hours in climate 23°/85% RH is recommended.

Provided that the samples from the object have been taken in a representative manner, the analysis should reflect the extent of any leaching. A suggested initial acceptance criterion is that a t-test shall not indicate a statistically significant difference in EMC between protected and exposed samples on the 0.95 level. If a statistically significant difference is observed, further evaluation of the façade is recommended.

One possibility is that there are buildings where severe leakage has occurred from both the protected and the exposed areas, leading to both sample sets showing similar but low values. This may be detected by comparing the EMC values obtained from the samples with the EMC values that can be expected from wood not treated with fire-retardants, see Table 8

Table 8: Possible reference values for EMC.

Material	**Reference EMC**	**Reference**
Natural softwood	18%	Table 3.1, p 64 in [22] and Figure 6.33, p 190 in [23]
Heat-treated softwood	8-12%	[24-26]

8 Conclusions

The results of this study demonstrate that EMC measurement can serve as a practical and cost-efficient indicator of the condition of fire-retardant treatments of wooden façades. Ageing and weather exposure consistently resulted in reduced EMC, indicating loss or migration of fire-retardant chemicals. A corresponding decline in fire performance was observed across three different fire testing scales. Weather-exposed samples showed higher peak HRR, in Cone Calorimetry tests, and FIGRA values, in SBI-tests, than protected samples, confirming degradation due to environmental exposure.

Even though there are uncertainties in the measurements due to nature of the studied material, correlations between EMC and fire performance were identified. These correlations were similar for the two sets of material treated with Woodsafe WFX, which supports the reliability of the methodology. In contrast, the pure-salt based system Burnblock exhibited a different EMC-fire relationship, reflecting differences in chemical composition of the impregnation. The results show that no universal EMC threshold can define acceptable fire performance for all systems. Instead, system-specific acceptance criteria will likely be required for reliable condition assessment. Further targeted studies are necessary to establish such limits for individual fire-retardant treatments.

An initial test procedure is proposed where relatively short cross section samples are used in order both to limit damage to the building and reduce conditioning time. A sample length of 10-20 mm and a conditioning time of 150 hours in climate 23° / 85% RH are recommended. Measurement of EMC on 20 samples collected from a protected area of a building and from an exposed area respectively is recommended. Provided that the samples from the object have been taken in a representative manner, the analysis will reflect the extent of any leaching.

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Appendix – Results from Single Burning Item tests at DBI

PFA12463A is the SBI test report for Material B (protected)

PFA12463B is the SBI test report for Material B (exposed)

DBI
FIRE AND SECURITY

Test Report

Name of client: WoodHolz Consult AB

Product name: Wood cladding collected by the client from a three-year-old four storeys building that burned in July 2025. The building is situated at Sparres väg 10, 19733 Bro

File no.: PFA12463A

Date: 2025-12-03 **Revision no.:** 0

Pages: 6 **Encl.:** 10

Ref: MPA / BPE

Danish Institute of Fire and Security Technology
Jernholmen 12, DK-2650 Hvidovre
Phone: +45 36 34 90 00 · Mail: dbi@dbigroup.dk · www.dbigroup.dk

Client information

Client: WoodHolz Consult AB

Address: Barrskogsgatan 21
SE-78468 Borlänge
Sweden

The results relate only to the items tested. The report should only be reproduced in extenso - in extracts only with a written agreement with this institute.

1. Product

Wood cladding collected by the client from a three-year-old four storeys building that burned in July 2025. The building is situated at Sparres väg 10, 19733 Bro.

Description

According to documentation of the building presented by the client the cladding is made of heat-treated and fire impregnated pine. The cladding boards shall have been fire impregnated with Woodsafe WFX.

2. Manufacturers

According to the documentation presented the cladding boards shall have been delivered by Moelven Wood AB after being fire impregnated with Woodsafe WFX at Woodsafe Timber Protection AB.

3. Nature of test

With reference to the ”Samples for SBI-testing” dated 2025-10-09“ by the WoodHolz Consult AB and Lund University, a fire test of the solid wood cladding sample was tested in accordance with EN 13823. According to the client the test material was collected from the fire damaged building on Sparres väg 10, 19733 Bro, NW Stockholm. DBI has no first-hand knowledge of the sampling or origin of the material.

This report covers test results on the cladding boards from the covered entrance of the building protected from weather. See sampling data taken from “Samples for SBI” in enclosure 1-3.

EN 13823 tests were also performed on the weather exposed cladding boards from the south side of building as shown on the drawing in enclosure 1. This is reported in DBI report PFA12463B.

4. Sample

On 2025-10-09 DBI received the following sample:

43 cladding boards, each with dimensions 1500 x 120 x 21 mm. The cladding boards had nail holes.

Density at 20°C (undried): 498 kg/m³ at the state of receipt determined by weight and measures of the sample.

Three test specimens were prepared from the sample to EN 13823.

5. Mounting of specimen for Single Burning Item test

A standard mounting of specimen was carried out in accordance with EN 13823 as follows:

Thickness of board	21 mm
Mounting:	Standard mounting option b) in clause 5.2.2 of EN 13823.
Substrate:	30 mm A1 stone wool with a density of 57 kg/m^3 cf. EN 13238 mounted on 12.5 mm gypsum plasterboard behind cf. EN 13238.

Air gap:	42 mm ventilated air gap created by horizontally and vertically orientated 21 mm wooden battens.
Orientation:	Vertical.
Fixing means:	Mechanical fixed with screws to horizontal battens. The old nail holes were reused as screw holes to prevent nail holes being venting holes. Adjacent boards from the building were as much as possible kept adjacent in the test.

The specimens were assembled by DBI.

6. Conditioning

On 2025-10-13 the specimens were stored in a conditioning room with an atmosphere of relative humidity of 50 ± 5 % and a temperature of 23 ± 2 °C. The test specimens were kept in this room until the tests were performed.

7. Test method

The test was performed in accordance with:

EN 13823:2020 +A1:2022	Reaction to fire tests for building products - Building products excluding flooring exposed to the thermal attack by a single burning item

8. Test results

Date of test: 2025-11-12

Three tests were performed.

During the tests, the following measurements were made: Volume flow in the exhaust duct, production of carbon dioxide, concentration of oxygen, and production of light-obscuring smoke. Based on these measurements the rate of heat release and the rate of smoke production were calculated.

The graphs, enclosures 4-7, show for the three tests performed:

Enclosure 4
- Average Heat Release Rate $HRR_{av}(t)$
- Total Heat Release THR (t)

Enclosure 5
- Average Heat Release Rate per unit time [$1000 \times HRR_{av}(t)/(t-300)$]
- $Figra_{0.2MJ}$-values

Enclosure 6
- $Figra_{0.4\ MJ}$-values
- Smoke Production Rate $SPR_{av}(t)$

Enclosure 7
- Total Smoke Production TSP(t)
- Smoke Production Rate per unit time [$10000 \times SPR_{av}(t)/(t-300)$]

The test results are shown in the following table

	Test No. 1	Test No. 2	Test No. 3	**Mean Value**
FIGRA$_{0.2\ MJ}$ [W/s]	273.4	370.5	331.0	**325**
FIGRA$_{0.4\ MJ}$ [W/s]	263.3	370.5	330.2	**321**
THR$_{600s}$ [MJ]	7.42	14.32	10.04	**10.6**
SMOGRA [m^2/s^2]	6.9	2.2	6.4	**5**
TSP$_{600s}$ [m^2]	45.3	45.6	51.1	**47**
FDP$_{<10s}$ [Yes/No]	No	No	No	**-**
FDP$_{>10s}$ [Yes/No]	No	No	No	**-**
LFS<wing	Yes	Yes	Yes	-

FDP$_{f\ \ 10s}$: Flaming Droplets/Particles burning less than 10 seconds.
FDP$_{f>10s}$: Flaming Droplets/Particles burning more than 10 seconds.
LFS: Lateral Flame Spread on the long wing of the test specimen.

Test No. 1

Minutes:seconds	
00:00	Start of test
18:00	Burn-through, flames in cavity
21:00	Gas burner stopped

Test No. 2

Minutes:seconds	
00:00	Start of test
09:30	Burn-through
12:00	Increasing flames in cavity
21:00	Gas burner stopped

Test No. 3

Minutes:seconds	
00:00	Start of test
16:30	Burn-through, flames in cavity
21:00	Gas burner stopped

Photographs of the test specimens show the effect of the damages, see enclosures 8-10

Enclosure 8: Test No. 1
Enclosure 9: Test No. 2
Enclosure 10: Test No. 3

9. Statement

The test results relate to the behaviour of the test specimens of a product under the particular conditions of the test; they are not intended to be the sole criterion for assessing the potential fire hazard of the product in use.

Boaz Petersen
Reaction to Fire Engineer

Martin Pauner
M.Sc.

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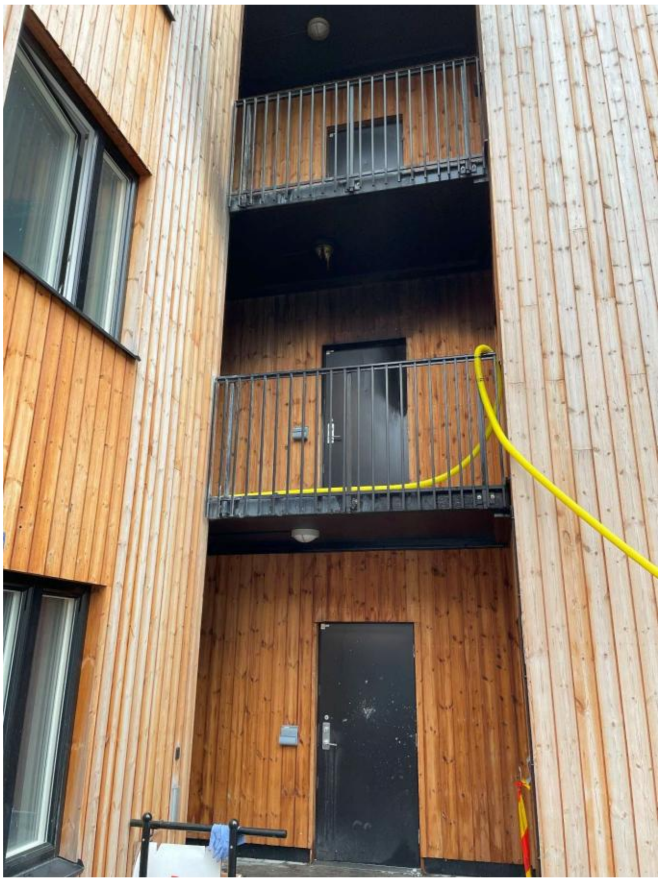
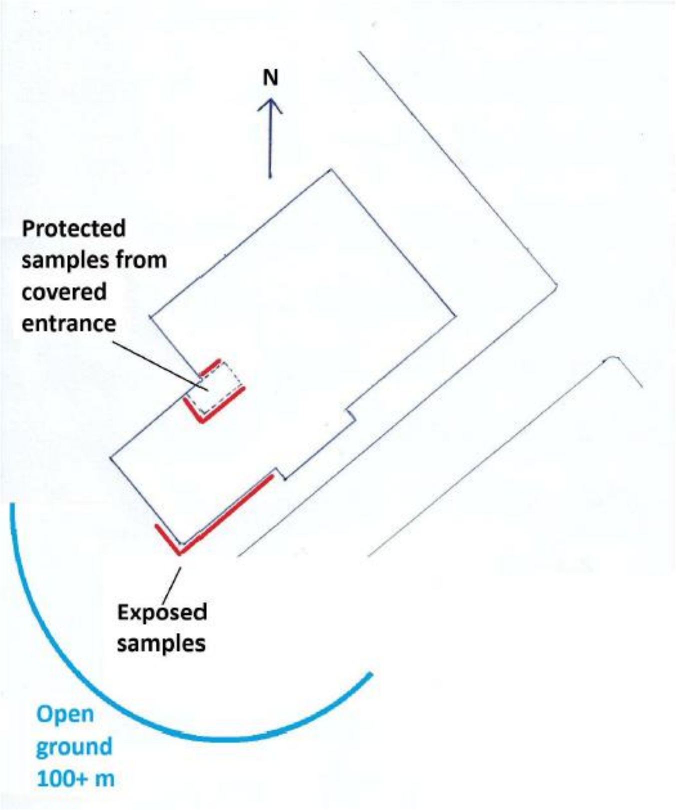
Sweden




N
Protected samples from covered entrance
Exposed samples
Open ground 100+ m

Location and numbering of protected samples

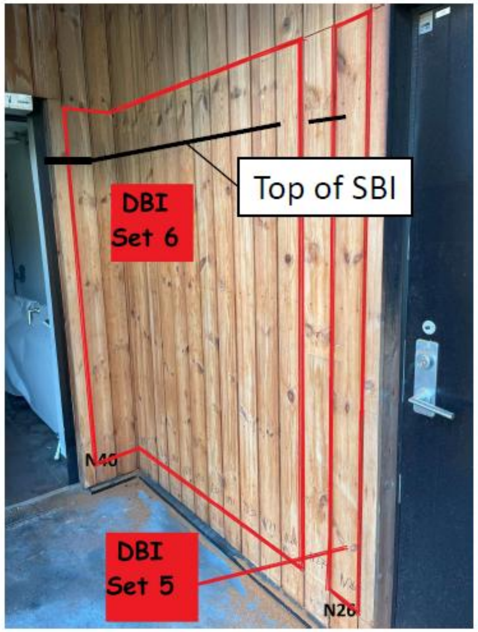
Samples collected from the ground floor

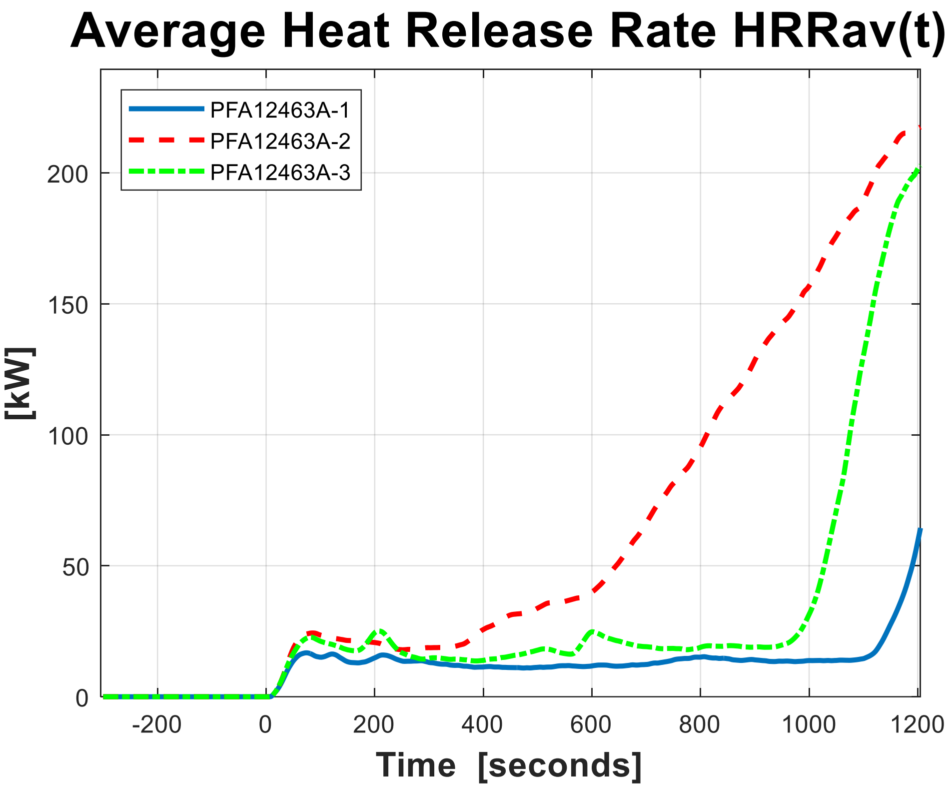
Protected samples from first floor

- First floor panels show discolouration top end

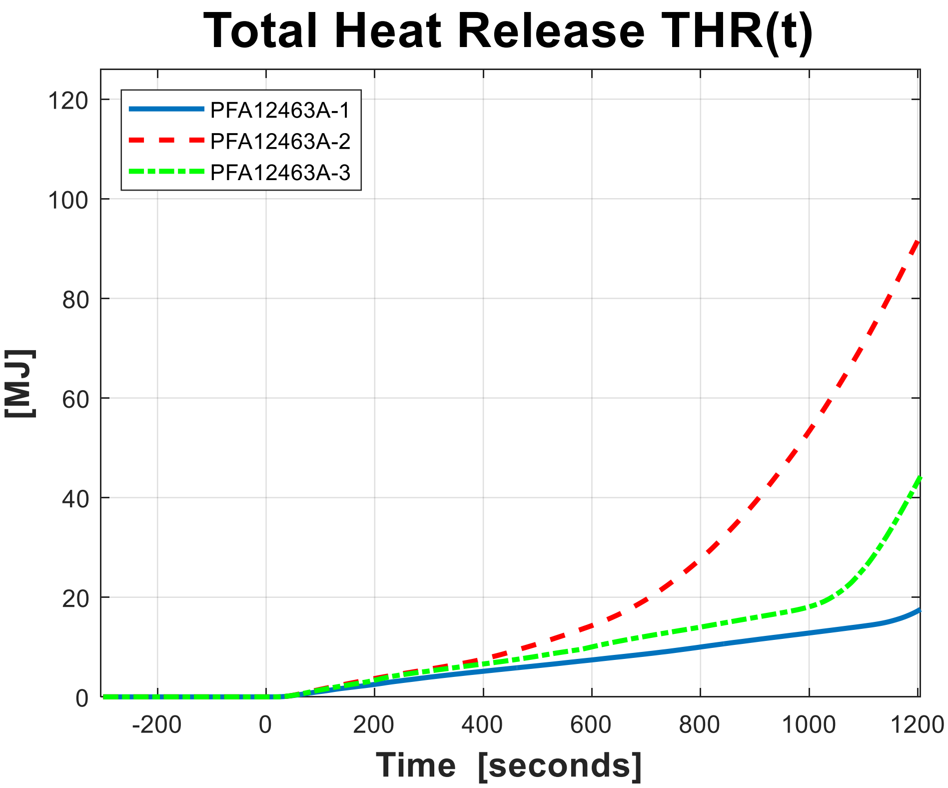
- SBI samples cut from lower end of boards
  - discolouration mainly above SBI-samples
  - exception samples N37, N38, N39 and N40

- Discolouration needs to be taken into account when building test samples

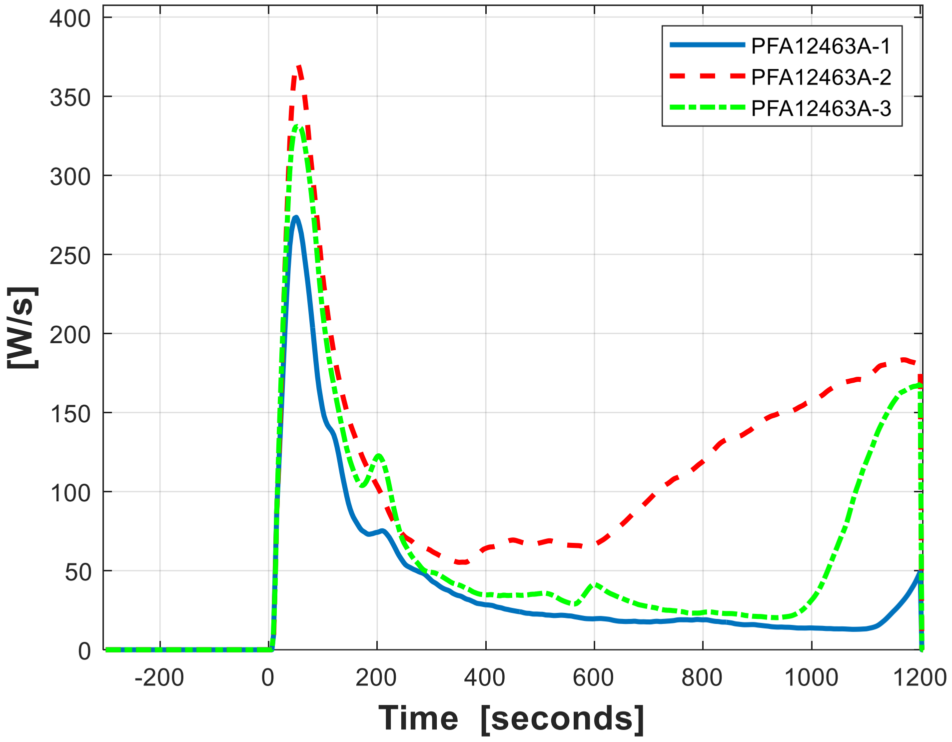




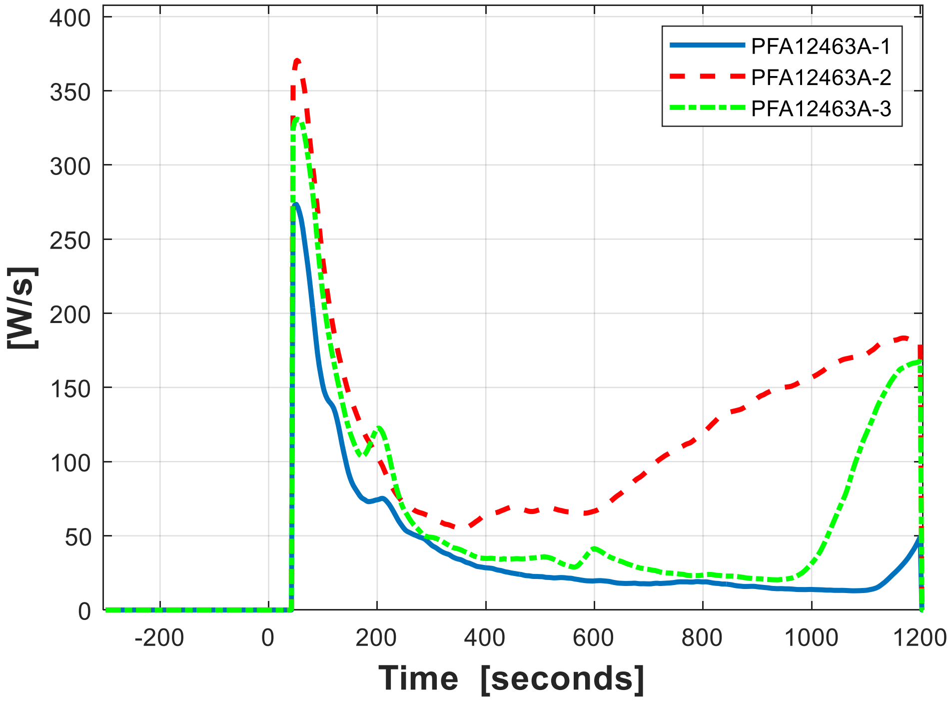
Average Heat Release Rate HRRav(t)



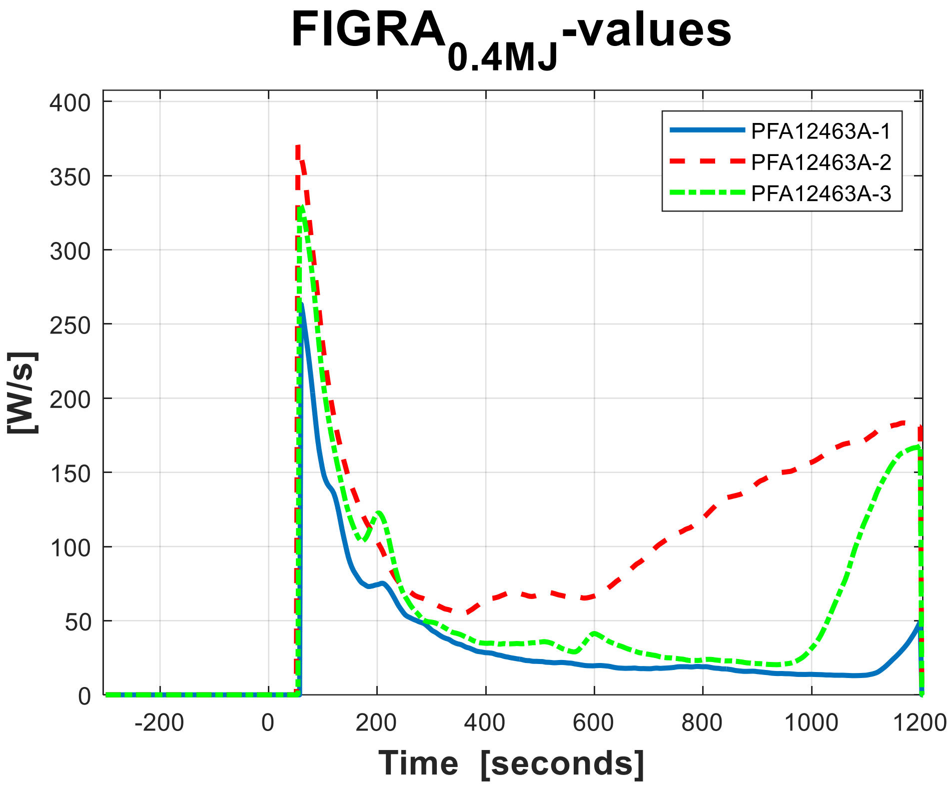
Total Heat Release THR(t)

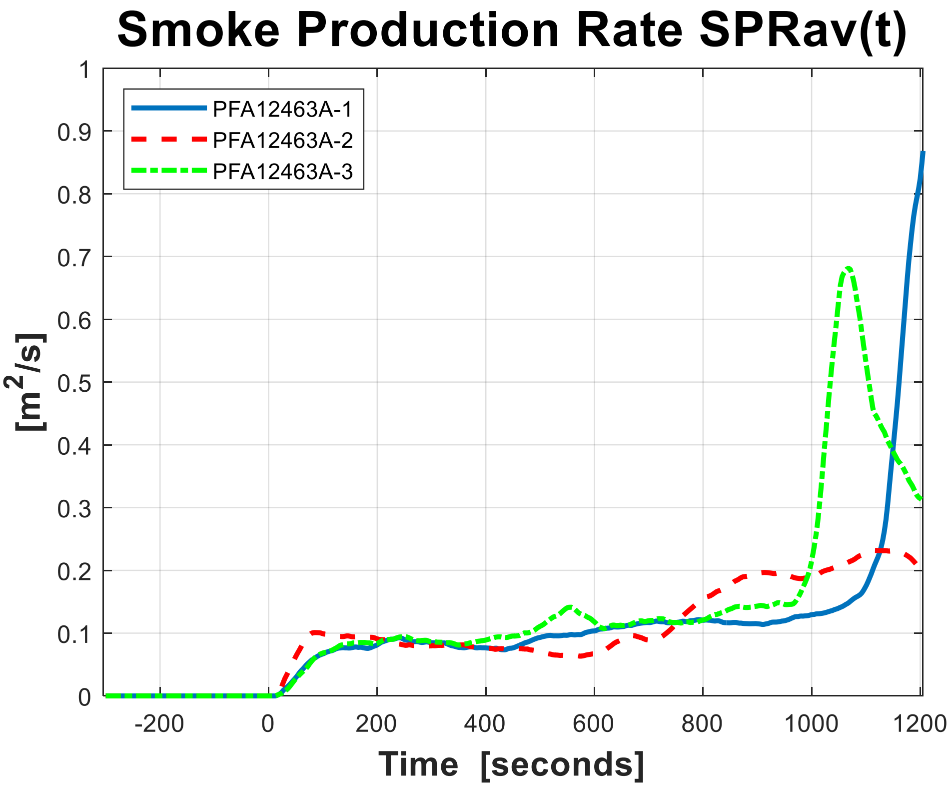


Average Heat Release Rate pr. unit time [1000*HRRav(t)/(t-300)]

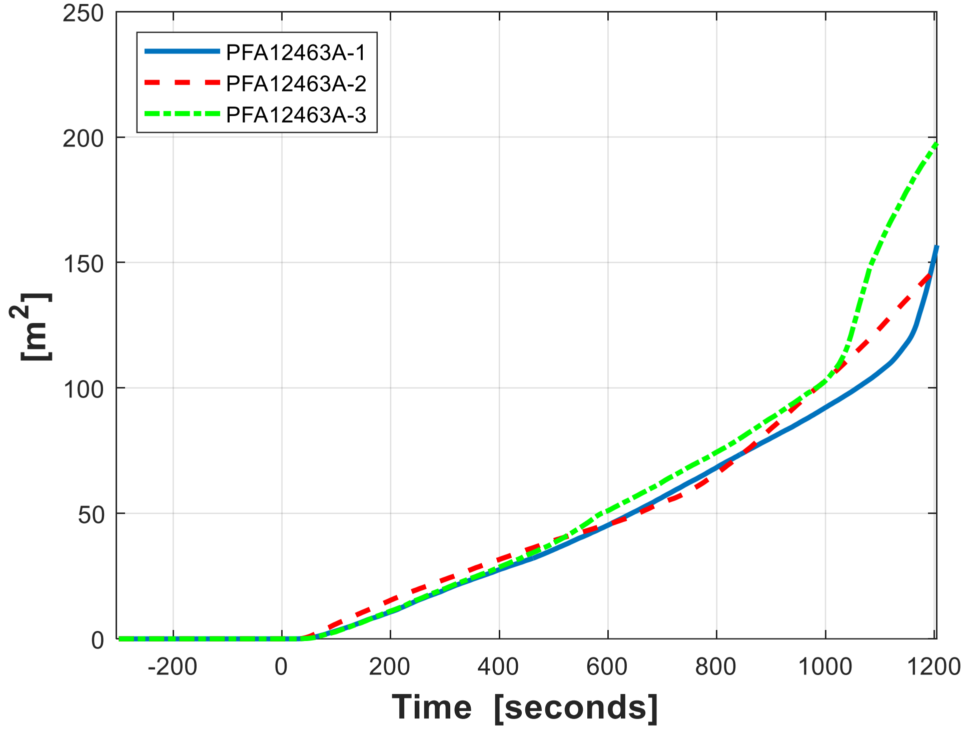


FIGRA$_{0.2MJ}$-values

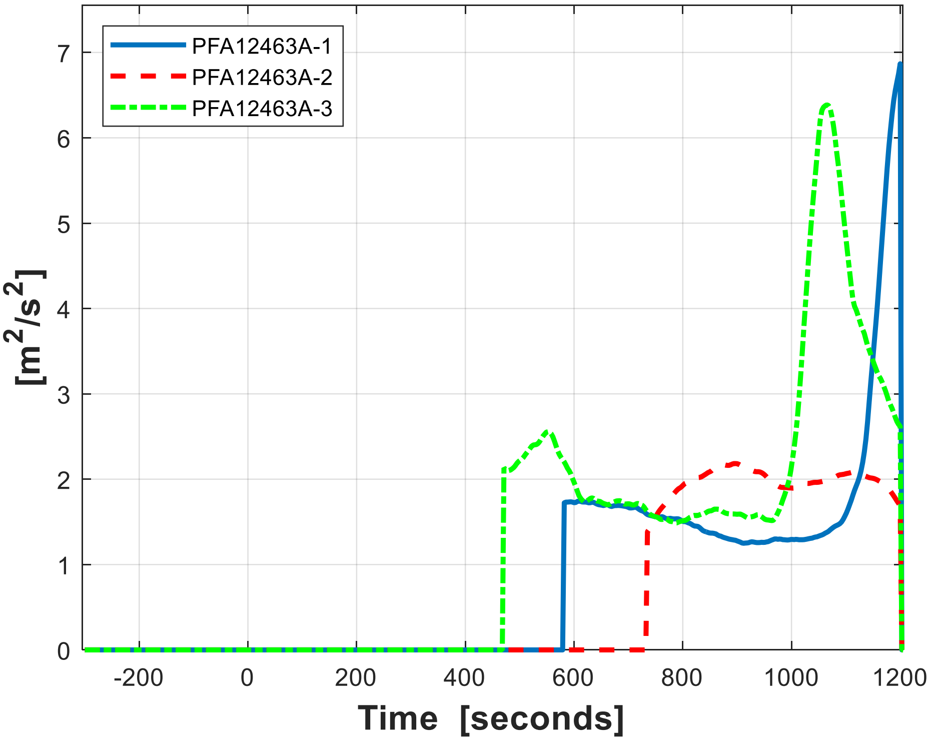

FIGRA0.4MJ-values
[W/s]
400
350
300
250
200
150
100
50
0
-200
0
200
400
600
800
1000
1200
Time [seconds]
PFA12463A-1
PFA12463A-2
PFA12463A-3


Smoke Production Rate SPRav(t)
[m2/s]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-200
0
200
400
600
800
1000
1200
Time [seconds]
PFA12463A-1
PFA12463A-2
PFA12463A-3

Total Smoke Production TSP(t)



Smoke Production Rate pr. unit time [10000*SPRav(t)/(t-300)]



TEST NO. 1


Sag: PFA 12463A
Dato: 2025-11-12
Test: 1
12.11.2025 10:21


Sag: PFA 12463A
Dato: 2025-11-12
Test: 1
12.11.2025 10:21


12.11.2025 10:55

TEST NO. 2


Sag: PFA 12463A
Dato: 2025-11-12
Test: 2
12.11.2025 13:25


Sag: PFA 12463A
Dato: 2025-11-12
Test: 2
12.11.2025 13:29


12.11.2025 14:06

TEST NO. 3


Sag: PFA 12463A
Dato: 2025-11-12
Test: 3
DBI
12.11.2025 14:58


Sag: PFA 12463A
Dato: 2025-11-12
Test: 3
DBI
12.11.2025 14:59


12.11.2025 15:28

DBI
FIRE AND SECURITY

Test Report

Name of client:	WoodHolz Consult AB		
Product name:	Wood cladding collected by the client from a three-year-old four storeys building that burned in July 2025. The building is situated at Sparres väg 10, 19733 Bro		
File no.:	PFA12463B		
Date:	2025-12-03	**Revision no.:**	0
Pages:	6	**Encl.:**	8
Ref:	MPA / BPE		

Danish Institute of Fire and Security Technology
Jernholmen 12, DK-2650 Hvidovre
Phone: +45 36 34 90 00 · Mail: dbi@dbigroup.dk · www.dbigroup.dk

ilac-MRA
DANAK
TEST Reg.no.0012

Client information

Client: WoodHolz Consult AB
Address: Barrskogsgatan 21
SE-78468 Borlänge
Sweden

The results relate only to the items tested. The report should only be reproduced in extenso - in extracts only with a written agreement with this institute.

1. Product

Wood cladding collected by the client from a three-year-old four storeys building that burned in July 2025. The building is situated at Sparres väg 10, 19733 Bro.

Description

According to documentation of the building presented by the client the cladding is made of heat-treated and fire impregnated pine. The cladding boards shall have been fire impregnated with Woodsafe WFX.

2. Manufacturers

According to the documentation presented the cladding boards shall have been delivered by Moelven Wood AB after being fire impregnated with Woodsafe WFX at Woodsafe Timber Protection AB.

3. Nature of test

With reference to the sampling ”-10-09 by the Woodsafe 2025 samples fo
AB and Lund University, a fire test of the solid wood cladding sample was tested in accordance with EN 13823. According to the client the test material was collected from the fire damaged building on Sparres väg 10, 19733 Bro, NW Stockholm. DBI has no first-hand knowledge of the sampling or origin of the material.

This report covers test results on the cladding boards from the south side of the building exposed to weather
was tested. See sampling-testing taken in enclosure 1 “Samples

EN 13823 tests were also performed on the protected cladding from the covered entrance shown on the drawing in enclosure 1 and is reported in DBI report PFA12463A.

4. Sample

On 2025-10-09 DBI received the following sample:

42 cladding boards, each with dimensions 1500 x 120 x 21 mm.

Density at 20°C (undried): 411 kg/m³ at the state of receipt determined by weight and measures of the sample.

Three test specimens were prepared from the sample to EN 13823.

5. Mounting of specimen for Single Burning Item test

A standard mounting of specimen was carried out in accordance with EN 13823 as follows:

Thickness of board	21 mm
Mounting:	Standard mounting option b) in clause 5.2.2 of EN 13823.
Substrate:	30 mm A1 stone wool with a density of 57 kg/m^3 cf. EN 13238 mounted on 12.5 mm gypsum plasterboard behind cf. EN 13238.

Air gap:	42 mm ventilated air gap created by horizontally and vertically orientated 21 mm wooden battens.
Orientation:	Vertical.
Fixing means:	Mechanical fixed with screws to horizontal battens. The old nail holes were reused as screw holes to prevent nail holes being venting holes. Adjacent boards from the building were as much as possible kept adjacent in the test.

The specimens were assembled by DBI.

6. Conditioning

On 2025-10-13 the specimens were stored in a conditioning room with an atmosphere of relative humidity of 50 ± 5 % and a temperature of 23 ± 2 °C. The test specimens were kept in this room until the tests were performed.

7. Test method

The test was performed in accordance with:

EN 13823:2020 +A1:2022	Reaction to fire tests for building products - Building products excluding flooring exposed to the thermal attack by a single burning item

8. Test results

Date of test: 2025-11-13

Three tests were performed.

During the tests, the following measurements were made: Volume flow in the exhaust duct, production of carbon dioxide, concentration of oxygen, and production of light-obscuring smoke. Based on these measurements the rate of heat release and the rate of smoke production were calculated.

The graphs, enclosures 2-5, show for the three tests performed:

Enclosure 2
- Average Heat Release Rate $HRR_{av}(t)$
- Total Heat Release THR (t)

Enclosure 3
- Average Heat Release Rate per unit time [1000 x $HRR_{av}(t)/(t-300)$]
- $Figra_{0.2MJ}$-values

Enclosure 4
- $Figra_{0.4\ MJ}$-values
- Smoke Production Rate $SPR_{av}(t)$

Enclosure 5
- Total Smoke Production TSP(t)
- Smoke Production Rate per unit time [10000 x $SPR_{av}(t)/(t-300)$]

The test results are shown in the following table

	Test No. 1	Test No. 2	Test No. 3	**Mean Value**
FIGRA$_{0.2\ MJ}$ [W/s]	544.0	629.1	609.4	**594**
FIGRA$_{0.4\ MJ}$ [W/s]	544.0	629.1	609.4	**594**
THR$_{600s}$ [MJ]	13.15	15.4	11.61	**13.4**
SMOGRA [m^2/s^2]	10.4	2.5	5.9	**6**
TSP$_{600s}$ [m^2]	57.4	43.3	50.3	**50**
FDP$_{<10s}$ [Yes/No]	No	No	No	**-**
FDP$_{>10s}$ [Yes/No]	No	No	No	**-**
LFS<wing	Yes	Yes	Yes	-

FDP$_{f\ \ 10s}$: Flaming Droplets/Particles burning less than 10 seconds.
FDP$_{f>10s}$: Flaming Droplets/Particles burning more than 10 seconds.
LFS: Lateral Flame Spread on the long wing of the test specimen.

Test No. 1

Minutes:seconds	
00:00	Start of test
11:00	Burn-through, flames in cavity
15:00	Increasing flames in cavity
21:00	Gas burner stopped

Test No. 2

Minutes:seconds	
00:00	Start of test
15:00	Burn-through
18:00	Increasing flames in cavity
21:00	Gas burner stopped

Test No. 3

Minutes:seconds	
00:00	Start of test
11:30	Burn-through
15:00	Increasing flames in cavity
21:00	Gas burner stopped

Photographs of the test specimens show the effect of the damages, see enclosures 6-8

Enclosure 6: Test No. 1
Enclosure 7: Test No. 2
Enclosure 8: Test No. 3

9. Statement

The test results relate to the behaviour of the test specimens of a product under the particular conditions of the test; they are not intended to be the sole criterion for assessing the potential fire hazard of the product in use.

Boaz Petersen Reaction Fire Engineer	Martin Pauner M.Sc.

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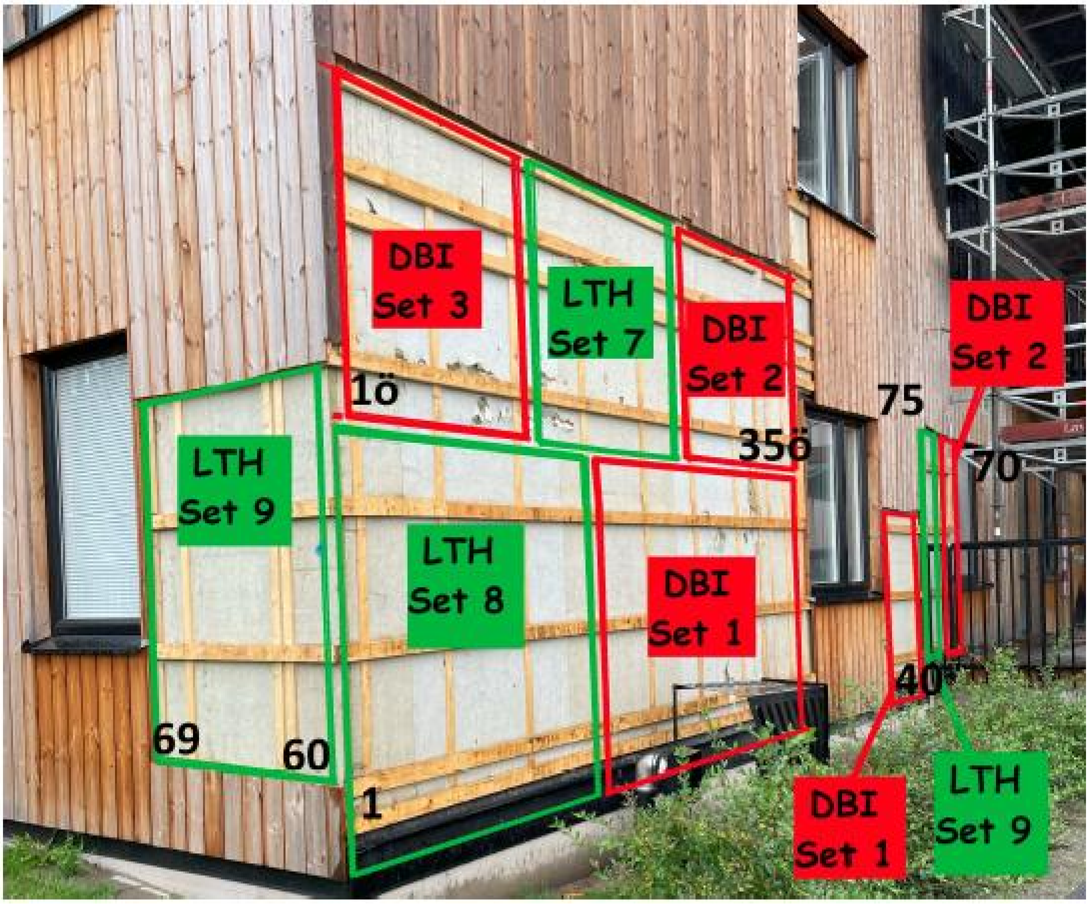
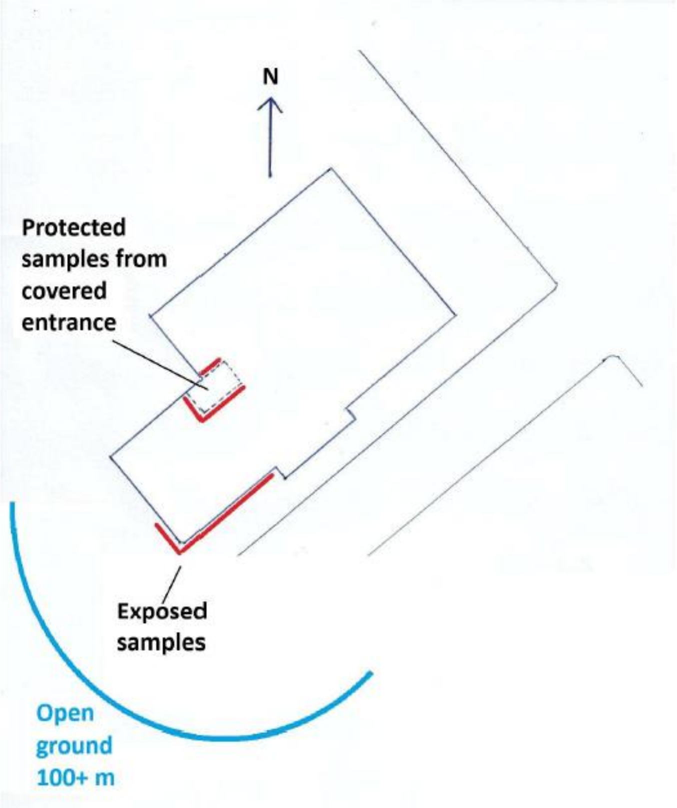
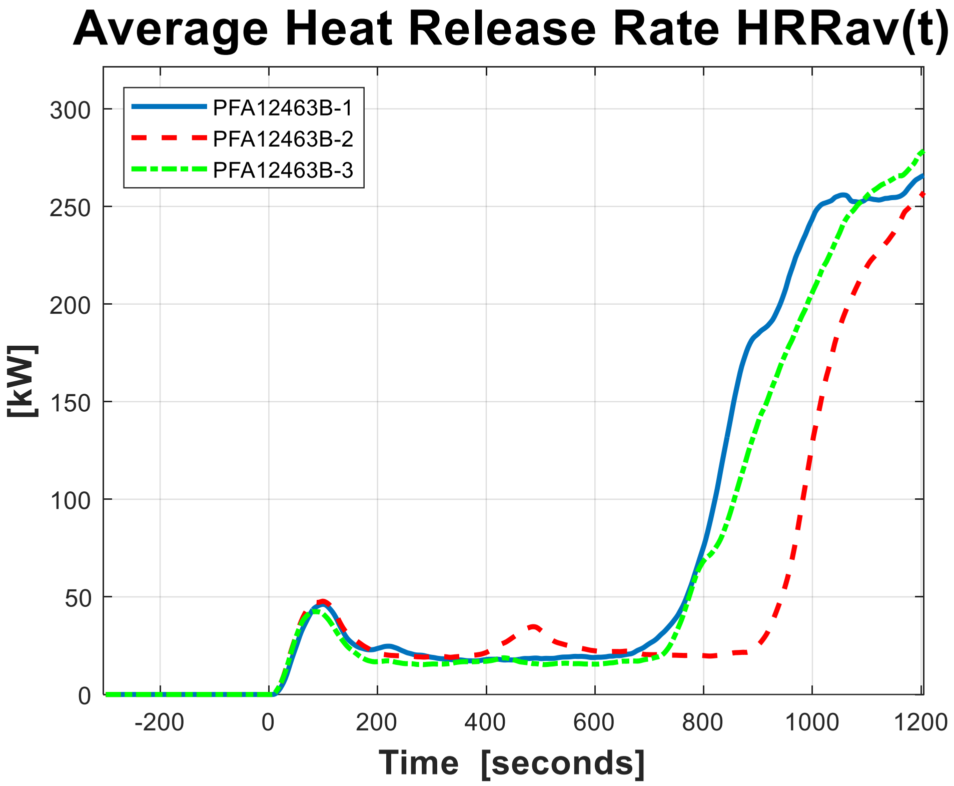
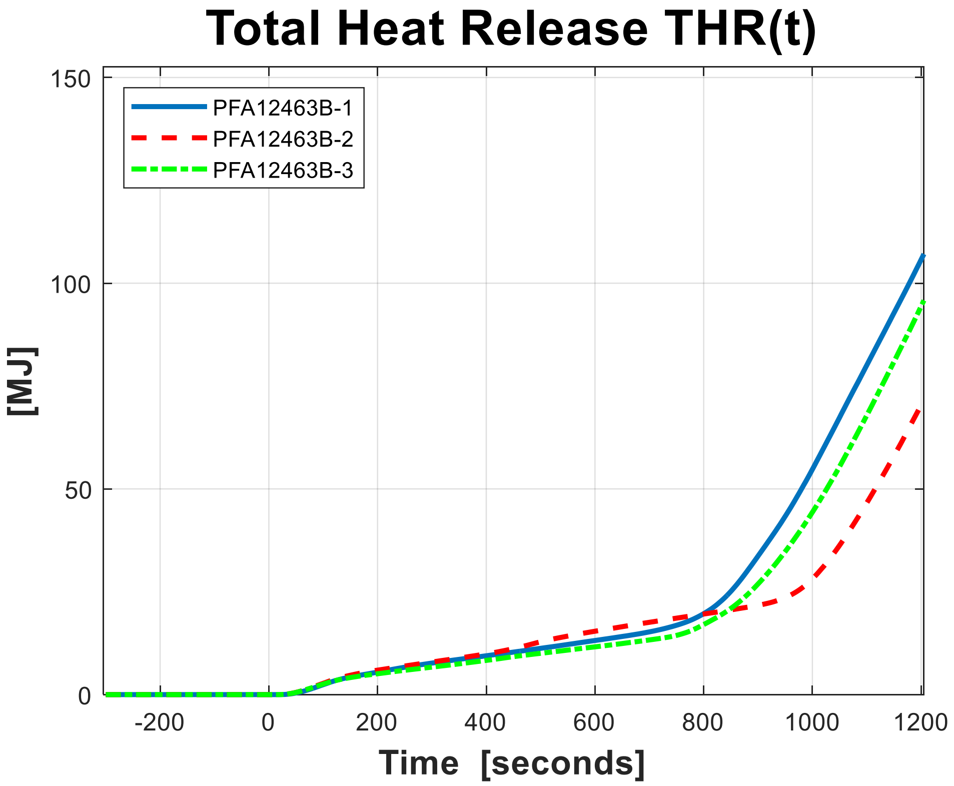
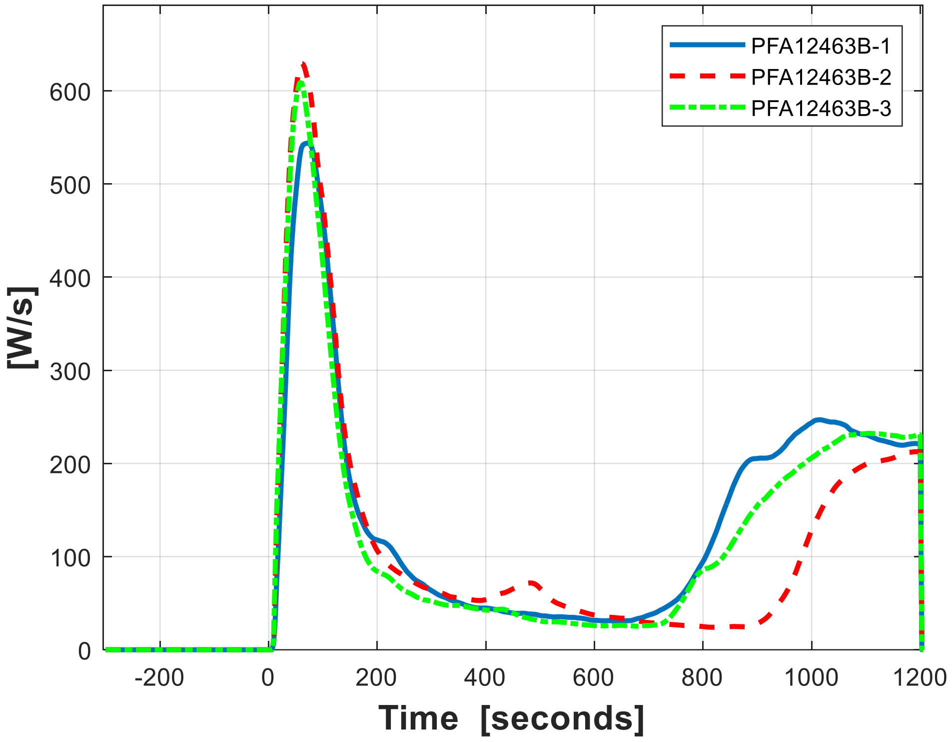

DBI Set 3
LTH Set 7
DBI Set 2
DBI Set 2
1ö
75
35ö
70
LTH Set 9
LTH Set 8
DBI Set 1
40
69
60
1
DBI Set 1
LTH Set 9


N
Protected samples from covered entrance
Exposed samples
Open ground 100+ m

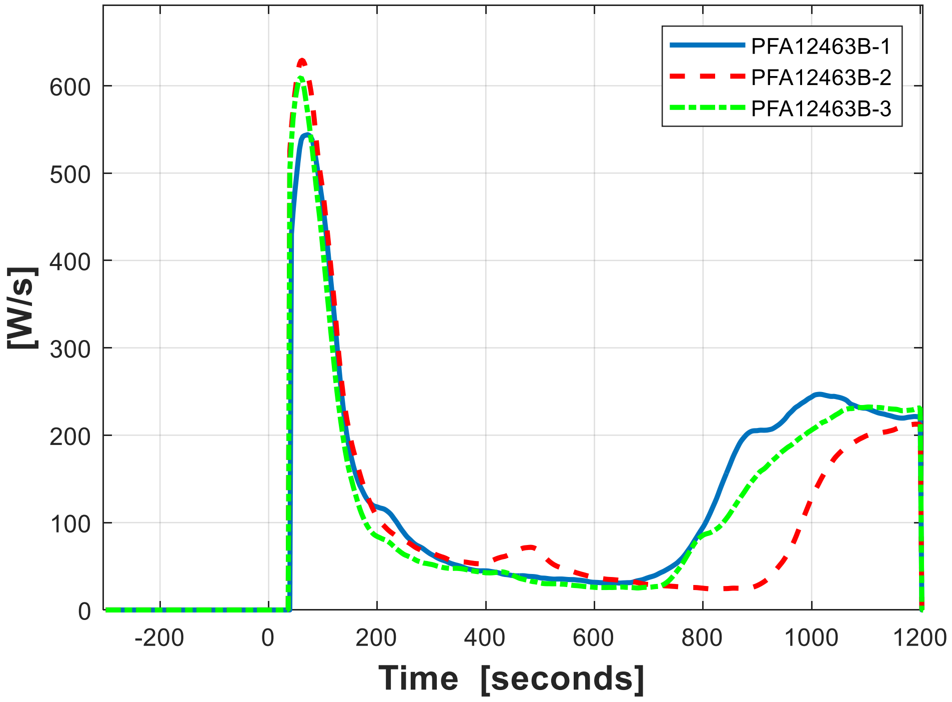

Average Heat Release Rate HRRav(t)
[kW]
0
50
100
150
200
250
300
-200
0
200
400
600
800
1000
1200
Time [seconds]
PFA12463B-1
PFA12463B-2
PFA12463B-3

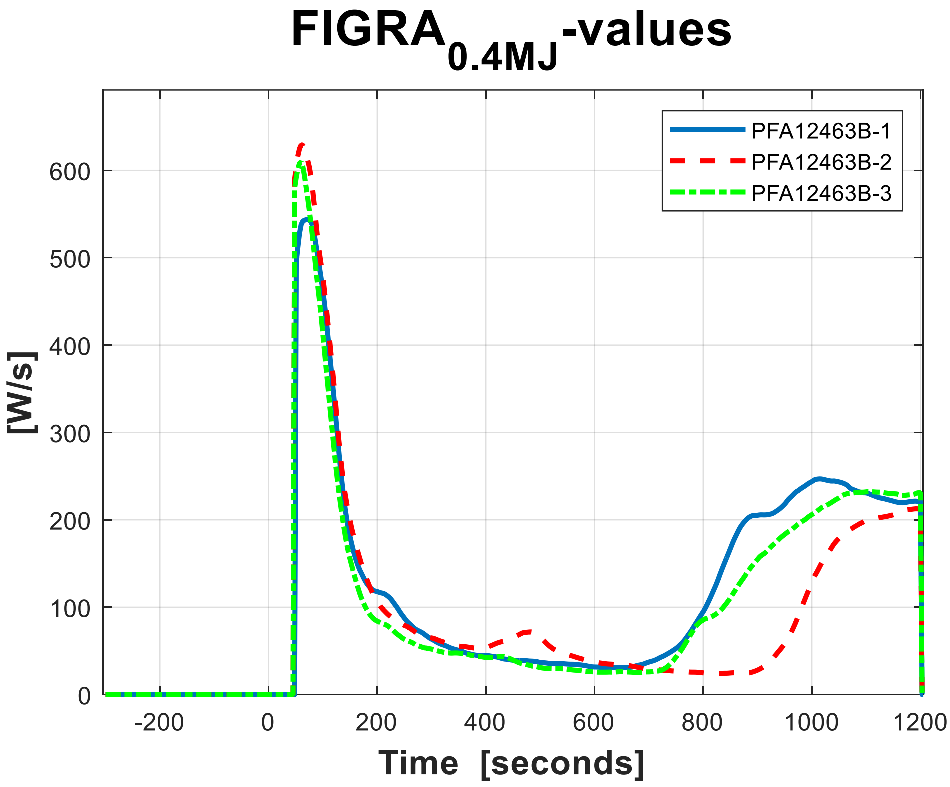

Total Heat Release THR(t)
[MJ]
0
50
100
150
-200
0
200
400
600
800
1000
1200
Time [seconds]
PFA12463B-1
PFA12463B-2
PFA12463B-3

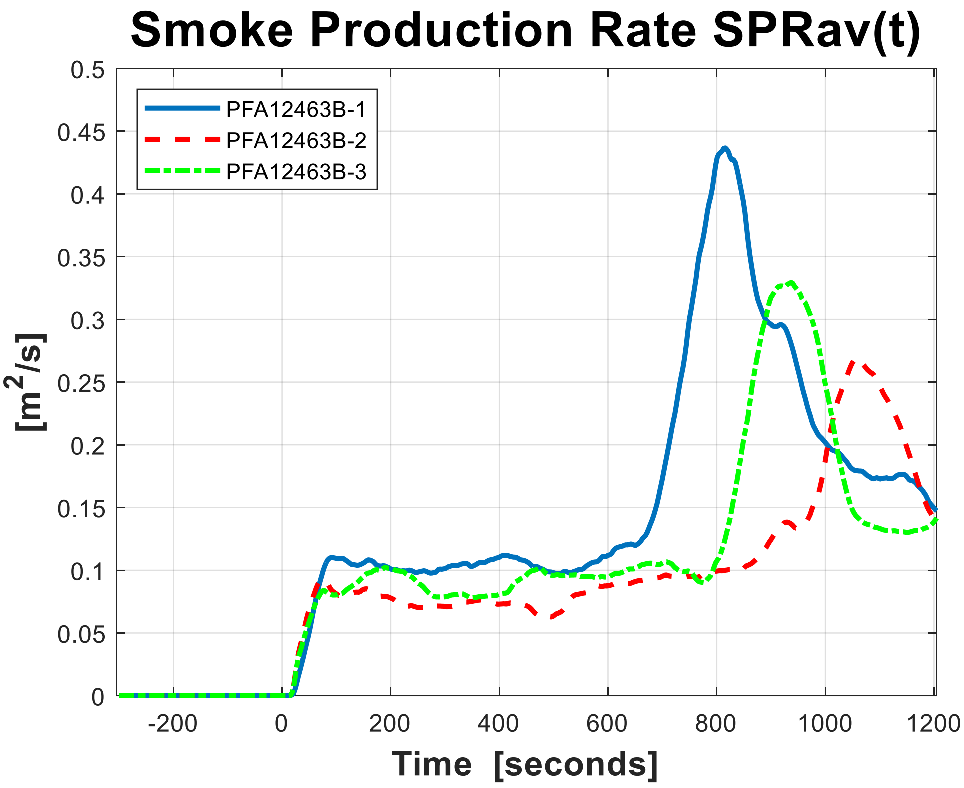
Average Heat Release Rate pr. unit time [1000*HRRav(t)/(t-300)]

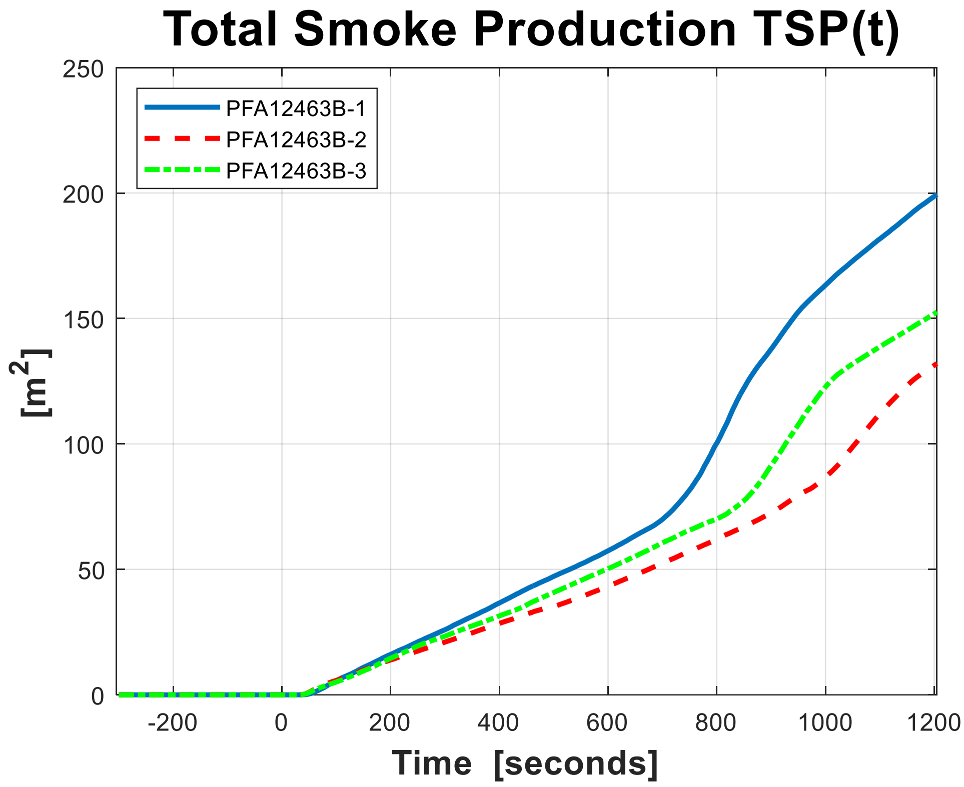


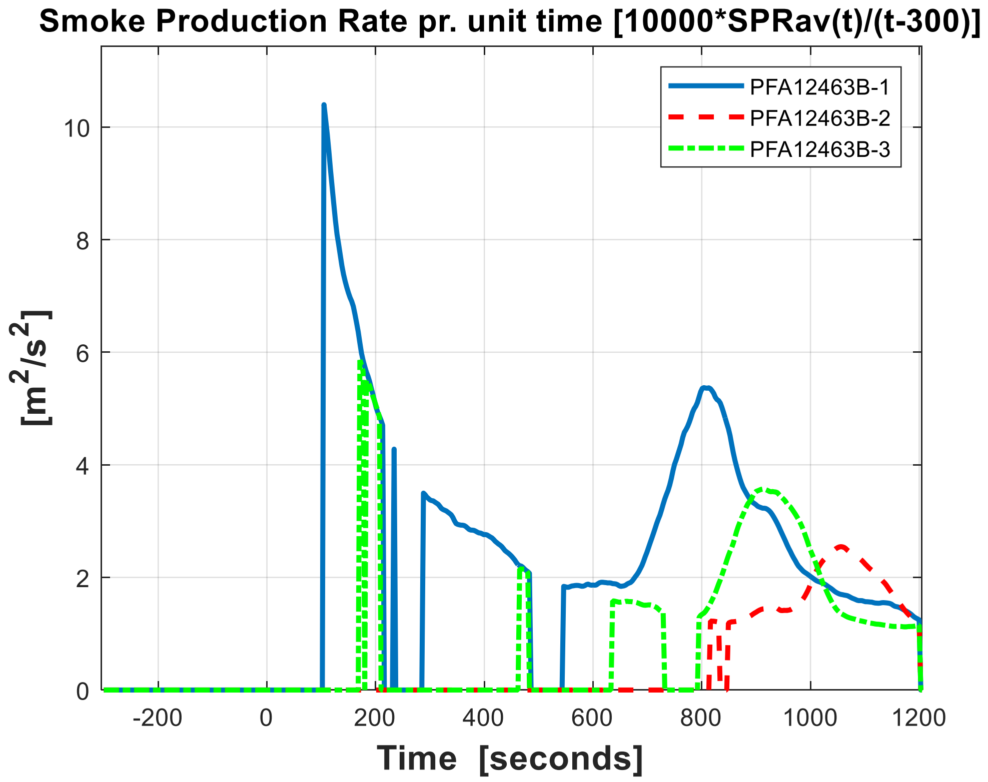
FIGRA$_{0.2MJ}$-values




FIGRA$_{0.4MJ}$-values
[W/s]
0
100
200
300
400
500
600
-200
0
200
400
600
800
1000
1200
Time [seconds]
PFA12463B-1
PFA12463B-2
PFA12463B-3


Smoke Production Rate SPRav(t)
[m^2/s]
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
-200
0
200
400
600
800
1000
1200
Time [seconds]
PFA12463B-1
PFA12463B-2
PFA12463B-3


Total Smoke Production TSP(t)
PFA12463B-1
PFA12463B-2
PFA12463B-3
[m^2]
250
200
150
100
50
0
-200
0
200
400
600
800
1000
1200
Time [seconds]


Smoke Production Rate pr. unit time [10000*SPRav(t)/(t-300)]
PFA12463B-1
PFA12463B-2
PFA12463B-3
[m^2/s^2]
10
8
6
4
2
0
-200
0
200
400
600
800
1000
1200
Time [seconds]

TEST NO. 1


Sag: PFA 12463B
Dato: 2025-11-13
Test: 1
13.11.2025 09:06


Sag: PFA 12463B
Dato: 2025-11-13
Test: 1
13.11.2025 09:06


Sag: PFA 12463B
Dato: 2025-11-13
1
13.11.2025 09:06


13.11.2025 09:57

TEST NO. 2


Sag: PFA 12463B
Dato: 2025-11-13
Test: 2
DBI
13.11.2025 11:31


Sag: PFA 12463B
Dato: 2025-11-13
Test: 2
DBI
13.11.2025 11:31


13.11.2025 12:00

TEST NO. 3


Sag: PFA 12463 B
Dato: 2025-11-13
Test: 3
13.11.2025 13:04


Sag: PFA 12463 B
Dato: 2025-11-13
Test: 3
13.11.2025 13:05


13.11.2025 13:35