Properties of polyamide PA66

Polyamides are among the most important thermoplastic synthetic materials. Thermoplastics can be reshaped by heating as often as required without undergoing chemical decomposition or other negative changes. This makes polyamide ideal for processing via injection moulding into high quality products. About 90% of cable ties and fixings from **HellermannTyton** are made from this material. Polyamide is also known under the brand name of Nylon®, which was introduced by the Dupont company.

The inner structure of polyamide displays a partial order of polymer chains, i.e. polyamides are partially crystalline. Due to the tighter packing of the individual molecular chains polyamide only has limited transparency to light. The plastic is therefore described as translucent.

The molecular chains of PA66 are made from two base units:

$$[\text{-NH}(\text{CH}_2)_6\text{NH-CO}(\text{CH}_2)_4\text{CO}]$$

1st base unit with 6 C atoms	2nd base unit with 6 C atoms

Each base unit contains 6 carbon atoms (C). Hence the name PA66. The polyamide PA66 has many properties which are highly advantageous for **HellermannTyton** cable ties and fixings, such as:

- High strength, rigidity and hardness.
- High dimensional stability, even under the effect of heat.
- High abrasion resistance.

Having a wide range of polyamides and additives allows for an optimum adaptation of the properties of the finished product to suit the respective requirements.

The following PA66 variants are used for HellermannTyton products:

- Polyamide 6.6 standard (PA66) for temperature conditions of up to +85°C.
- Polyamide 6.6 Heat Stabilised (PA66HS) for temperature conditions of up to +105°C.
- Polyamide 6.6 UV Stabilised (PA66W) for exterior use.
- Polyamide 6.6 Heat Stabilised and UV Stabilised (PA66HSW) for exterior use up to +105°C.
- Polyamide 6.6 Impact Resistant (PA66HIR) for high elasticity requirements.
- Polyamide 6.6 impact Resistant and Heat Stabilised (PA66HIRHS) for high elasticity requirements and temperatures up to +105°C.
- Polyamide 6.6 V0 for high standards of fire protection.

Water content in polyamide

Polyamide is a hygroscopic material - this means that it absorbs and releases water. The mechanical properties are significantly affected by the water content – especially flexibility and minimum tensile strength. In a standard atmosphere of 23°C and 50% relative humidity, the degree of water saturation of polyamide is around 2.5%. For optimal processing of cable ties it is therefore important that the polyamide has a water content of approximately 2.5% in a state of equilibrium.

The quality and functionality of the products are thus affected by the water content, therefore the correct storage of our products is crucial. Please read our separate instructions on storage.

Since humidity is so critical to the quality of the tie, the question arises: What happens if the tie is installed and the water content in the tie alters?

The water content determines the flexibility and strength of a tie. At a water content of approximately 2.5% the tie has the ideal flexibility for installation. When the strap is being threaded through the head of the tie, the pawl must be flexible enough to 'seesaw' over the serration of the strap without breaking. On the other hand, there must also be adequate material rigidity for the serrations of the pawl to engage with the serrations of the strap during the tying process so that a 'positive locking' action is achieved. After achieving the positive locking action the tie is in a static condition. Changes in the mechanical properties of the tie as a function of water content are insignificant during this status.

Properties of UV-stabilised polyamide (PA66W)

The question constantly arises as to whether a black cable tie is suitable for use outside. This is dependant on the application of the tie, but in general the following statements can be made:
A black cable tie made of polyamide 6.6 standard (PA66) is only coloured black with a low proportion of carbon black. This is not sufficient to protect the material from damage caused by UV-radiation in the long term.

Products made from UV-stabilised polyamide PA66W are produced in accordance with ASTM standard D6779 with a higher carbon black percentage of at least 2%. So they resist UV-radiation in the European area for a considerably longer period than standard PA66.

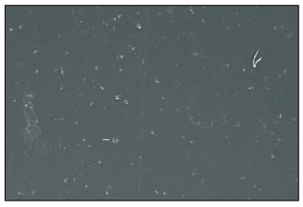
This is clearly illustrated by the comparison of the two images on the right:

After 500 hours of UV radiation exposure

Polyamide 6.6 standard (PA66) dyed black

The joint has been damaged throughout by UV radiation.

Polyamide 6.6 UV-stabilised (PA66W) with at least 2% carbon black



The joint has only been altered at isolated points by the UV radiation.

For outdoor use, therefore, we recommend our range of products made from UV stabilised polyamide (PA66W).

A simple practical test: "the hammer test"

You can quickly determine whether or not a cable tie is UV stabilised. Strike with a hammer the tail of the strap on the tie. Hold up this flattened end to the light. Cable ties with a carbon black content of at least 2% allow no light through and look black throughout. Standard black ties, however, are transparent on the flattened end.

Properties of polyamide PA12

Apart from PA66, there are polyamides which are less hygroscopic. These include PA12, which has a molecular chain made of a base unit with 12 carbon atoms:

$$[-NH(CH_2)_{11}CO-]$$

PA12 has the following advantages over PA66:

- Less hygroscopic - saturation at 23°C and 50% relative humidity is approximately 1%.
- Better impact performance.
- Good weather resistance, even without a special additive.

These three properties make PA12 ideal for use outdoors, in particularly when requirements may include impact resistance.

The water absorption of PA12 is not only less than that of PA66 but also slower. This is the requirement where the mechanical properties need to remain relatively unaffected by changing environmental conditions.

Properties of polyamide PA46

Polyamide PA66, despite the use of additives, is not suitable for long-term use in temperatures of +105°C. Due to considerably better heat resistance, polyamide PA46 is more suitable for temperatures of up to and exceeding 150°C (depending on the length of time of operation).

The molecular chain of PA46 is composed of two base units:

$$[NH-(CH_2)_4NH-CO-(CH_2)_4-CO-]$$

1st base unit with 4 C atoms

2nd base unit with 6 C atoms

Advantages of PA46 over PA66:

- Greater rigidity, even at higher temperatures.
- Higher operating temperature ranges of up to +150°C (5,000 hours).
- Greater form stability at higher temperatures.
- Excellent chemical resistance.

Chemical resistances of various plastics

+ = resistant
o = partly resistant
- = not resistant

These values are only rough guides. They should be regarded as a material specification and are no substitute for a suitability test.
Please see our technical datasheets for further details.

Medium	Conc. (%)	Temp. (°C)	PA66	PA46	PA12	POM	PP	TPU	Tefzel
Acetaldehyde, liquid	100	23	+	+		+	o	-	+
Acetone	100	23	+	+	+	+	+	-	+
Allyl chloride	100	23					+	-	
Formic acid	98	23	-		-	+	+	-	+
Aniline	100	23	+	o	o	o	+	-	+
Aromatic compounds						+	-		+
Benzaldehyde	any	23	+	o		+	+	-	+
Benzine/benzol mix		23	+	+	+	+	o	o	+
Benzol	100	23	+		+	+	o	-	+
Bromine		23			-		-	-	
Chlorine, gaseous	100	23					-	o	
Chlorine, liquefied	100	23					-		
Chlorobenzene	100	23			-		+		
Chloroform	100	23		-	-		o		
Chromic acid	10	20	o			+	+		+
Chromic acid	20	23	-			-	+		+
Chromic acid	50	20	-			-	+		+
CFC							o		
Cyclohexane	100	23	+			+	+	+	+
Cyclohexanone	100	23	+			+	+		+
Decahydronaphthalene	100	23	+			+	o		+
Diethyl ether	100	23	+			+	o		+
Di-isopropyl ether	100	23					o		
Dimethyl formamide	100	23	+	o		+	+		+
Dioctyl phthalate		23	+			+	+	-	+
Ethanoic acid	10	20	-	o	o	+	+		+
Ethanoic acid	25	20	-			o	+		+
Ethanoic acid	50	20	-			o	+		+
Ethanoic acid	100	23	-	-		o	+		+
Ethyl acetate	tech. pure	23		+	+		o		
Freon		23					+		
Heptane	100	23	+	+	+	+	+		+
Potass. permanganate	<= 6	23	-		-	+	+		+
Ketone				+	+		+	+	+
Methyl ethyl ketone	100	23	+	+		o	+	-	+
Methylisobutylcetone	100	23	+			+	+		+
Engine oil		23			+		+		
Nitrobenzene	100	23	+	o		+	+	-	+
Ordinary petrol		23					+		
Paraffin oil		23	+	+	+	+	+		+
Perchloroethylene		23	+		+	+	o	-	+
Petroleum		23	+	+	+	+	+		+
Phenol	approx. 70	23	-		-	o	+	-	+
Nitric acid	10	20	-		-	-	+	-	+
Nitric acid	50	23	-		-	-	-	-	+
Carbon bisulphide	100	23	+	-	+	+	-	-	+
Sulphuric acid	10	20	-		o	+	+	+	+
Sulphuric acid	50	20	-			-	+	+	+
Sulphuric acid	96	23	-			-	-	+	+
Silicon oil		23	+	+	+	+	+	+	+
Salad oil		23		o			+		
Carbon tetrachloride	100	23	+		o	+	o	-	+
Toluol	100	23	+		+	+	o	-	+
Trichlorethylene	100	23	+		o	+	o	-	+
Water, cold							+		
Water, hot							+		
Hydrogen peroxide	10	20	-			+	+		+
Hydrogen peroxide	30	23	-	-		+	+	+	+
Xylene	100	23	+	+	+	+	o	-	+

Introduction to the three common locking technologies used for cable ties

HellermannTyton offers a wide range of cable ties for use in different applications. By constantly refining our products and satisfying the ever-changing demands of the market, various locking technologies have been developed. Below you will find a brief overview of three most common locking technologies and their characteristics.

Cable ties with plastic pawls

This technology is used in 90% of all polyamide (PA) cable ties applied by HellermannTyton. In order to cover a variety of applications, there are different variants of this system, for example: releasable versions, in-line versions, open head versions.
These are one-piece cable ties, that is the pawl is moulded as an integral part of the cable tie, thereby building in inherent strengths.

Locking technology

Positive locking is achieved by engaging the pawl with the strap serrations. This allows the cable tie to perform to the published minimum tensile strength, that is the loading that the cable tie can hold under application.

KR series cable ties

This cable tie is distinguished by its smooth strap and unique locking mechanism. With the KR series the chamfered head achieves an especially firm fit around the bundled material.

Locking technology

This patented lock technology takes advantage of the excellent deformation properties of polyamide (PA). Here, the glass fibre-reinforced (GRP) locking pin (yellow) is forced into the strap by the use of an application tool - either the KR6/8 or KR8PNSE. The strap is deformed into the head of the tie by the application of the pin, thereby locking the cable tie in position and allowing for the bundling of heavy loads.

MBT series of cable ties

Made of stainless steel grades 304 or 316, the MBT range of cable ties have no serrations on the strap and are threaded parallel through the head, gliding under a metal ball-bearing locking mechanism. By using the MK9SST (see page 2/10) application tool the cable tie is tensioned and the strap cut to a flush finish.

Locking technology

The strap is locked into the head by means of the small ball-bearing. The ball locks into the small end of the wedged shape housing, forming a positive locking with the strap.
This cable tie is not suitable for rigid objects. Retraction of the ball-bearing (see drawing Fig 1.) is required into the small end of the wedged shaped housing to allow for a positive locking of the strap and also to make a flush cut of the end of the strap. Retraction, therefore, cannot take place with the bundling of inflexible materials. To bundle rigid objects LFPC channel (see page 2/40) should be laid as buffer between strap and bundled material to compensate for this retraction. This locking technology allows for minimum tensile strengths of up to 2225 Newton (227 kg).

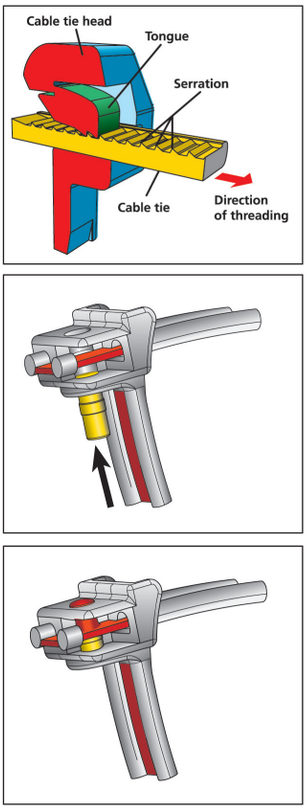
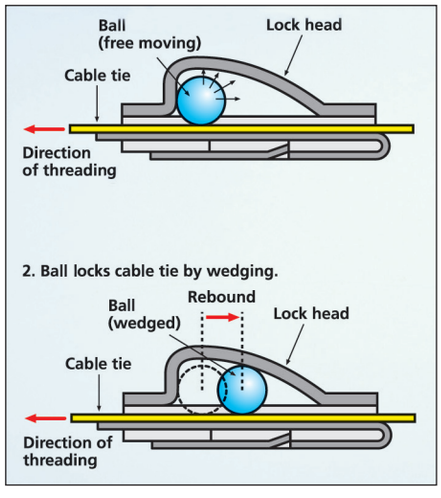


Fig 1.



Determination of minimum tensile strength

The minimum tensile strength is a critical selection criteria for cable ties. It expresses how much loading a cable tie can bear. This minimum tensile strength is determined in accordance with the Military Specification and Standards of the USA. Test conditions being laid down precisely in MIL-S-23190E:

- Conditioning of the test pieces.
- Construction of the test apparatus.
- Application of the tie on a split test probe.
- Test speed.

Explanation of minimum tensile strengths

What does a minimum tensile strength of 225 N (22 kg) mean?
To explain what this value means, the **mass** with which the tie can be loaded is calculated. The unit of measurement of the mass is stated in **kg**. To do so, the unit Newton (N) is shown in the following way:

[N] = [kg * m/s2]

The formula for calculating the mass is:

Mass =
minimum tensile strength/acceleration due to gravity

The acceleration due to gravity is 9.81 m/s2:

Mass =
minimum tensile strength/ [kg * m/s2] /9.81 [m/s2]

At a minimum tensile strength of 225 N (22 kg) the mass is:

Mass = 225 [kg * m/s2] /9.81 [m/s2]

The units m/s2 cancel each other out, leaving the unit [kg] for the mass. Thus:

Mass = 225/9.81 kg = 22.9 kg

Therefore, a T50R cable tie with a minimum tensile strength of 225 N (22 kg) can be loaded with 22.9 kg.
Conversely, with the required loading capacity the minimum tensile strength can be calculated by a mass:

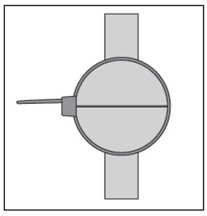
Min. tensile strength =
mass * 9.81[m/s2]

If the tie is to be loaded with, for example, 53 kg this produces:

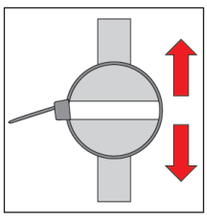
Minimum tensile strength =
[53 kg] * 9.81 [m/s2] = 520 N

In order to withstand a load of 53 kg, the tie must therefore have a minimum tensile strength of 520 N. In this case, select our T120R with a minimum tensile strength of 535 N (54 kg).

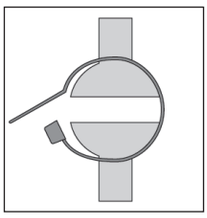
The test procedure to determine minimum tensile strength



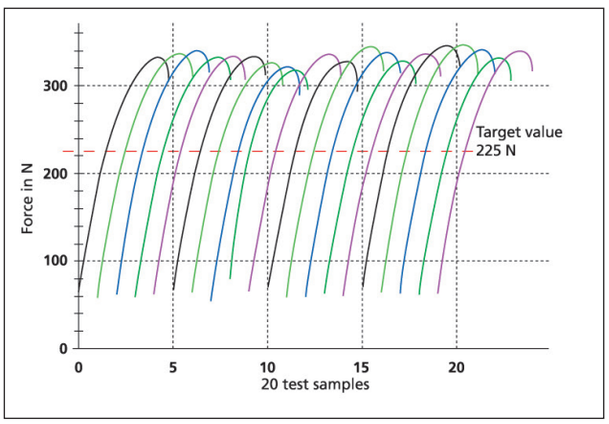
The cable tie is fixed onto a split mandrel test probe with the suitable cable tie application tool.



The mandrel is opened at a defined speed.



The loading at which the cable tie fails is determined. This value is stated in Newtons (N) and is recorded through a computer programme reading the tests. This programme produces graphs as outlined below.



Typical measurement protocol of a T50R made of PA66 with a minimum tensile strength of 225 N.

225 N/9,81 = 22,9 kg

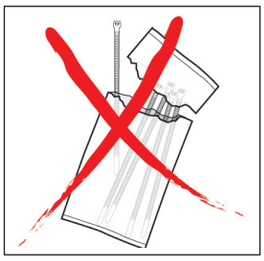
*53 kg * 9.81 = 520 N*

Optimum storage conditions for cable ties made of polyamide (PA)

HellermannTyton cable ties, fastenings and fixings are manufactured from high quality polyamide (PA). This industrial synthetic material is mainly processed using injection moulding, but can also be extruded.

Polyamide is a hygroscopic material. This means that the material absorbs and loses moisture. For optimum handling of cable ties it is important that the material is in a condition of equilibrium with a water content of approximately 2.5%.

The packaging used by HellermannTyton ensures that the water content in the material remains constant. Therefore, it is important to store the products in their original packaging to preserve the quality of the ties.

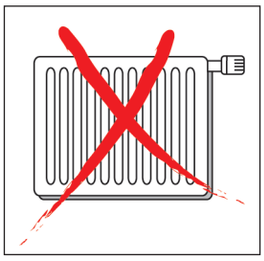


Always store ties in the sealed plastic bag made of polyethylene!

Once opened you should use the ties as quickly as possible!

Do not expose the product to direct sunlight!

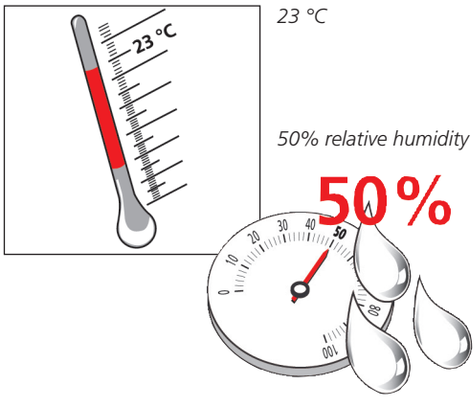
Do not store the product in sunlight; for example, on the window sill!



Store the product away from direct sources of heat!

Avoid contact with heat: for example, do not place on the radiators!

The ideal storage conditions are those of African standard climate:



23 °C

50% relative humidity

HellermannTyton cable ties conform to DIN standard

HellermannTyton is a supplier of high quality solutions for the routing, organising and securing of cables, hoses and pipes. The level of quality has been inspected by the VDE (Verband der Elektrotechnik, Elektronik, Informationstechnik e.V) [German Association for Electrical, Electronic and Information Technologies]. Cable ties from the inside-serrated T-Series and the outside serrated OS-Series have been tested in accordance to the cable tie standard DIN EN 50146 (VDE 0604 PART 201): 2000-12; EN 50146:1999-08. The result of this independent testing is complete compliance:

These cable ties therefore qualify to bear the VDE symbol.

In addition to cable ties made of the standard material polyamide 6.6 (PA66), ties made from heat-stabilised (PA66H) and UV-stabilised polyamide 6.6 (PA66W) have been successfully tested and approved.
HellermannTyton is the only manufacturer to offer cable ties with inside and outside serration with DIN approval. So all current applications in the field of electrical installation are covered.

The standard includes the following tests:

- Test of minimum installation temperature.
- Test of minimum application temperature.
- Minimum tensile strength (in the standard this is described as the looping test).
- Load test and heat ageing test.
- Temperature cycle test.
- Contribution to the spread of fire.
- Corrosion resistance.

The following HellermannTyton cable ties have been tested and certified:

T-Series inside-serrated cable ties

Polyamide 6.6 (all colours)	38 types x 11 colours	=	418 cable ties
Polyamide 6.6 heat-stabilised (all colours)	38 types x 11 colours	=	418 cable ties
Polyamide 6.6 UV stabilised (black)	38 types in black	=	38 cable ties
Total number of cable ties in T-Series to DIN standard			874 cable ties

OS-series outside-serrated cable ties (see page 2/29)

Polyamide 6.6 heat-stabilised (all colours)	7 types x 11 colours	=	77 cable ties
Total number of cable ties in OS series to DIN standard			77 cable ties
Total number of HellermannTyton cable ties to DIN standard			**951 cable ties**

Material Specification

Material	Operating Temperature	Colour	Flammability	Chem. Material Properties
Ethylenterafluorineethylene - Tefzel (E/TFE) RoHS	-80°C to +150°C	Blue (BU)	UL94 V0	This material absorbs radioactive and electron beams as well as UV radiation. It has very good chemical resistance, particularly with respect to acids, bases and oxidising agents. It does not absorb water.
Polyamide 6.6 High Impact Modified (PA66HIR) RoHS	-40°C to +80°C Continuous, (+105°C for 500 h)	Black (BK)	UL94 HB	The slightly impact-modified polyamide 6.6 (HIR) can also be processed at low temperatures.
Polyamide 6.6 High Impact Modified, Heat Stabilised (PA66HIRHS) RoHS	-40°C to +105°C	Black (BK)	UL94 HB	This material has the same properties as polyamide 6.6 HIR but, through the use of additives, has a temperature range extending to + 105°C.
Polyacetal (POM) RoHS	-40°C to +85°C	Natural (NT), Black (BK)	UL94 HB	This highly flexible material is resistant to both UV radiation and to the effect of chemicals. The slightly impact-modified POM has a high tensile strength and remains flexible even at low temperatures. The technical properties of POM are not affected by moisture.
Stainless Steel Type SS304, Type SS316 RoHS	-80°C to +538°C	Metal	–	A distinctive feature of this material is its corrosion resistance, it is non-rusting and antimagnetic.

Material Specification, Halogen Free

Material	Operating Temperature	Colour	Flammability	Chem. Material Properties
Polyamide 12 (PA12) RoHS	-40°C to +85°C Continuous, (+105°C for 500 h)	Black (BK)	UL94 HB	Polyamides 11 and 12 have good chemical resistance. They have limited resistance to acids, bases and oxidising agents but very good UV stability. The melting of N11 (185°C) is higher than that of N12 (175 °C).
Polyamide 6.6 (PA66) RoHS	-40°C to +85°C Continuous, (+105°C for 500 h)	Natural (NT), Black (BK)**	UL94 V2	This material has a very high tensile strength and can be used up to a temperature of +85°C.
Polyamide 6.6 Heat Stabilised (PA66HS) RoHS	-40°C to +105°C Continuous, (+145°C for 500 h)	Natural (NT), Black (BK)**	UL94 V2	This material has the same properties as polyamide 6.6 (N66) but, through the use of additives in the material, the temperature range has been extended up to + 105°C.
Polyamide 6.6 UV Resistant (PA66W) RoHS	-40°C to +85°C Continuous, (+105°C for 500 h)	Black (BK)	UL94 V2	This material has been rendered weather resistant by the use of additives. It is particularly suitable for outdoor use, i.e. in direct sunlight.
Polypropylene (PP) RoHS	-20°C to +85°C	Natural (NT), Black (BK)**	UL94 HB	Polypropylene has a good resistance to organic acids. The density of the material is less than that of water and so polypropylene floats.
Thermoplastic Polyurethane (TPU) RoHS	-40°C to +85°C Halogen Free	Black (BK)	UL94 HB	Thermoplastic polypropylene is highly elastic and resistant to UV light. It has good chemical resistance to acids, bases and oxidising agents.

Material Specification, Limited Fire Hazard

Material	Operating Temperature	Colour	Flammability	Chem. Material Properties
Polyamide 4.6 (PA46) RoHS	-40°C to +150°C for 5000 h, (+195°C for 500 h)	Natural (NA), Grey (GY)**	UL94 V2	Polyamide 4.6 withstands high temperatures. The combustion performance of this plastic meets UL94 V2. It is also halogen free and, in the event of a fire, is characterised by its minimal generation of smoke, toxic fumes and corrosive acids.
Polyamide 6.6 V0 (PA66V0) RoHS	-40°C to +85°C Continuous, (+105°C for 500 h)	White (WH)	UL94 V0	This material conforms with both the UL94 V0 standards and the requirements relating to low smoke generation and evolution of toxic gases and corrosive acids in the event of a fire.
Polyolefin RoHS	-40°C to +90°C	Black (BK)	UL94 V0	Polyolefins also have flame propagation characteristics in compliance with UL94 V0. They are halogen free, self-extinguishing and, in the event of a fire, are characterised by their minimal generation of smoke, toxic fumes and corrosive acids. They are stable in water, salt solutions, acids and oxidising agents.

Tefzel® is a registered trademark of DuPont.

* These details are only rough guide values. They should be regarded as a material specification and are no substitute for a suitability test. Please see our datasheets for further details.

** Other colours on request.