ARPRO

Heat resistance properties

The heat resistant properties of ARPRO can be crucial depending on application.

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

1. Expected ARPRO lifetime – aesthetic degradation
2. Expected ARPRO lifetime – performance degradation
3. Change in mechanical properties due to ageing
4. Change in mechanical properties due to usage
5. Change in moulded part dimensions due to ageing
6. Change in moulded part dimensions due to usage
7. Thermal insulation

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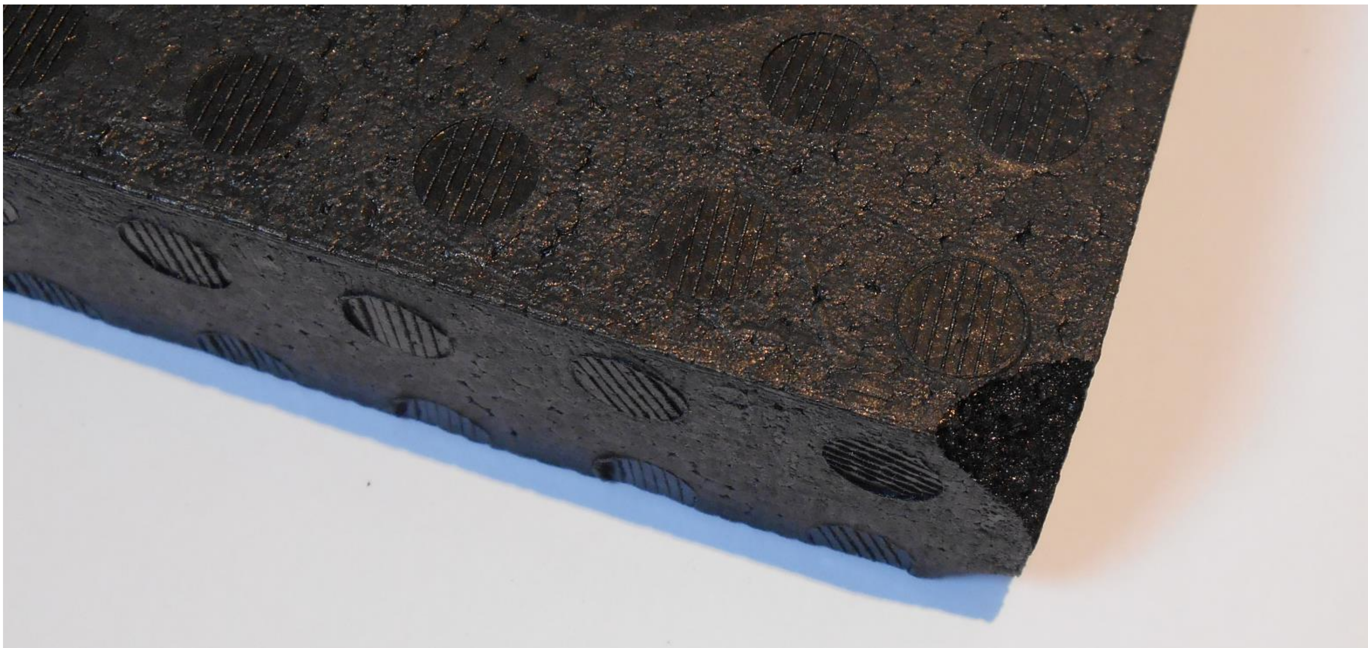
1. Expected ARPRO lifetime – aesthetic degradation

"Expected ARPRO lifetime" links the absolute temperature, the duration of continuously applied temperature and the moulded density of the application. The data in this document will provide an indication of how ARPRO performs under continuously applied temperatures. The graphs, in this section, illustrate where the first signs of degradation appear (various temperatures, without any stress on the part).

Test method: ARPRO moulded parts are exposed in a dry oven to varying temperatures between 85°C and 120°C. Data gathering is stopped at the first sign of any degradation (e.g. powdering or breaking of the polymeric chains). Tested densities are ARPRO Black between 20g/l and 100g/l.

Criteria: The first signs of degradation is when the sample becomes a powdered state. This provides a data point for lifetime calculation at the given temperature. Usually, powdering begins on the corners and edges of the moulded part (see picture). When signs of degradation appear, the ARPRO parts are removed from the dry oven. As long as this powdering does not occur, there is no drop in physical properties.



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The graph below indicates the expected duration before the first signs of degradation appear at various temperatures, without any stress on the part.

In order to use the curves, the minimum lifetime expected or the average functional temperature has to be known. For instance, if the application has a lifetime of 10 years, then ARPRO can be used when the continuous functional temperature equals 60°C or below. If the application has to sustain a temperature profile (under variable temperatures or during both winter and summer seasons) then the average temperature should be used as the reference to obtain the expected lifetime.

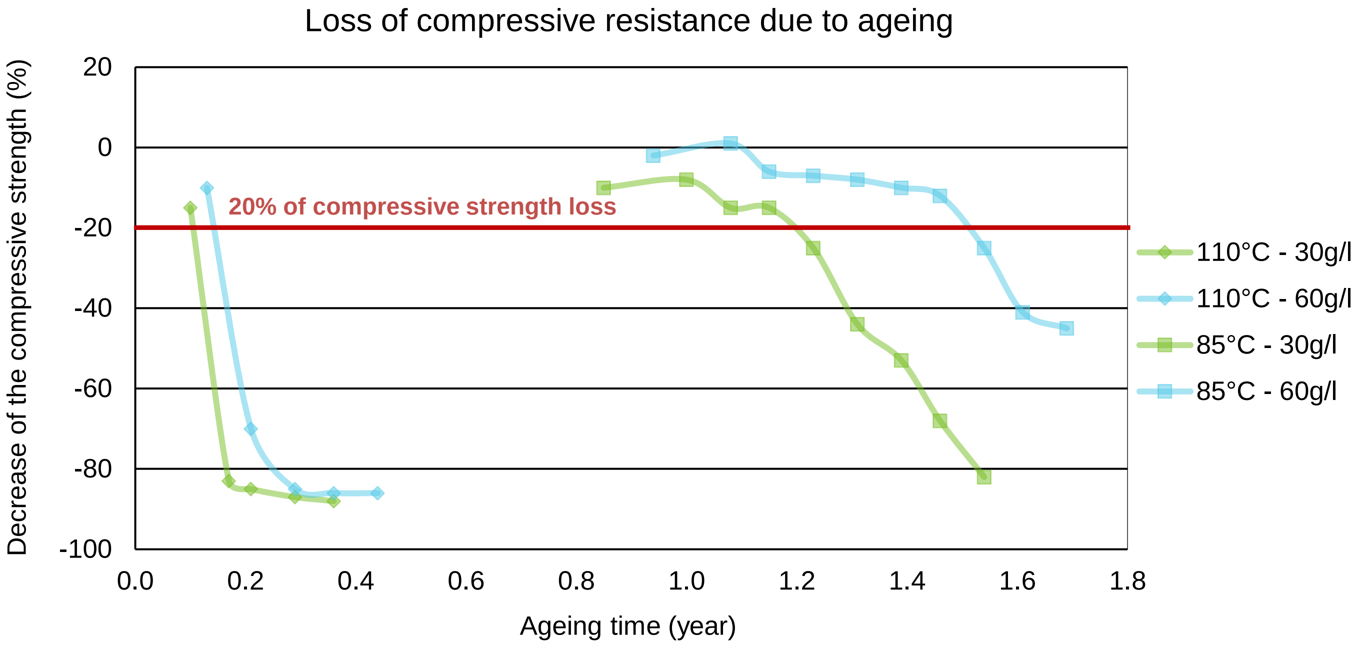
Notes: There are some accelerating factors that could lead to shorter lifetime.

- Exposure to UV (please contact us regarding the “coating method” for further details).
- Direct contact to copper parts, depending on the temperature of use. The effect of copper on ARPRO degradation is 3 to 6 times faster at temperatures above 100°C but almost insignificant at temperatures below 80°C. In order to avoid contact between ARPRO and copper, the following solutions can be applied:
  - Layer of air.
  - Another material used as a protective layer (e.g. aluminium foil).
  - Paint copper with epoxy paint.

2. Expected ARPRO lifetime – performance degradation

Powdering is not always the right “fail criteria” depending on the application (visible or not) as the mechanical properties are still unaffected at first occurrence. Loss of compressive strength is dependent on time and temperature (the initial point of each curve comes from the “Lifetime expectation” graph, in section 1). At lower temperatures, the degradation is much lower than at higher temperatures.

Test method: ARPRO moulded parts are exposed in a dry oven to temperatures of 85°C and 110°C. Once the first sign of aesthetic degradation appears (see section 1), the compressive resistance of the ARPRO moulded parts is monitored regularly. The performance of ARPRO moulded parts is usually considered as compromised when the loss of compressive strength is higher than 20%. Tested densities were ARPRO Black 30g/l and 60g/l.



Test results explanation: At a constant temperature of 110°C, ARPRO at 30g/l and 60g/l will start degrading and losing performance after two months. At a constant temperature of 85°C, ARPRO at 30g/l will lose 20% of its initial compressive strength after 15 months. For ARPRO at 60g/l, this will occur after 18 months.

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3. Change in mechanical properties due to ageing

Exposure to heat softens ARPRO, which can modify the mechanical properties of the material irreversibly over a long period of time. However, once the temperature returns to ambient the ageing stops.

Test method: Compression strength and tensile strength are measured before and after ageing. The specimens are cut from 400 x 300 x 80mm blocks and aged at 110°C for 10 days or at 130°C for 5 days according to ISO 2440. Tested density is 60g/l ARPRO Black.

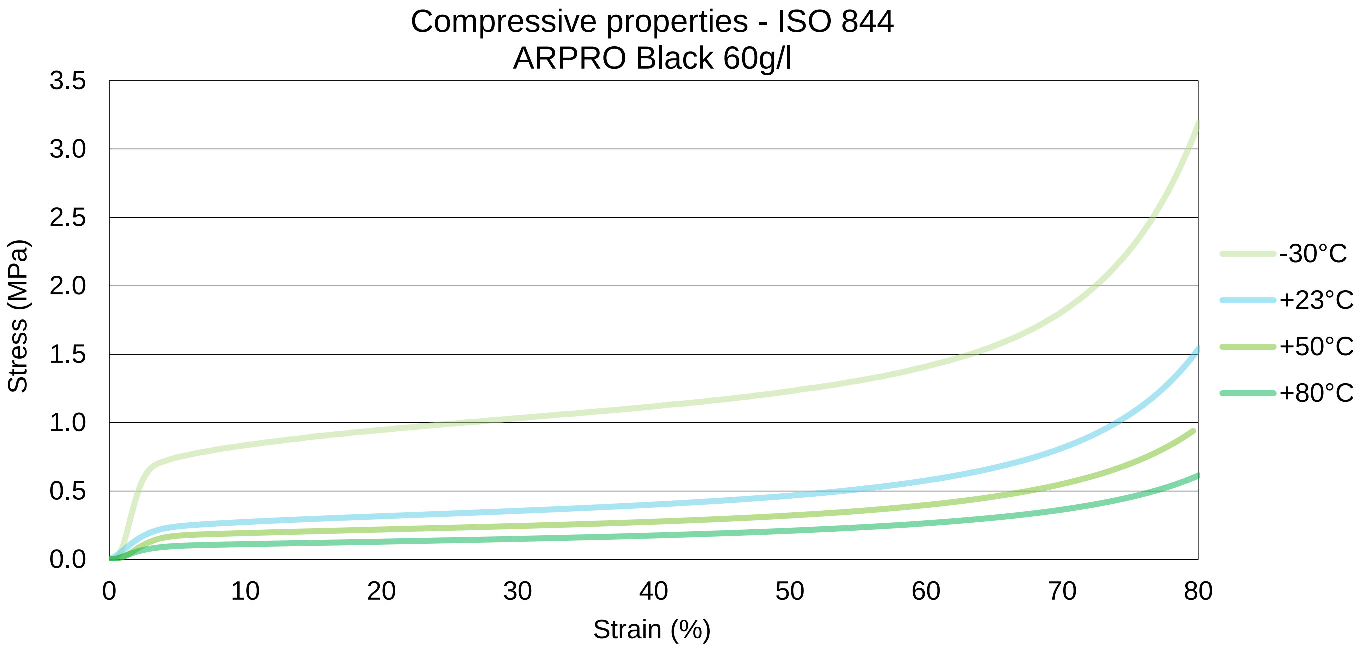
Test	Method	Unit	Result	Result
Heat ageing	ISO 2440		110°C – 10 days	130°C – 5 days
Tensile strength				
Initial ambient temperature	ISO 1798	kPa	930	930
Change after heat ageing		%	up to 15*	up to 15*
Tensile elongation				
Initial ambient temperature	ISO 1798	%	25	25
Change after heat ageing		%	up to 15*	up to 30*
Compressive strength at 25% strain				
Initial ambient temperature	ISO 844	kPa	340	340
Change after heat ageing		%	up to 5*	up to 10*

* Part of the property variation is due to test variation. Tensile test results, especially elongation, are much more variable than compression results. Other variation is due to densification of specimens, due to slight shrinkage during ageing.

4. Change in mechanical properties due to usage

Exposure to heat softens ARPRO, which can modify the mechanical properties of the material during use, however these changes are reversible. Once the temperature returns to ambient, the mechanical properties of ARPRO will revert to those of ambient level.

Test method: Compression according to ISO 844 with a speed of 5mm/min. Tested density is 60g/l ARPRO Black.



Test results: If heat is applied to ARPRO, the material will soften, but it will maintain residual resistance, even at high temperatures. The general thermoplastic behaviour will remain steady whatever the temperature tested, even below the glass transition (around -10°C).

5. Change in moulded part dimensions due to ageing

Moulded parts contain ARPRO particles. As the dimensions of each particle can be affected by heat, moulded part dimensions will also be affected.

Cold temperatures have less effect on the dimensions; the largest variations come from high temperature. The effect is a slight shrinkage of the part, depending on the temperature applied, the ageing duration and the tested density. A slight densification, by 1g/l to 5g/l is observed for the temperatures and densities presented below.

Test method: ISO 2796. Three ARPRO samples, with dimensions of 100 x 100 x 25mm are heated in an oven with dry air and aged at 110°C for 10 days or at 130°C for 5 days. The temperature is regulated within ± 2°C. The dimensions are measured before and after the ageing process, at 3 different points in time, in every direction. The values presented in this datasheet are the average of the length, width and thickness variation.

ARPRO moulded density (g/l)	Linear dimensional change (%)	
	Ageing at 110°C for 10 days	Ageing at 130°C for 5 days
30	- 1.0	- 5.8
60	- 0.6	- 3.0
80	- 0.6	- 1.7
150	- 0.6	- 1.1

Note: This effect can be partially increased or decreased by varying the press settings during the moulding. (Please contact us for more information on “varying the press settings during moulding”).

6. Change in moulded part dimensions due to usage

The Coefficient of Linear Thermal Expansion (CLTE) of a material is its tendency to expand (or shrink) due to temperature influence (both heat and cold). However, ARPRO can compensate for these dimensional variations if a mechanical constraint is applied.

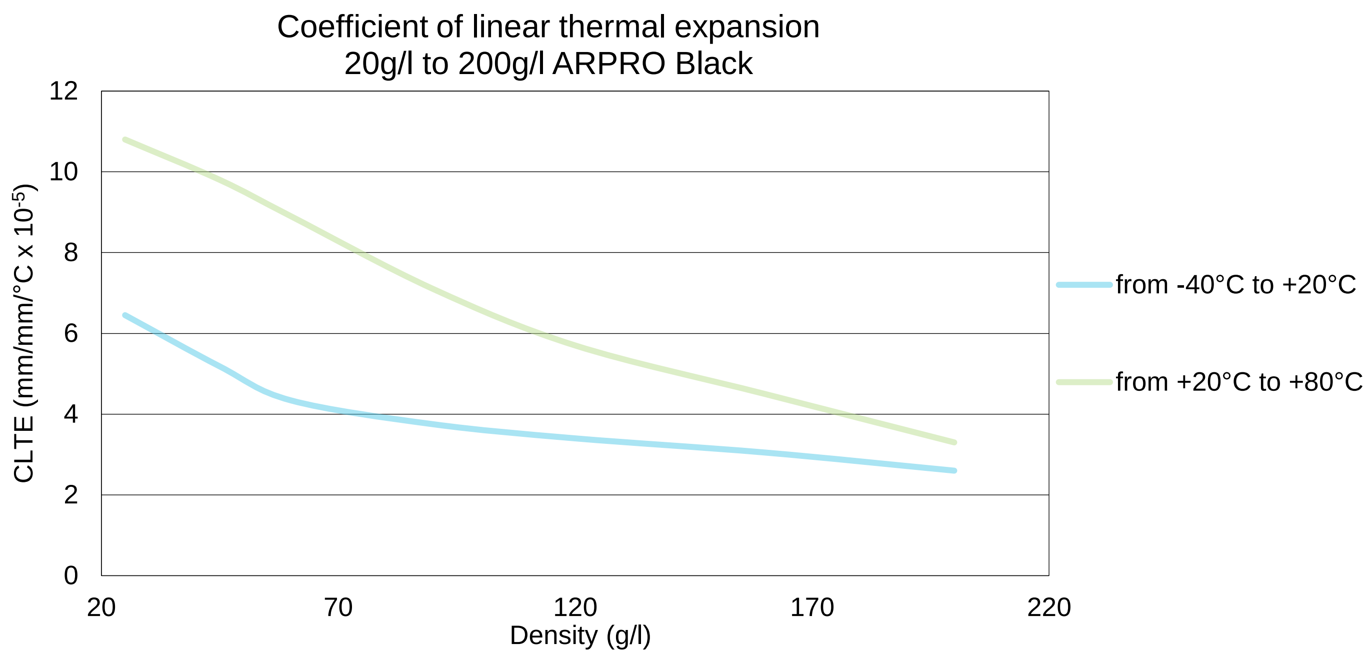
Test method: Gauge marks are placed at 25mm intervals lengthwise from one end of the sample in a thermostatic chamber at an initial temperature for 24 hours. The gauge length is measured immediately after removing the sample from the thermostatic chamber. Then, the sample is placed at a final temperature for 24 hours. The gauge length is measured once more, immediately after this temperature treatment. The initial and final temperatures used are -40°C to 20°C and 20°C to 80°C. Tested densities are between 20g/l to 200g/l ARPRO Black.

The CLTE, expressed as K, is calculated by the equation:

$$K = (L_1 - L_0) / (\Delta T * L_0)$$

Where L_1 is the sample length at the final temperature exposure, L_0 is the sample length at the initial temperature exposure and ΔT is the final temperature minus the initial temperature.

Note: The final results may vary slightly according to the specific moulded part geometry.



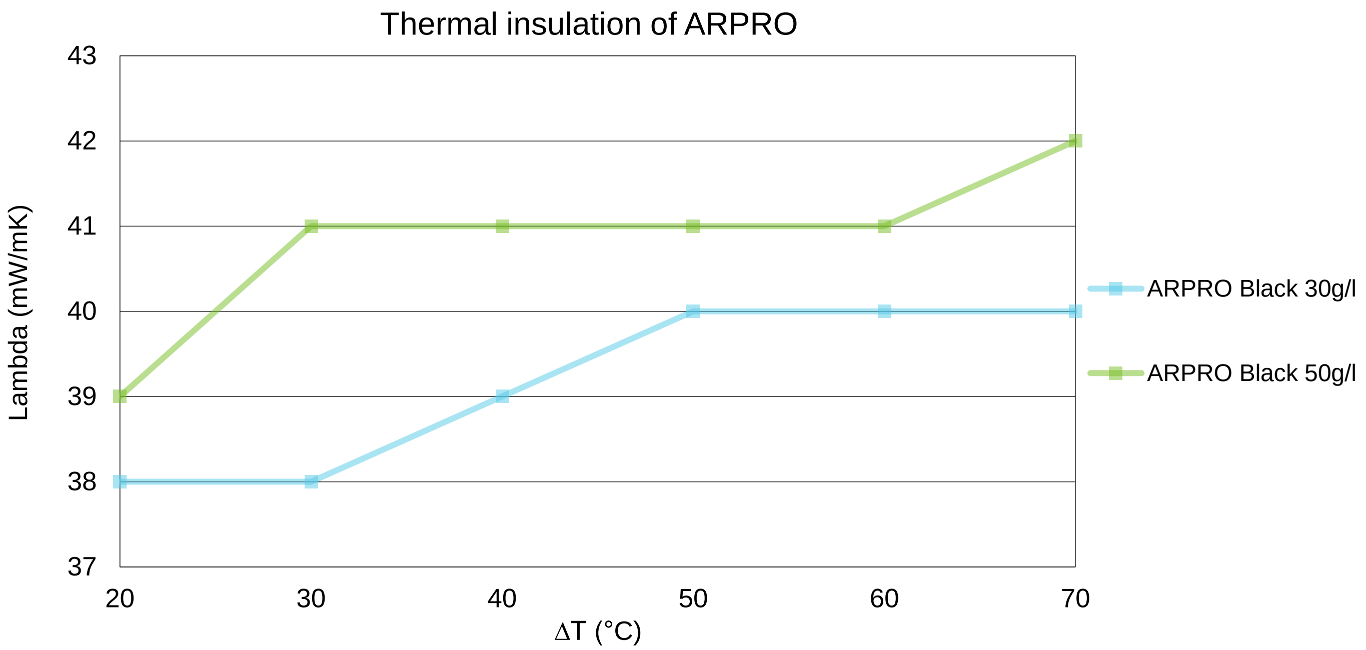
Test result explanation: For ARPRO at 160g/l from 20°C to 80°C ARPRO dimensions change by $4.5*10^{-5}$mm per mm, per °C. This means that if a 160g/l ARPRO part has an original length of 100mm, after 24 hours conditioning at 80°C the final length of the part will be 100.27mm.

$$L_1 = L_0 + K * \Delta T * L_0 = 100 + 4.5.10^{-5} * 60 * 100 = 100.27mm$$

7. Thermal insulation

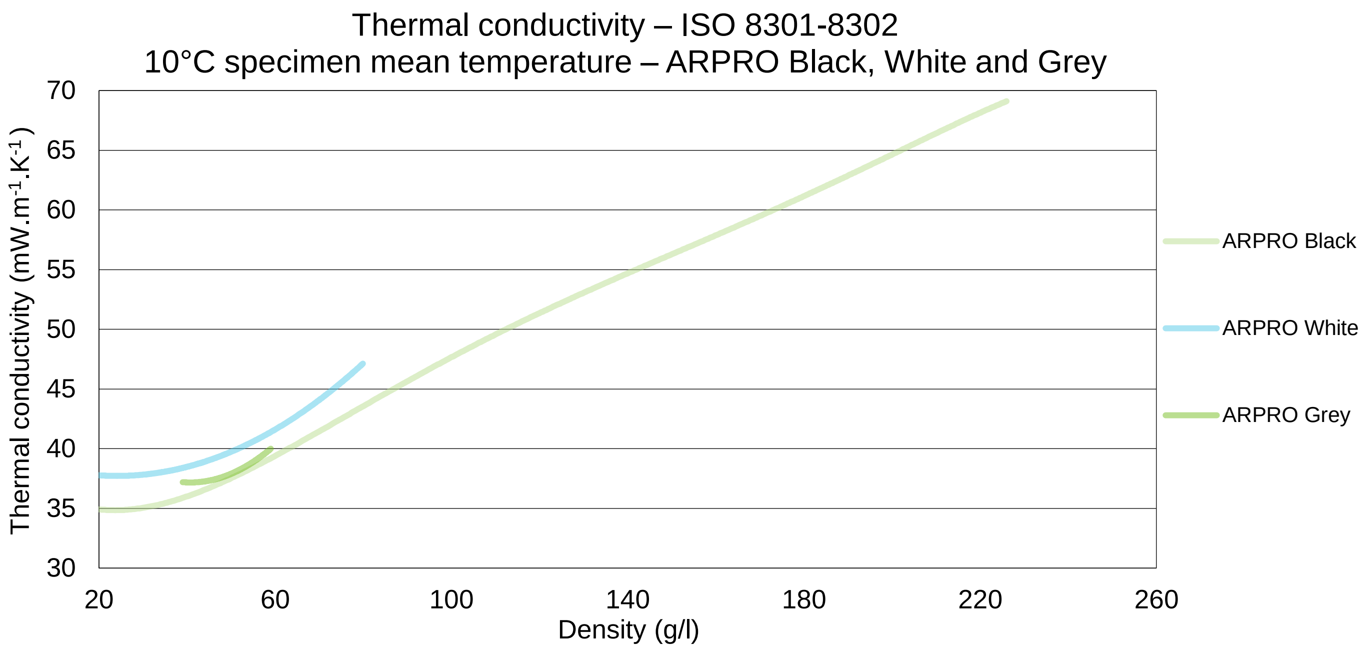
The data below is obtained from 2 different tests, it gives the thermal conductivity (λ) of a material. The smaller the λ, the better the insulation.

Test method A: ISO 8301. The results are obtained by applying an increasing temperature difference between two plates. The temperature is from 20 to 70°C. The cold plate temperature is kept at 21°C, while the hot plate temperature is variable. Here, λ characterises the function of the temperature gradient. Tested densities are 30g/l and 50g/l ARPRO Black.



Test method B: ISO 8301-8302. A guarded heater is placed between two moulded samples that are in contact with a heat flow meter and a cooling plate. The value is determined by the heat flow, the mean temperature difference between the sample surface and the dimensions of the sample. These results are obtained with a variation of the average temperature (from 10 to 40°C), but the difference between the cold and hot plate is always 16°C. Here, λ characterises the energy transferred per unit area and time under a temperature gradient of 1°C/m. Tested densities are between 20g/l and 220g/l for ARPRO Black, between 20g/l and 80g/l/ for ARPRO White and between 40g/l and 60g/l for ARPRO Grey.

Note: Some additives can influence the thermal insulation. For example, carbon black pigment allows the reflection of some radiation, and so ARPRO Grey insulates better than ARPRO White.



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