INNOVATIVE AND COMPETITIVE CHEMICAL TECHNOLOGY FOR PRODUCTION OF FIRE RETARDANT WOOD BASED PANELS

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ABSTRACT

The demand for wood based panels with fire retardant properties has been increasing over the last years. Products showing such properties have an increased cost due to increased raw material prices and higher production cost. State and international standards of fire performance have promoted the production of boards that meet these requirements. Standards include flammability tests and in some cases toxicity tests of the gases released. In this paper the leading standards and regulations concerning fire performance are reviewed. The available technical solutions are presented. CHIMAR HELLAS, wood chemicals technology provider, has developed product technologies for the production of wood based panels with fire retarding properties. An overview of these products is given and data from lab scale tests are presented.

Keywords: Fire retardants, wood based panels, aminoplastic resins.

1. INTRODUCTION

Wood, which mainly consists of cellulose, lignin and hemicellulose, catches fire easily and burns vigorously with flame. As wood is used in furniture, home decoration and building materials, it will be essential to make wood products fire resistant/retardant. It is well known that materials made of wood can be treated with compounds containing nitrogen, phosphorus, halogens, and boron to improve their fire performance and accelerate the formation of a carbonized layer on the materials.

The field of flame retardants has witnessed in the last decade a vigorous development of new technologies and new products and materials to meet the challenge of the needs of wood industry[1-3]. An additional challenge was presented by the growing awareness of environmental issues and by the stiffening demands of consumer safety, which have been put forward by governments and public agencies. It became clear that new flame-retardant systems are needed to meet the new product and market demands. New regulations, standards and testing methods, as well as instruments, are essential for assessing and defining these needs. Such new regulations are indeed being introduced, particularly in recent years, in the European community. These new regulations present new challenges to the flame-retardants industry. It is not surprising therefore; that the number of scientists and technologists engaged in this field, as well as the number of universities and companies working with flame retardants, is steadily growing[4]. Every manufacturer needs to be aware of new regulations and the products and processes that will help in meeting them. New materials and formulations are rapidly changing the economic equation. Companies that adopt the latest technology will acquire a competitive advantage in providing their customers with the best balance of properties at the lowest possible price.

2. Fire safety classification systems

The general goal of fire safety regulations is to provide life safety and sufficient protection to property in case of fire[5-6]. To achieve this goal, requirements for structures, building materials, evacuation arrangements, and relative locations of buildings are set to define how buildings should be designed and constructed for their respective use. The requirements are related to prevention of ignition and fire spread, limitation of fire growth, evacuation provision, load-bearing capacity of structures, and prevention of spread of fire between buildings.

Traditionally, fire testing and classification systems are developed individually in each country, based on its specific regulatory background and circumstances. A wide variety of requirements has thus been drawn up. However, as a result of the development of transportation facilities and international trade, the harmonization of standards and fire classification systems has become an issue of increasing importance.

Fire classification systems and building codes in general, can be divided into prescriptive and performance-based codes on the basis of the formulation of the requirements. The current trend of fire safety regulations is to proceed from prescriptive criteria towards performance-based approaches. However, prescriptive requirements will remain as an acceptable option for verifying fire safety, and the importance of fire testing will not decrease as a result of the development of performance-based fire codes.

Fire safety classifications systems in the EU

In the European Union (EU), the development of the Euroclass system is approaching its completion after work of roughly ten years. The Commission Decision 94/611/EC implementing Article 20 of Directive 89/106/EEC on construction products in the field of fire safety set in place the background to the harmonization process. The decision on the classification of the reaction-to-fire performance of construction products was published in February 2000[7-14,17].

The Euroclass decisions include a classification system for construction products and define the test methods according to which the classification is determined. The Euroclass system requires that the member countries of the EU include the test methods and the classification in their legislation. The required fire performance for various purposes of use of construction products will still be decided nationally, but the requirements will be expressed in terms of harmonized standards.

The European classes of reaction-to-fire performance for construction products excluding floorings are based on four fire test methods: the non-combustibility test prEN ISO 1182, the gross calorific potential test prEN ISO 1716, the single burning item (SBI) test prEN 13823, and the ignitability test prEN ISO 11925-2. The same test methods, excluding the SBI test, are used for floorings with the addition of the radiant panel test prEN ISO 9239-1. The details of specimen conditioning and substrate selection are given in EN 13238, and the classification procedure is described in prEN 13501-1.

Structural design rules, including fire design, are provided in Structural Eurocodes for the use of the member countries of the EU. The objective of the Eurocode programme initiated by the Commission of the European Community is to establish a set of harmonized technical rules for the design of building and civil engineering works. These rules would at first serve as an alternative to the national rules in force in the member states and ultimately replace them.

Many of the member countries of the European Union (EU) have adopted the harmonized Euroclass system of reaction to fire performance of building products. In the Euroclass system, building products are divided to seven classes on the basis of their reaction-to-fire properties. The performance description and the fire scenario for each class are presented in Table 1 according to the main principles used in the development of the Euroclass system. Table 1 includes some examples of typical building products used in walls and ceilings in each Euroclass. It is noted that certain materials containing only a very small amount of organic compounds are deemed to satisfy the requirements of class A1 without testing. Examples of such materials are concrete, steel, stone and ceramics. The decision on the classification of the reaction to fire performance of construction products was made in February 2000. The test methods and classification criteria are presented in Table 2 for construction products excluding floorings. The highest possible European class for fire retardant wood products is class B.

The European fire classification system does not include requirements for the combustion toxicity of construction products. However, the combustion toxicity and environmental aspects of industrial products are currently of growing interest and concern. The questions of which fire products, and in what concentrations, are emitted from building materials when they burn are increasingly important. There is also an increasing need for regulatory requirements.

Table 1: Indicative performance descriptions and fire scenarios for Euroclasses[18]

Class	Performance description	Fire scenario and heat attack		Examples of products
A1	No contribution to fire	Fully developed fire in a room	At least 60 kW/m^2	Products of natural stone, concrete, bricks, ceramic, glass, steel and many metallic products
A2	"	"	"	Products similar to those of class A1, including small amounts of organic compounds
B	Very limited contribution to fire	Single burning item in a room	40 kW/m^2 on a limited area	Gypsum boards with different (thin) surface linings Fire retardant wood products
C	Limited contribution to fire	"	"	Phenolic foam, gypsum boards with different surface linings (thicker than in class B)
D	Acceptable contribution to fire	"	"	Wood products with thickness ≥ about 10 mm and density ≥ about 400 kg/m^3 (depending on end use)
E	"	Small flame attack	Flame height of 20 mm	Low density fibreboard, plastic based insulation products
F	No performance requirements	–	–	Products not tested (no requirements)

Table 2: Classes of reaction to fire performance for construction products excluding floorings[18]

Product	EN product standard	End use condition [6]	Min. density kg/m^3	Min. thickness mm	Class [7] (excl. floorings)	Class [8] (flooring
Cement-bonded particleboard [1]	EN 634-2	without an air gap behind the panel	1000	10	B-s1, d0	B_{fl}-s1
Fibreboard, hard [1]	EN 622-2	without an air gap behind the wood-based panel	900	6	D-s2, d0	D_{fl}-s1
Fibreboard, hard [3]	EN 622-2	with a closed air gap not more than 22 mm behind the wood-based panel	900	6	D-s2, d2	-
Particleboard [1, 2, 5]	EN 312	without an air gap behind the wood-based panel	600	9	D-s2, d0	D_{fl}-s1
Fibreboard, hard and medium [1, 2, 5]	EN 622-2 EN 622-3					
MDF [1, 2, 5]	EN 622-5					
OSB [1, 2, 5]	EN 300					
Plywood [1, 2, 5]	EN 636	-“-	400	9	D-s2, d0	D_{fl}-s1
Solid wood panel [1, 2, 5]	EN 13 353			12		
Flaxboard [1, 2, 5]	EN 15 197	-“-	450	15	D-s2, d0	D_{fl}-s1
Particleboard [3, 5]	EN 312	with a closed or an open air gap not more than 22 mm behind the wood-based panel	600	9	D-s2, d2	-
Fibreboard, hard and medium [3, 5]	EN 622-2 EN 622-3					
MDF [3, 5]	EN 622-5					
OSB [3, 5]	EN 300					
Plywood [3, 5]	EN 636	-“-	400	9	D-s2, d2	-
Solid wood panel [3, 5]	EN 13 353			12		
Particleboard [4, 5]	EN 312	with a closed air gap behind the wood-based panel	600	15	D-s2, d0	D_{fl}-s1
Fibreboard, medium [4, 5]	EN 622-3					
MDF [4, 5]	EN 622-5					
OSB [4, 5]	EN 300					
Plywood [4, 5]	EN 636	-“-	400	15	D-s2, d1	D_{fl}-s1
Solid wood panel [4, 5]	EN 13 353				D-s2, d0	
Flaxboard [4, 5]	EN 15 197	-“-	450	15	D-s2, d0	D_{fl}-s1
Particleboard [4, 5]	EN 312	with an open air gap behind the wood-based panel	600	18	D-s2, d0	D_{fl}-s1
Fibreboard, medium [4, 5]	EN 622-3					
MDF [4, 5]	EN 622-5					
OSB [4, 5]	EN 300					
Plywood [4, 5,]	EN 636	-“-	400	18	D-s2, d0	D_{fl}-s1
Solid wood panel [4, 5]	EN 13 353					
Flaxboard [4, 5]	EN 15 197	-“-	450	18	D-s2, d0	D_{fl}-s1
Particleboard [5]	EN 312	any	600	3	E	E_{fl}
OSB [5]	EN 300					
MDF [5]	EN 622-5	-“-	400	3	E	E_{fl}
			250	9	E	E_{fl}
Plywood [5]	EN 636	-“-	400	3	E	E_{fl}
Fibreboard, hard [5]	EN 622-2	-“-	900	3	E	E_{fl}
Fibreboard, medium [5]	EN 622-3	-“-	400	9	E	E_{fl}
Fibreboard, soft	EN 622-4	-“-	250	9	E	E_{fl}

1 Mounted without an air gap directly against class A1 or A2-s1,d0 products with minimum density 10 kg/m3 or at least class D-s2,d2 products with minimum density 400 kg/m3.

2 A substrate of cellulose insulation material of at least class E may be included if mounted directly against the wood-based panel, but not for floorings

3 Mounted with an air gap behind. The reverse face of the cavity shall be at least class A2-s1, d0 products with minimum density 10 kg/m3.

4 Mounted with an air gap behind. The reverse face of the cavity shall be at least class D-s2, d2 products with minimum density 400 kg/m3.

5 Veneered, phenol- and melamine-faced panels are included for class excl. floorings.

6 A vapour barrier with a thickness up to 0,4 mm and a mass up to 200 g/m2 can be mounted in between the wood-based panel and a substrate if there are no air gaps in between.

7 Class as provided for in Table 1 of the Annex to Decision 2000/147/EC.

8 Class as provided for in Table 2 of the Annex to Decision 2000/147/EC.

2.2Fire safety testing methods on wood based panels (EU)

2.1.1 Non combustibility test

The purpose of the non-combustibility test EN ISO 1182 is to identify the products that will not, or significantly not, contribute to a fire. A test specimen of cylindrical shape is inserted into a vertical tube furnace with a temperature of about 750°C. Temperature changes due to the possible burning of the specimen are monitored with thermocouples. The flaming time of the specimen is visually observed. After the test, the mass loss of the specimen is determined. The quantities used in the European classification are the temperature rise of the furnace (ΔT), the mass loss of the specimen (Δm), and the time of sustained flaming of the specimen (t_f).

2.1.2 Gross calorific potential test

The gross calorific potential test EN ISO 1716[8] determines the potential maximum total heat release of a product when burned completely. A powdery test specimen is ignited in pressurized oxygen atmosphere inside a closed steel cylinder (calorimetric bomb) surrounded by water jacket. The temperature rise of water during burning is measured. The gross calorific potential is calculated on the basis of the temperature rise, specimen mass, and correction factors related to the specific test arrangement used. The classification parameter of the method is the gross calorific potential (PCS) measured in MJ/kg or MJ/m^2 depending on the features of the product and its components.

2.1.3 Single burning item test

The SBI test[9] is a relatively new fire test method developed specially for the Euroclass system. The test is based on a fire scenario of a single burning item, e.g. a wastebasket, located in a corner between two walls covered with the lining material to be tested. The SBI test is used for construction products excluding floorings.

The classification parameters of the SBI test are fire growth rate index (FIGRA), lateral flame spread (LFS), and total heat release (THR_{600s}). Additional classification parameters are defined for smoke production as smoke growth rate index (SMOGRA) and total smoke production (TSP_{600s}), and for flaming droplets and particles according to their occurrence during the first 600 seconds of the test.

2.1.4 Ignitability test

In the ignitability test EN ISO 11925-2[10], the specimen is subjected to direct impingement of a small flame. The test specimen of size 250 mm × 90 mm is attached vertically on a U shaped specimen holder. A propane gas flame with a height of 20 mm is brought into contact with the specimen at an angle of 45 °. The application point is either 40 mm above the bottom edge of the surface centreline (surface exposure) or at the centre of the width of the bottom edge (edge exposure). Filter paper is placed beneath the specimen holder to monitor the falling of flaming debris. The classification criteria are based on observations whether the flame spread (Fs) reaches 150 mm within a given time and whether the filter paper below the specimen ignites due to flaming debris. In addition, the occurrence and duration of flaming and glowing are observed.

Fire safety classification systems in USA and Japan

In Japan, the fire safety regulations are included in the Building Standard Law (BSL)[16] consisting of General Provisions, Building Codes and Zoning Codes. After its establishment in 1950, the BSL has undergone several revisions. Concerning fire safety, the latest reform emphasized the introduction of internationally accepted fire test methods and the possibility of performance based fire regulations. The law to amend the BSL was issued in June 1998. The Enforcement Order and Notifications defining the details of the new fire classification system went into effect in June 2000. In the new Japanese fire classification system, the main test method is the cone calorimeter test ISO 5660-1, applicable to all classes of so-called fire preventive materials.

USA fire standards based on classifications of building type and occupancy, the codes set limits on the areas and heights of buildings. Major building codes generally recognize five classifications of construction based on types of materials and required fire resistance ratings. The two classifications known as fire resistant construction (Type I) and non-combustible construction (Type II) basically restrict the construction to non-combustible materials. Wood is permitted to be used more liberally in the other three classifications, which are ordinary (Type III), heavy timber (Type IV), and light-frame (Type V). Numerous flame spread tests are used, but the one cited by building codes is ASTM E84, the “25-ft tunnel” test. In this test method, the 508-mm-wide, 7.32-m-long specimen completes the top of the tunnel furnace.

3. Fire retardant systems

General

The choice of fire retardant chemicals is an important factor for the final properties of the end product. Fire retardant wood products are so marginal for the use of fire retardants, but it is still very important for wood product producers to emphasize that the fire retardants used are different from those used by the plastic industry.
Chemicals often used in fire retardant formulations for treating wood are [18-21] : ammonium polyphosphate, di- and monoammonium phosphate, ammonium sulphate, ammonium sulphamate, phosphoric acid, borax, boric acid, boric oxide, borax pentahydrate, anhydrous borax, sodium perborate tetrahydrate, dicyandiamide, melamine, urea, aluminium trihydroxide, melamine phosphate, guanyl phosphate, melamine, formaldehyde resins.

Present and Future

At present, the level of development of wood products with improved fire performance is not high enough for their extensive utilization[18]. The main problem is the long-term durability of fire retardant treatments in exterior applications where weather exposure may leach out the fire retardant chemicals. In interior use, the most important durability issue is the permanence of the aesthetic appearance that cannot always be predicted or guaranteed. Many traditional fire retardants are hygroscopic that might cause e.g. salt crystallization on surfaces also at interior applications. Even though some wood products with improved fire performance exhibit excellent fire properties, examples of products with hardly any benefit compared to ordinary wood also exist. The main reason is the vast range of variation related to the manufacture of fire retarded wood products: the properties of wood can vary notably even within a species, e.g. the permeability that mainly influences the possibility to impregnate the wood. The product properties can therefore vary from a batch to another. Another problem is the selection of an unsuitable product for a certain application. The financial aspects of high fire performance wood products are greatly affected by general trends in the society and the resulting needs at present and in the future. In most cases, the additional costs outweigh the fire safety benefits. The current trend of fire safety systems is to proceed from prescriptive criteria towards performance-based approach. This development will probably facilitate the use of high fire performance wood products. Performance-based fire design increases the freedom of architects, designers and constructors to choose materials and structures, as far as the solutions meet the fire safety objectives defined for the application. Therefore, high fire performance wood products have equal opportunities with other construction products.

Fire retardant system with improved compatibility

Traditional halogen-containing flame retardants have good fire performance. However, their use is restricted due to the release of toxic substances during their thermal decomposition as well as due to the difficulty in recycling of the corresponding flame retardant wood panels. Therefore, at present, halogen-free products have received increased attention in replacing those halogen-containing ones. Among the existing halogen-free ones, a relatively new flame retardant for wood products is examined in this work. Its components are mainly guanyl urea phosphate (GUP) and boric acid (BA), which are generally environmentally acceptable; relatively low in toxicity; relatively non-corrosive and non-hygroscopic; and which can be stored for relatively longer periods of time.
The novelty which the described flame retardant system exhibit, is the preparation of a flame retardant mixture with improved compatibility with the classical aminoplastic resins used for the preparation of the wood panels. In order to improve the compatibility of the flame retardant substance, a mixture of aqueous GUP solution was mixed with appropriately modified melamine formaldehyde resin.

3.3.1 Experimental Part

The preparation procedure of the aqueous GUP solution which was followed have been described else where[22]. The modified melamine resin (MFS) used in this work is a high water tolerance melamine formaldehyde resin (commercial product of Chimar Hellas S.A.). The flame retardant mixture was prepared according to the following formulation (Table 3).

Table 3: Flame retardant mixture formulation

Type	Quantity
FR: GUP+Boric acid 30% in Water	1500g
Resin: MFS ~40% in Water	500g
NaOH 50% in Water	80g

The flame retardant mixture was subsequently dried in spray drying lab device in order to obtain the fire retardant substance in solid form (Table 4).

Table 4: Spray drying parameters

Experimental Device	BUCHI Mini Spray Dryer B-290
Parameters	Inlet Temperature: 165°C
	Outlet Temperature: 98°C
	Pump Rate: 18% (250ml in 28min)
Final Product: FR Fine Powder	

3.3.2 Results and Discussion

3.3.2.1 Flame Retardant characterization

The solid flame retardant substance was characterized with the aim of the Thermogravimetric Analysis (TGA) and its microstructure was observed with Transmission Electron Microscopy (TEM). The results of the TGA analysis are depicted in Figure 1.
From the TGA curve, it was found that GUP can accelerate dehydration and carbonization resulting in the formation of less flammable products and correspondingly more char[[22,23]]. Meanwhile, boric acid relatively increases thermal stabilization, which suppresses the mass loss. The FR includes simultaneously GUP, boric acid and melamine, the synergistic effect of which results in more char and less flammable volatile products and consequently in good fire performance.

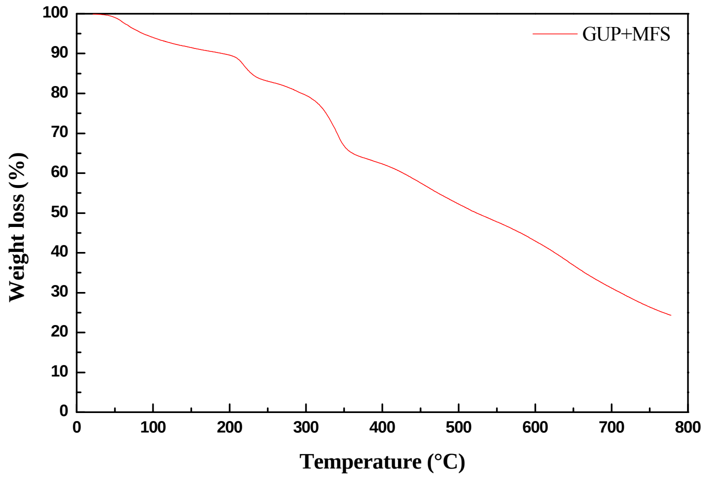

Figure 1: TGA curve of the flame retardant substance.

The TEM picture (Figure 2) depicts the mixture of the melamine formaldehyde resin with the FR substance.

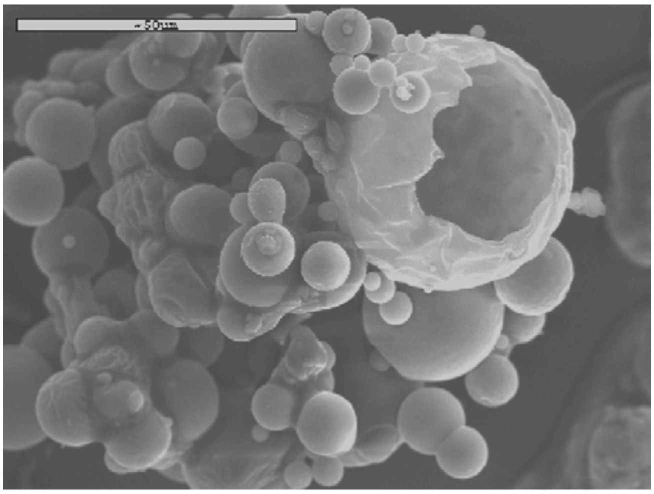

Figure 2: TEM image of the flame retardant substance.

3.3.2.2 FR Lab board production

The solid flame retardant mixture was tested in the production of FR lab boards. The percentage of the solid FR was 15% solid FR in dry chips. For the lab board production, the addition of the solid FR was performed on the dry chips with a holding period of 2 min of agitation followed by the addition of the glue mix. The resin used in the glue mix formulation was a MUF resin with 20% melamine percent. Furthermore the FR substance was tested against Chimar's standard commercial non halogen fire retardant product (Pyro-SM) based on phosphate salts. The full details of the lab board production are depicted in Table 5.

Table 5: Pressing details of the lab board production

Press Factor (s/mm): 12
Resin Loading (% dry on dry wood): 12
FR content (% on dry wood): 15
Hardener Level (% dry on dry resin): 3
Wax Level (% on dry wood): 0.5
Press Temperature: 200^{o}C

3.3.2.3 FR Lab board properties

The fire tests were performed in the cone calorimeter. Measurements of the rate of heat release parameters were made according to ISO-5660-1 and smoke release parameters according to ISO-5660-2. The tests were carried out at horizontal orientation. A retainer frame was used to protect the edges of the specimen. The incident heat flux was 50 kW/m^2. The dimensions of the specimens were 100mm x 100mm. The results of the fire tests are depicted in Table 6.

Table 6: Cone calorimeter test data for lab board (Test 1→ standard MUF board, Test 2→new FR formulation board, C→ Test 3 Pyro-SM board)

		Test 1		Average	Test 2		Average	Test 3		Average
		1	2		1	2		1	2	
Thickness	mm	17,2	17,5	17,4	17,7	17,7	17,7	17,9	17,7	17,8
Weight	G	127,0	129,1	128,1	127,2	129,2	128,2	131,3	129,7	130,5
Density	kg/m3	734	733	734	714	724	719	731	730	731
Time to ignition	S	27	27	27	32	33	33	32	32	32
RHR_{60}	kW/m^2	152	149	151	87	70	79	136	131	134
RHR_{80}	kW/m^2	133	127	130	64	59	62	108	100	104
RHR_{300}	kW/m^2	119	115	117	49	49	49	97	89	93
RHR_{max}	kW/m^2	186	173	180	104	101	103	155	149	152
THR	MJ/m^2	117,6	111,7	114,7	55,3	57,1	56,2	108,1	97,5	102,8
EHC	MJ/kg	11,0	10,3	10,7	6,1	6,2	6,2	10,5	9,6	10,1
Mass loss	g	94,5	95,5	95,0	79,9	80,9	80,4	90,5	89,1	89,8
Burning Period	s	1030	1030	1030	1205	1245	1225	1205	1165	1185
SEA	m^2/kg	65	52	59	64	54	59	34	30	32
RSP	m^2/s	$6,3 *10^{-3}$	$4,8*10^{-3}$	$5,6*10^{-3}$	$5,2*10^{-3}$	$3,5*10^{-3}$	$4 4*10^{-3}$	$2 5 *10^{-3}$	$2,3*10^{-3}$	$2 4*10^{-3}$
TSP	m^2	6,7	5,0	5,9	5,8	4,4	5,1	3,1	2,7	2,9

Furthermore the Cone calorimeter test data were used to predict the time to flashover in the full scale room corner test according to the Tratek model[24]. The possible Euroclass (EN 13501-1) for building products is also predicted (Table 7).

From the fire performance tests it is concluded that the flame retardant system presented in this paper is competitive to the commercial product. However, a higher loading of the flame retardant system could improve further the fire retardant properties of the boards. Chimar's commercial FR product (Pyro-SM) has shown very good flame retardant properties, considering that with an amount of 15% w/w (based on dry chips weight), the lab boards have achieved the highest possible European class for fire retardant wood products.

Table 7: Prediction of time to flashover and Euroclass

Product	**Time to flashover (R/C) Predicted (min)**	**Euroclass predicted**
Particle board	3,2 and 3,3	**D**
FRT Particle board 1 with Pyro-SM™	7,9 and 8,1	**B**
FRT Particle board 2 with the new flame retardant substance	3,9 and 4,3	**C**

As far as the mechanical properties and emission potential of the boards are concerned the following tests were made: Internal bond strength according to EN-319, modulus of rapture according to EN-310, thickness swelling according to EN-317 and formaldehyde content with the Perforator method EN-120. The results of these tests are depicted in table 8.

Table 8: Lab board mechanical and emission properties

	1	2	3
Resin	**MUF**	**MUF + Pyro-SM**	**MUF + new FR**
Density	680		
Press time (s)	12	12	12
Resin factor (%)	12	12	12
Board moisture (%)	11.37	11.79	12.39
Internal Bond (N/mm^2)	1.00	0.76	0.81
Thickness swelling 24h (%)	9.90	14.27	13.08
Modulus of rapture (N/mm^2)	22.27	14.71	14.1
Formaldehyde emission (Perforator method)	11.79	1.78	1.84

The results from the mechanical tests indicate that the new FR formulation exhibit superior mechanical strength in comparison with the commercial FR board. This behaviour could be attributed due to the presence of the small amount of the melamine formaldehyde resin in the fire retardant formulation. Furthermore both FR substances act also as formaldehyde scavengers, resulting in boards with formaldehyde emission potential of the F^{****} level.

4. Conclusions

The flame retardant treatment significantly improves the fire safety of wood products by reducing its heat contribution to a fire. For applications where a higher level of fire safety is desirable or necessary, fire-retardant-treated wood products provide a viable alternative to traditional non-combustible materials. In this work some key aspects of the fire classification system and the methods used for the determination of the flame retardant properties have been briefly discussed.

Furthermore some preliminary results of a new FR formulation with improved compatibility towards the aminoplastic resins were presented. The basis of this new FR formulation is the non toxic FR mixture of guanyl urea phosphate, boric acid and modified melamine formaldehyde resin.

The new formulation has been tested in lab scale boards against a commercial product provided by Chimar Hellas S.A. The flame retardant, mechanical and formaldehyde emission properties were in accordance to the ones of the commercial FR boards.

5. References

1. LeVan SL. 1984. Chemistry of fire retardancy. The chemistry of solid wood. In: Rowell R (ed) Advances in chemistry series 207. American Chemical Society.
2. Lyons JW. 1970. The chemistry and use of fire retardants. Wiley Interscience, New York.
3. LeVan, S. L. & Winandy, J. E. 1990. Effects of fireretardant treatments on wood strength: A review. Wood and Fiber Science. 22: 113-131.
4. Wang Q-W, Li S-J, Cui Y-Zh. 1999. The fire retardancy of FRW fire retardant for wood. J Northeast Forestry Univ. 26:31–33

5. Östman, B. & Rydholm, D. 2002. National fire regulations in relation to the use of wood in European and some other countries. Stockholm: Swedish Institute for Wood Technology Research.
6. Östman, B., Voss, A., Hughes, A., Hovde, P. J. & Grexa, O. 2001. Durability of fire retardant treated wood at humid and exterior conditions. Review of literature. Fire and Materials. 25, 3:95-104.
7. prEN ISO 1182. Reaction to fire tests for building products – Noncombustibility test (ISO/FDIS 1182:2000). Brussels: European Committee for Standardization, December 2000. 31 p.
8. prEN ISO 1716. Reaction to fire tests for building products – Determination of the heat of combustion (ISO/FDIS 1716:2001). Brussels: European Committee for Standardization, October 2001. 26 p.
9. prEN 13823. Reaction to fire tests for building products – Building products excluding floorings exposed to the thermal attack by a single burning item. Brussels: European Committee for Standardization, September 2001. 95 p.
10. prEN ISO 11925-2. Reaction-to-fire tests – Ignitability of building products subjected to direct impingement of flame – Part 2: Single-flame source test. Brussels: European Committee for Standardization, December 2000. 28 p.
11. prEN ISO 9239-1. Reaction to fire tests for floorings – Part 1: Determination of the burning behaviour using a radiant heat source (ISO/FDIS 9239-1:2000). Brussels: European Committee for Standardization, January 2001. 26 p.
12. EN 13238. Reaction to fire tests for building products – Conditioning procedures and general rules for selection of substrates. Brussels: European Committee for Standardization, May 2001. 9 p.
13. prEN 13501-1. Fire classification of construction products and building elements – Part 1: Classification using test data from reaction to fire tests. Brussels: European Committee for Standardization, September 2001. 40 p.
14. ENV 1991-2-2. Eurocode 1: Basis of design and actions on structures. Part 2-2: Actions on structures exposed to fire. Brussels: European Committee for Standardization, 1994. 55 p.
15. Introduction to the Building Standard Law. 3rd edition. Tokyo: The Building Center of Japan, May 1995. 41 p. ISBN 4-88910-072-5
16. ISO 5660-1. Fire tests − Reaction to fire − Part 1: Rate of heat release from building products (Cone calorimeter method). Geneva: International Organization for Standardization, 1993. 31 p.
17. ISO/TR 13387-1. Fire safety engineering − Part 1: Application of fire performance concepts to design objectives. Geneva: International Organization for Standardization, 1999. 52 p.
18. Tuula Hakkarainen, Esko Mikkola, Birgit Östman, Lazaros Tsantaridis, Harry Brumer, Peter Piispanen, 2005, Innovative eco-efficient high fire performance wood products for demanding applications, InnoFireWood STATE-OF-THE-ART REPORT.
19. Östman, B. A.L. 1984. Fire retardant woodfiber insulating board. Journal of Fire Sciences. 2:454-467.
20. 17. FireRetard.com. 2003. Case Studies [web page]. [quoted 23.6.2004]. Available: http://www.fireretard.com/casestudies.html.
21. Porter, D., Metcalfe, E. & Thomas, M. J. K. , 2000 Nanocomposite fire retardants – A review. Fire and Materials. 24:45-52.
22. Ming Gao, Jincheng Niu and Rongjie Yang, 2006, Synergism of GUP and BA Characterized by Cone Calorimetry and TG, Journal of Fire Sciences, 24: 499.

23. Kemp, R. B. 1999. Handbook of Thermal Analysis and Calorimetry; Elsevier Science BV. Vol. 4, Chapter 14.
24. Birgit A.-L. Östman, Lazaros D. Tsantaridis, 1994, Correlation between cone calorimeter data and time to flashover in the room fire test, Fire and Materials. 18: 205-209.