



Fire resistance properties

The fire resistance properties of ARPRO can be crucial depending on application.

Below is the set of technical information that is covered in this document.

1. Characteristics of ARPRO Black vs. ARPRO FR
2. Burn rate and fire class of ARPRO in different applications:
 - A. Automotive: ISO 3795
 - B. Electronics:
 - i. UL 94 (ISO 9772)
 - ii. Glow wire flammability index
 - iii. Needle flame test
 - C. Building: Euroclasses
 - D. Aircraft: CS 25
 - E. Toys: ISO 8124-2
3. ARPRO effective heat of combustion
4. ARPRO toxicity of smoke

Version 03

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1. Characteristics of ARPRO Black vs ARPRO FR

ARPRO Black	ARPRO 4135 FR
Not self-extinguishing	Self-extinguishing
Increasing ARPRO part density or thickness will lower the burning rate.	Decreasing ARPRO part thickness will make the flame stop quicker.

ARPRO 4135 FR is a flame retardant grade, free of halogenated components according to UL 746 H.

2. Burn rate and fire class of ARPRO in different applications

Requirements of material flammability standards range from one application to another. Tests are different in terms of flame ignition, test procedures, shape and size of samples, and recorded parameters. Therefore, several standards may be required for one application. In addition, flame performance also depends on thickness and density of ARPRO.

A. Automotive: ISO 3795 (FMVSS 302)

This international standard specifies a method for determining the horizontal burning rate of materials used in the occupant compartment of road vehicles. This method permits testing of materials and parts of the vehicle interior equipment individually or in combination up to a thickness of 13mm.

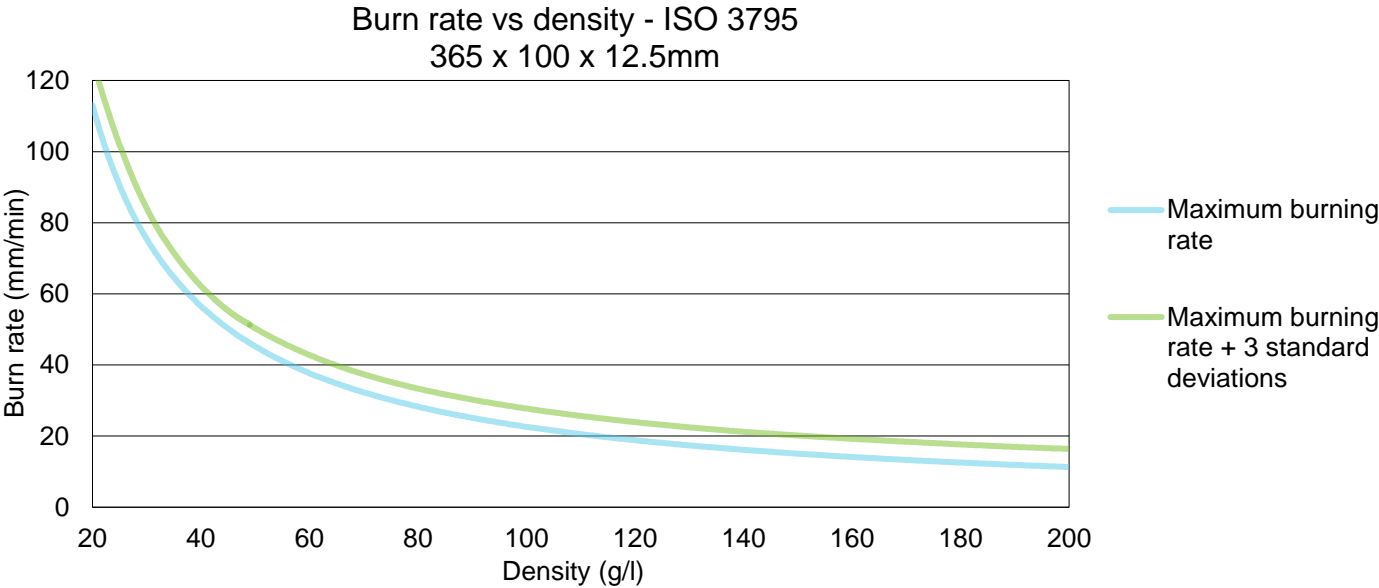
Test method: ISO 3795. Five 356 x 100 x 12.5mm samples are mounted horizontally in a U-shaped holder and are exposed to a well-defined low-energy flame for 15 seconds in a combustion chamber. The flame is applied to the free end of the samples. The test determines if and when the flame extinguishes, or the time at which the flame passes a measured distance, resulting in a burning rate in mm/minute. Tested density is ARPRO Black 25 to 200g/l and the thickness of the sample is 12.5mm, without moulded surface.

Test results: Burn rate vs density.

To pass the specifications for burning rate, bullet pointed below, we recommend considering the maximum burning rate + 3 standard deviations (light green curve on graph). ARPRO passes the following burning rate criteria at a thickness of 12.5mm and from the minimum density presented hereafter:

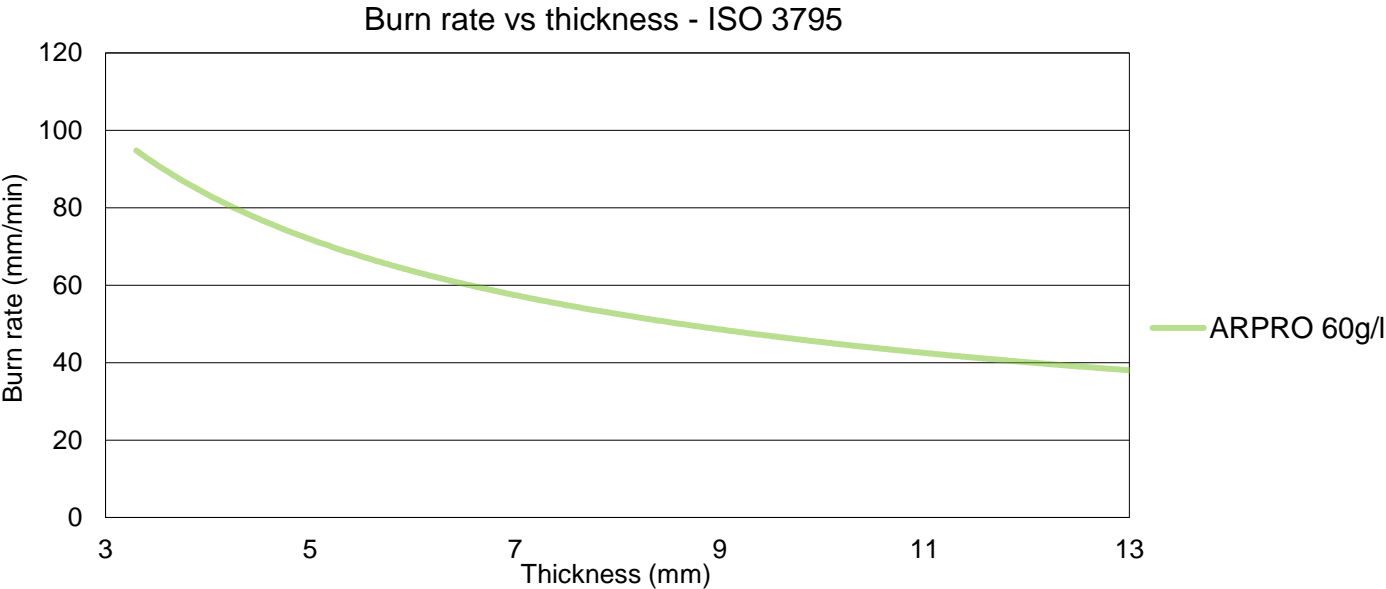
- Maximum burning rate < 100mm/min: the minimum density to pass this criteria is 25g/l.
- Maximum burning rate < 80mm/min: the minimum density to pass this criteria is 32g/l.

The moulding process variations should be considered to ensure that the minimum density recommended will be obtained on any moulded part.



Maximum burning rate + 3 standard deviations includes the test variation.

Test results: Burn rate vs thickness.
Increasing ARPRO part density or thickness will lower the burning rate as there is more material to consume.



B. Electronics:

i. UL 94 (ISO 9772)

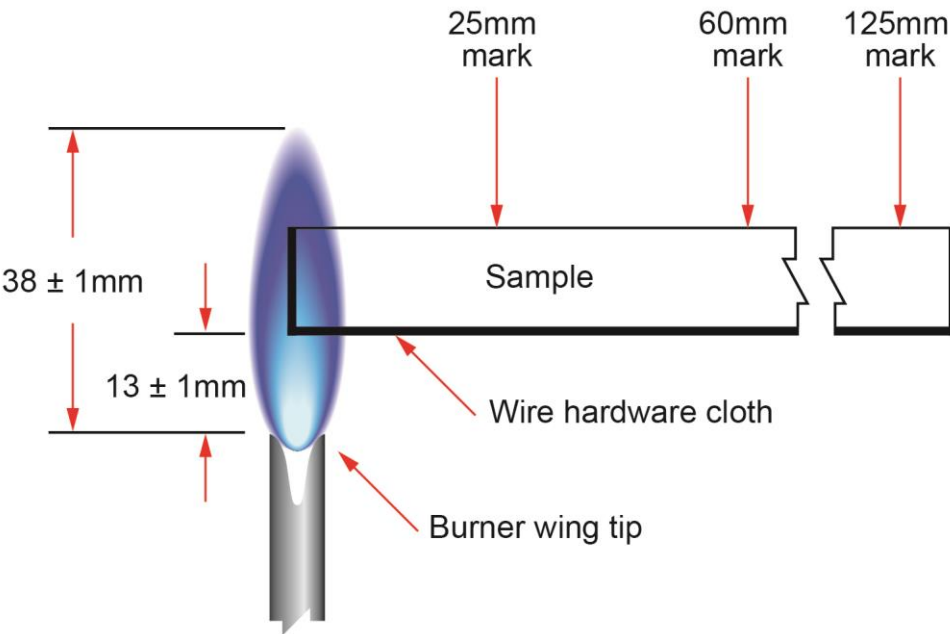
Section 12 of UL 94 describes a small scale horizontally oriented burning test procedure for comparing the relative rate of burning, the extent of burning and the time of burning of cellular polymeric materials which have a density less than 250g/l. Section 12 of UL 94 is equivalent to ISO 9772.

From lowest (least flame-retardant) to highest (most flame-retardant), the following classification system applies:

- HBF: No sample with a burning rate exceeding 40mm/minute over a 100mm span OR each sample ceases to burn before flaming or glowing reaches the 125mm gauge mark.
- HF-1 and HF-2:

Criteria	HF-1	HF-2
After-flame time	4/5 samples are ≤ 2s 1/5 samples are ≤ 10s	4/5 samples are ≤ 2s 1/5 samples are ≤ 10s
Afterglow time for each individual sample	≤ 30s	≤ 30s
Cotton indicator ignited by flaming particles or drops	No	Yes
Damaged length for each individual sample	< 60mm	< 60mm

The below picture displays the setup of the apparatus for UL94 horizontal testing.



Test results: ARPRO Black = HBF.

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Tested densities are ARPRO Black between 55g/l and 140g/l (min. thickness 8mm).

Test results: ARPRO 4135 FR = HF-1.

Tested densities are ARPRO 4135 FR between 20g/l and 60g/l (min. thickness 3mm).

ii. **Glow wire flammability index of ARPRO: IEC 60695-2-12 (GWFI), IEC 60695-2-13 (GWIT)**

The Glow Wire Flammability Index (GWFI) and the Glow Wire Ignition Temperature (GWIT) provide a way of comparing the temperatures at which materials ignite. The apparatus simulates the effect of heat that could be released by electrical components.

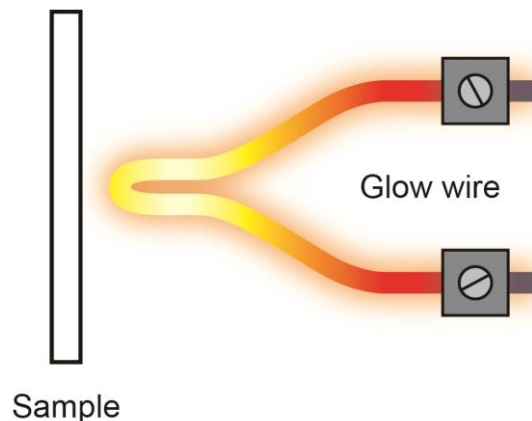
Test method: common test method and apparatus are described in IEC 60695-2-10.

The IEC (International Electrotechnical Commission) is the international standard and conformity assessment body for all fields of electrotechnology.

The glow wire is heated to a specific temperature. The test sample is held for 30 seconds against the glow wire. Cotton is placed beneath the sample to determine the effects of burning drops. The Glow Wire Flammability Index (GWFI) is the highest temperature that satisfies one of the following conditions:

- There is no flame and no glowing (no ignition).
- Burning / glowing is less than 30 seconds after removal of the glow wire and cotton does not ignite.

The Glow Wire Ignition Temperature (GWIT) is set 25°C higher than the maximum temperature at which the glow wire does not cause material burning for more than 5 seconds during three tests.



Test results: ARPRO Black – Effect of density:

ARPRO Black 3mm	Tested density 60g/l	Tested density 80g/l	Tested density 130g/l
GWFI (°C)	825	800	800

Test results: Effect of ARPRO grades and thickness:

Thickness	3mm	15mm	30mm
ARPRO Black 60g/l			
GWFI (°C)	825	750	775
GWIT (°C)	850	775	800
ARPRO 4135 FR 60g/l			
GWFI (°C)	700	960	n/a
GWIT (°C)	725	960	n/a
ARPRO 5135 ESDP 60g/l			
GWFI (°C)	n/a	675	n/a
GWIT (°C)	n/a	700	n/a

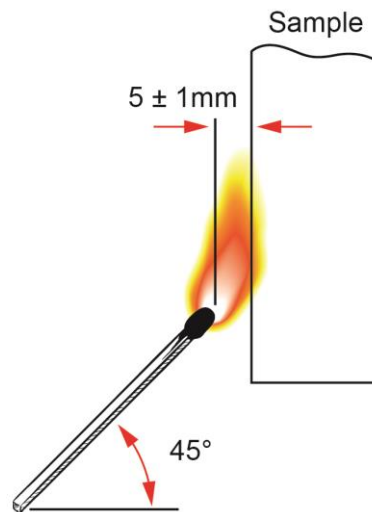
iii. Needle flame test: IEC 60695-11-5

The test is performed to determine if a small flame, that may arise from other ignited components, will cause ignition of the material or if the material will present limited burning and no fire spreading.

The time of flame application and acceptance criteria (burning duration) depends on individual product specification.

A 12mm flame is applied for 5, 10, 20, 30, 60 or 120 seconds, according to the product specification, on a representative surface of the sample. A wrapping tissue (lightweight and strong wrapping paper between 12g/m² and 30g/m²) is placed 200mm underneath the sample. 3 test samples, representative of final application are tested.

Duration of burning denotes the time interval from the moment the test flame is removed from the test specimen, until the last flames have extinguished and the glowing of the test specimen, the specified layer and/or the surrounding parts is no longer visible.



Test results: ARPRO 4135 FR at 60g/l, with a flame applied for 30 seconds:

Sample thickness	6mm	50mm
Duration of burning (sec)	0	0

Test results: ARPRO Black at 80g/l, with a flame applied for 30 seconds:

Sample thickness	10mm	50mm
Duration of burning (sec)	0	0

Between 10 to 50mm thick ARPRO Black at 60g/l burns completely for a duration of more than 30 seconds.

C. Buildings: Euroclasses EN 13501-1

EN 13501-1 is the European building code standard that defines flammability of building materials and fire resistance of building elements.

Possible classifications for the EN 13501-1 standard are:

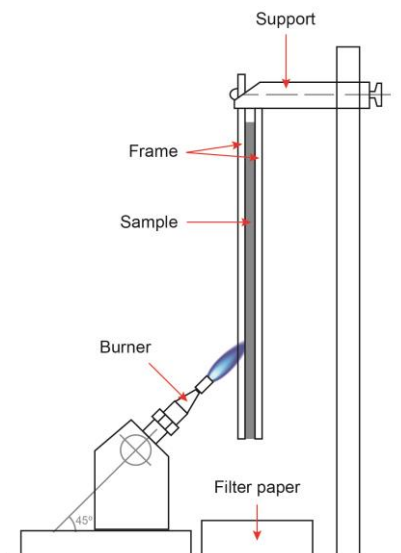
- Euroclass F: no performance criteria.
- Euroclass E: acceptable fire reaction to the attack of a small flame for a short period of time.
- Euroclass D: products satisfying criteria for class E and capable of resisting, for a longer period, a small flame attack without substantial flame spread. In addition, they are also capable of undergoing thermal attack by a single burning item with sufficiently delayed and limited heat release.
- Euroclass C: products satisfying criteria for class D and under single thermal attack by a single burning item, they have limited lateral spread of flame.
- Euroclass B: products satisfying criteria for class C and more stringent requirements on the Fire Growth Rate (FIGRA) and on Total Heat Release (THR).
- Euroclass A2: products satisfying criteria for class B. In addition, under conditions of a fully developed fire these products will not significantly contribute to the fire load and fire growth.
- Euroclass A1: materials are considered incombustible.

According to the class level, different tests have to be performed. The sub-index “s” and “d” are classifications for smoke development and dripping.

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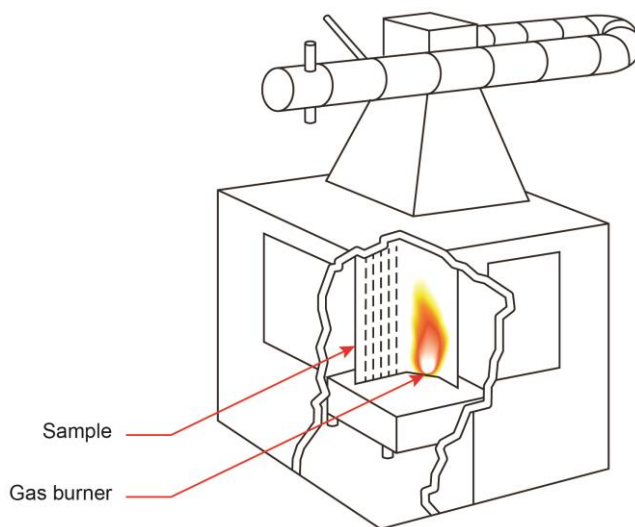
Test method: ISO 11925-2 ignition test with a small flame. The test takes place inside a test chamber where the test sample is mounted vertically. The test sample is subjected to edge and / or surface exposure from a gas flame. During the test, time of ignition, burning droplets and whether the flames reach the top marking of the test sample within a prescribed time period, are registered. For classification E or F the test consists of 15s of flame application. For E classification, there shall be no flame spread in excess of 150mm vertically from the point of application of the test flame within 20s from the time of application. For F classification, the product fails to obtain E classification when tested according to ISO 11925-2.



For classes E and F, only the ignition test with a small flame is required. For classes A1, A2, B, C and D the test EN 13823 is required.

EN 13823: Small burning item.

The small burning item test according to EN 13823 consists of lighting a fire at the corner of two plates (1500 x 1000mm and 1500 x 495mm) mounted at right angles. A gas burner with a heat release rate of 30kW is located in the corner during testing. The test time is 21 minutes. The combustion gases are collected through a hood where heat release rate and smoke production are measured.



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Test results: ARPRO Black:

Sample thickness (mm)	Tested density (g/l)				
	20	30	45	60	120
10	F	F	F	E	E
15	F	F	F	E	E
20	F	E	E	E	E
30	F	E	E	E	E
60	E	E	E	E	E

Test results: ARPRO White:

Sample thickness (mm)	Tested density 80g/l
10	E

Test results: ARPRO 4135 FR:

Sample thickness (mm)	Tested density 40g/l	Tested density 60g/l
10	D s1 d0	D s1 d0
15	Not tested	D s2 d0
30	Not tested	D s2 d1 expired in 2014
50	E	E

D. Aircraft: certification specification CS25 for large aeroplanes

This certification specification specifies a method for determining the vertical burning behaviour of materials used in interior compartments occupied by crew or passengers, along with the corresponding requirements.

Test method: CS25.853 App. F Part I (b). Three samples are mounted vertically in a metal frame and the lower edge of the samples, representative of the actual cross-section of the material or part as installed in the aeroplane, is exposed to the action of a calibrated flame for a certain time, depending on parts application. The test determines the average burn length, the average flame time after removal of the flame source, and the dripping extinguishing time.

CS25.853 App. F Part I (a) (1) (ii) – 12 seconds vertical burning

Test results: ARPRO 4135 FR.

Flame applied for 12 seconds. ARPRO 4135 FR passes the CS25.853 App. F Part I (a) (1) (ii) criteria, at a thickness of 13mm and at a density of 40 and 60g/l.

Test criteria	Requirement	Tested density 40g/l	Tested density 60g/l
Burnt length (cm)	20 max	6	6
After-flame time (s)	15 max	0	0
Dripping extinguishing time (s)	5 max	0	0

CS25.853 App. F Part I (a) (1) (i) – 60 seconds vertical burning

Test results: ARPRO 4135 FR.

Flame applied for 60 seconds. ARPRO 4135 FR passes the CS25.853 App. F Part I (a) (1) (i) criteria, at a thickness of 13mm and at a density of 40 and 60g/l.

Test criteria	Requirement	Tested density 40g/l	Tested density 60g/l
Burnt length (cm)	15 max	13	5
After-flame time (s)	15 max	0	0
Dripping extinguishing time (s)	3 max	0	0

E. Toys: ISO 8124-2

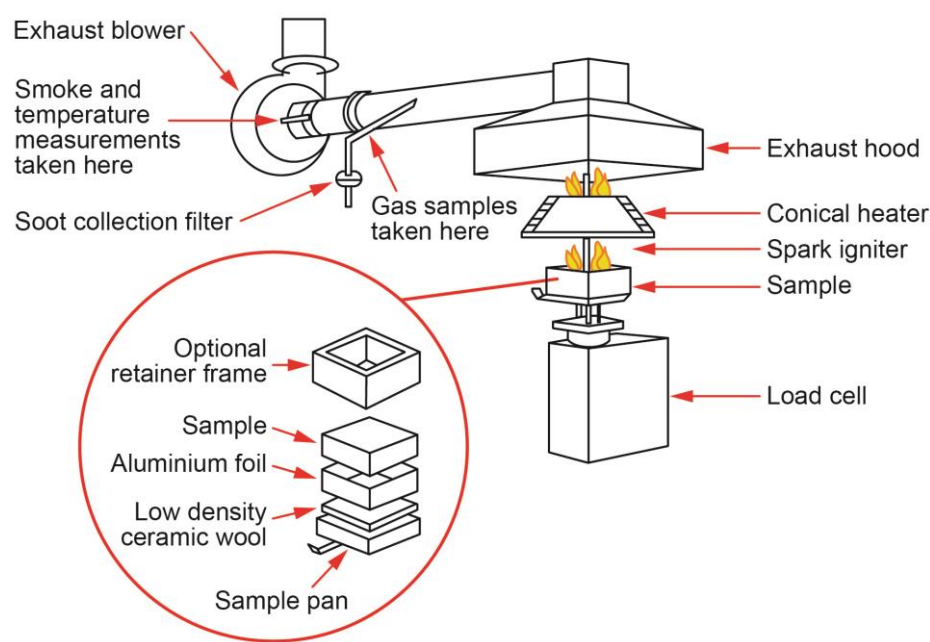
A sample with dimensions 610 x 100 x 10mm and density of 60g/l is put into a U-shaped holder, inclined at 45°. The sample is exposed to a flame in a combustion chamber. The flame acts on the free end of the sample with the rate of spread being 1 – 2mm/s. The test determines if and when the flame extinguishes, or the time at which the flame passes a measured distance, resulting in a burning rate in mm/minute.

Grade	Result
ARPRO 5135	Pass
ARPRO 4133	Pass
ARPRO 3133	Pass
ARPRO 1133 Blueberry	Pass
ARPRO 1133 Dragon Fruit	Pass
ARPRO 1133 Orange	Pass
ARPRO 1133 Lemon	Pass
ARPRO 1133 Lime	Pass

3. ARPRO effective heat of combustion: ISO 5660-1

ISO 5660-1 specifies a method for assessing the heat release rate of a sample exposed in the horizontal orientation to controlled levels of irradiance with an external igniter. The heat release rate is determined by measurement of the oxygen consumption derived from the oxygen concentration and the flow rate in the combustion product stream. The time to ignition (sustained flaming) is also measured in this test.

Test method: ISO 5660-1. The surface of the test sample is exposed to a constant level of heat irradiance, within the range 0 - 100kW/m², from a conical heater. Volatile gases from the heated sample are ignited by an electrical spark igniter. Other parameters include an irradiance level of 35kW/m² and 3 test samples with the dimensions of 100 x 100 x 25mm.



Test results: ARPRO Black.
Tested densities are ARPRO Black 50 and 70g/l, with 3 test samples being tested for each.

	ARPRO Black 50g/l	ARPRO Black 70g/l
Average effective heat of combustion - MJ/kg	39	40

Test results: ARPRO 4135 FR.
Tested density: ARPRO 4135 FR 60g/l. Three test samples have been tested for each.

	ARPRO 4135 FR 60g/l
Average effective heat of combustion - MJ/kg	34

4. ARPRO toxicity of smoke: ISO 5660-1

During its combustion, ARPRO emits gases. Analysis of the gases emitted during combustion enables the determination of whether the smoke produced is toxic or not.

Test method: ISO 5660-1. As in point 3, the surface of the test sample is exposed to a constant level of heat irradiance, within the range 0 - 100kW/m², from a conical heater. Volatile gases from the heated sample are ignited by an electrical spark igniter. Other parameters include an irradiance level of 35kW/m² and test samples with the dimensions of 100 x 100 x 25mm, with additional analysis by IRFT (Infra-Red Fourier Transform) of the gases emitted by ARPRO during the combustion. Tested densities are ARPRO Black 70g/l and ARPRO White 70g/l.

Test results: the following gases have been detected at the described level:

	ARPRO Black 70g/l	ARPRO White 70g/l
CO (kg/kg)	0.029	0.027
CO ₂ (kg/kg)	2.45	2.55

The following gases have not been detected:

Gas	Detection limit (ppm)
NO Nitric Oxide	2.22
NO ₂ Nitrogen Dioxide	1.97
NH ₃ Ammonia	1.75
N ₂ O Nitrous Oxide	0.53
SO ₂ Sulphur Dioxide	1.12
HCN Hydrogen Cyanide	1.42
HCOH Formaldehyde (Methanal)	7.00
HCL Hydrochloric Acid	1.54
CH ₄ Methane	4.75
C ₂ H ₂ Acetylene (Ethyne)	5.28
C ₂ H ₄ Ethylene (Ethene)	21.13