Arnitel® TPE-E

General information on applications, processing and properties

DSM Engineering Plastics

Unlimited. DSM

Contents

DSM is a highly integrated group of companies that is active worldwide in life science products, performance materials and industrial chemicals. The group has annual sales of EUR 8 billion and employs about 22,000 people at more than 200 sites worldwide. DSM's strategic objective is to secure, by 2005, a place among the world's leading specialty companies, with businesses characterized by high added value, strong growth and more stable profit levels. DSM's focus will be on advanced chemical and biotechnological products and performance materials in which the company will hold global leadership positions.

Arnitel® team - dedicated to you

Our organisation is dedicated to our customers. We have Arnitel® dedicated sales representatives in Korea, Japan, China, Taiwan, Singapore and India. Thus direct support is immediately available, backed up by Technical Marketing and Technical Field Service Engineers who visit customers regularly. These people are coached by a Regional Product Manager and supported by Global Research department. The Arnitel® organisation has the same structure in Europe, USA and Asia. This allows us to create synergy for you across the regions.

DSM Engineering Plastics is a business group forming part of DSM's Performance Materials cluster. DSM EP is a global supplier of various types of polyamides (PA6, PA66 and PA46), polyesters (PBT, PET and TPE-E), polycarbonate and Ultra High Molecular Weight PE and extrudable adhesive resins. These materials are used in technical components for electrical appliances, electronic equipment and cars, as well as in mechanical and extrusion applications. The business group has annual sales of EUR 603 million in 2001.

DSM Engineering Plastics operates in all major markets of the world including Asia, the Americas and Europe. Within each region customers can count on our innovative research, development, and support facilities. Our in-house resources are backed by a corporate research and development center that is utilized in creating new solutions for customer needs. The advanced level of account management, in combination with our effective global communication network secures the support customers need wherever it is required.

With polymerization and compounding facilities for a range of polyamides, polyesters and polycarbonates, we serve our global customers base and assure constant, reliable supply of products.

Recently, DSM completed major investments in the building of Akulon® polyamide 6 polymerization plants both in the USA and in the Netherlands, as well as finalizing a joint venture with Xinhui in China for the production of polyamide 6 polymer. The capacity of the polymerization plant for Stanyl® polyamide 46 in the Netherlands was increased by 30% to meet the high growth demand for this product. Besides this, DSM EP expanded the Arnitel® production by 50% over the past 4 years, with a new expansion implemented in 2003.

All our compounding facilities in the world (in China, the Netherlands, Belgium, USA, Canada, and India) are being expanded continuously to keep up with the growing demand.

As a result of a constant product innovation and creation process, DSM Engineering Plastics can offer a cohesive portfolio of high performing engineering plastics. Established trade names are:
Arnitel® (TPE-E)
Akulon® (PA6 and PA66)
Akulon® **Ultraflow**™ (high flow Akulon PA6)
Arnite® (PBT, PET)
Stanyl® (PA46)
Stanyl® **High Flow** (high flow PA46)
Stapron® (PC-blends)
Xantar® (PC)

These materials all have their specific properties, yet they share the same high quality, thanks to state-of-the-art production processes and quality systems, like Total Quality Management, ISO 9001 and QS 9000. It is an approach to quality that can be found throughout the DSM organization:

- in relations with industry partners, working closely together in true co-makership, ready to meet any technical challenge.
- in technical service and after sales, providing support to help customers optimize their processes.
- in logistics and delivery, shipping products anywhere in the world, quickly and reliably.

From product concept, through processing, to final application DSM Engineering Plastics delivers the portfolio, the skills and the global presence to help its industrial partners create world-class products and solutions.

It's surprising what we can do together!

Production sites

Asia Pacific

Jiangsu - China
(compounding)

Pune - India
(compounding)

Tokyo - Japan
(compounding)

Europe

Emmen - Netherlands
(polymerization and compounding)

Geleen - Netherlands
(polymerization)

Genk - Belgium
(compounding)

Stade - Germany
(polymerization)

North America

Evansville - Indiana
(compounding)

Augusta - Georgia
(polymerization)

Stoney Creek - Ontario Canada
(compounding)

Introduction

Arnitel® overview

Arnitel® is a family of thermoplastic copolyester based elastomers (TPE-E or COPE). These copolyesters combine the strength and processing characteristics of engineering plastics with the performance of thermoset elastomers providing benefits in processing and productivity.

As thermoplastics, they do not require vulcanisation to obtain their optimal properties, which often leads to substantial reductions in part cost. Relative to other elastomers, polyester-based materials offer the most consistent performance over their entire operating temperature range since their properties vary little from low to high temperature extremes.

Arnitel® TPE-E is produced in three types, each utilizing specific chemistry. The three types are “E”, “P” and “U”. The Arnitel® E and P types are more traditional polyether-ester formulations, while Arnitel® U grades are based on unique polyesterester technology that extends the traditional temperature range of thermoplastic elastomers. Arnitel® copolyester elastomers are positioned in the high performance regions of the elastomers spectrum (see Figures 1, 2 and 3).

Figure 1.
Positioning of Arnitel® Copolyester elastomers relative to other TPE’s on a hardness scale.

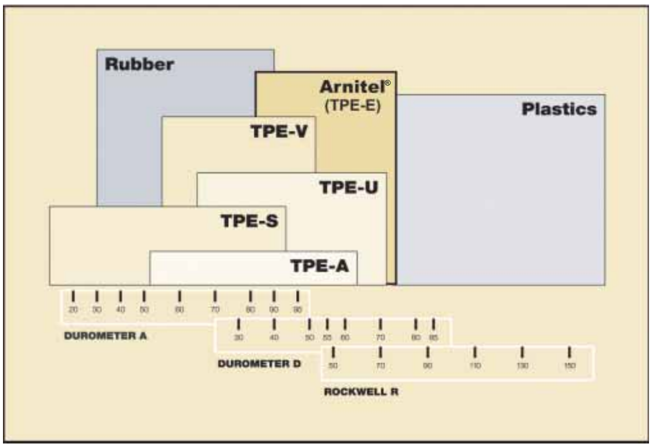


Figure 2.
Positioning of Thermo-plastic elastomers versus thermoset materials.

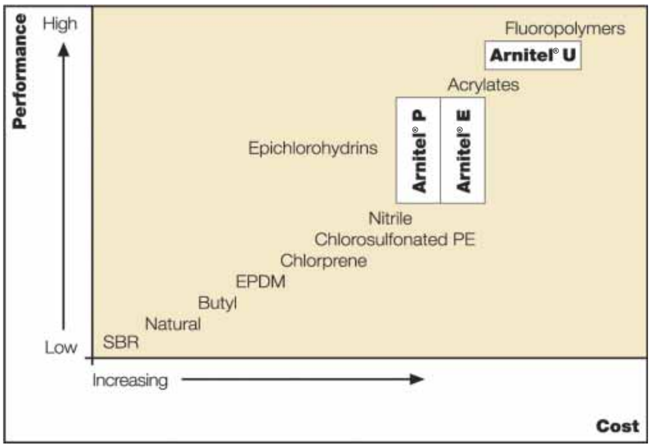
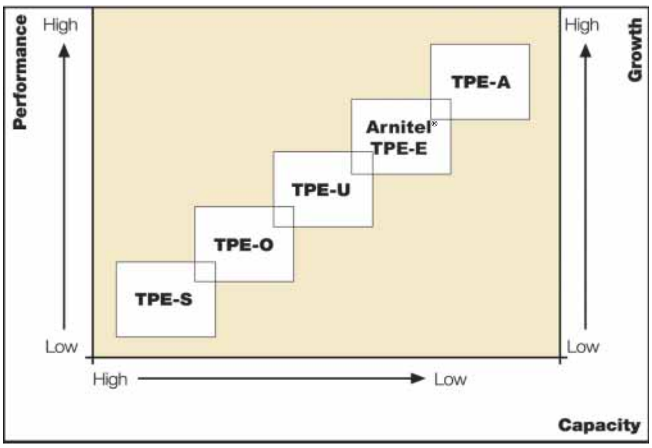


Figure 3.
TPE’s positioning in Performance capacity/ growth.



Copolyester elastomers product scope

Table 1.
Arnitel® product range.

Shore D	38/42	46/47	50	55/58	63	74
Arnitel® E	EM400 EM401	EB463 EB464 EM460	EB500	EL550 EM550	EL630 EM630	EL740 EM740
Arnitel® P	PL381 PM381	PL460 PL460-S		PL581 PM581		

Table 2.
Arnitel® product coding.

U	M	55	1-	V

Thermoplastic elastomer type

E = poly**ether**-ester
P = poly**ether**-ester
U = poly**ester**-ester

Indication of viscosity range or processing technigue

L = injection moulding
M = extrusion
B = blow moulding

Hardness (Shore D)

Serial number

Specific properties

S = flame retardant (V-0), halogen containing
G = glass fiber teinforced
V = flame retardant (not V-0), halogen free

The Arnitel® product range offers grades with hardnesses from 38 to 74 Shore D (see Table 1). Besides these multi-purpose grades, specialty grades are available for specific applications. General characteristics can be determined from the product coding. This is demonstrated in Table 2.

DSM has developed a number of masterbatches to improve heat, hydrolysis stability and UV stability (see Table 3).

More detailed information can be obtained through your local DSM sales office.

Table 3.
Masterbatches available.

Type of stabilizer	Name	Typical addition (weight %)
Heat ageing for Arnitel® E or P	Arnitel® E - Heat	0.50 - 3.00
UV for Arnitel® E or P	Arnitel® E - UV	1.25 - 2.50
Hydrolysis for Arnitel® E or P	Stabaxol® KE9514*	2.50 - 7.50
Hydrolysis for Arnitel® U	Stabaxol® KE9464*	8.00 - 10.00

**Stabaxol is a registered trademark of Rhein Chemie Corp.*

Characteristic properties of Arnitel®

General properties

Arnitel® components.
Arnitel® copolyesters consist of fully polymerized hard and soft segments (see Figure 4).The hard segments are crystalline polybutylene-terephthalate (PBT); the soft segments are amorphous polyesters or polyethers. The range of Arnitel® grades cover a broad variety of applications where flexibility, durability, high and low temperature performance and/or mechanical strength are required.

Figure 4.
Arnitel® composition.

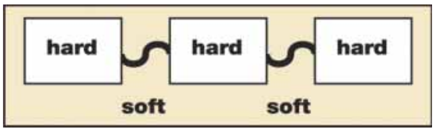


Table 4.
Arnitel® property profile.

Property profile	Arnitel® E Polyether-ester	Arnitel® P Polyether-ester	Arnitel® U Polyester-ester
Stability*:			
- heat ageing	++	++	+++
- UV	++	+	+++
- hydrolysis	+++	++	o
Low temp. impact properties	++	+++	+++
Tear strength	+++	++	++
Chemical resistance	++	+	+
Oil resistance	+++	+++	+++
Dielectric	+++	+/-	+/-
Wear	++	+	+
Water/vapor	++	+++	+++

** heat, UV and hydrolysis resistance can be improved by adding respective masterbatches.*

Arnitel® properties.
The ratio of soft to hard block and the composition of the soft segment can be varied, creating a wide range of properties. Main characteristics of Arnitel® include:

- excellent flexural fatigue endurance.
- high peak temperature resistance.
- high impact strength, even at low temperatures.
- high tear and abrasion resistance.
- good resistance to chemicals and weathering.
- good electrical properties.
- high load-bearing capability.
- excellent over-moulding adhesion to ABS, PBT, PC and metals.
- good tactile feel.
- excellent adhesion to paint and glues.
- high MVTR (Moisture Vapour Transmission Rate).

In addition, Arnitel® U offers:

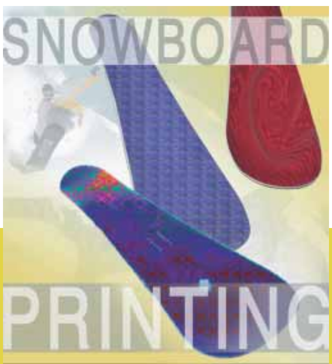
- UL listed continuous use temperature of 160°C.
- the best UV stability of elastomers.
- Excellent (Urethane-like) abrasion resistance.
- inherent resistance to copper initiated degradation.

Table 4 illustrates the performance of each specific Arnitel® product range.

Colouring.
There are several options for colouring Arnitel®:

- dust the granules in drum mixers while adding approximately 0.2% of dusting oil if needed.
- use colour concentrates (master batches). These can be based on TPE-E (Arnitel®), LDPE, EVA or liquid colouring.

In principle the performance of PE based MB will lead to sufficient colouring. To prevent blooming of the polyethylene it is advised to leave the dosage below 2%.
If colour consistency or heat resistance are needed, it is strongly recommended to use Arnitel® based MB. If you use Arnitel® based MB, it's best to use the base material as carrier. If not available the use of EM460 is recommended due to melting point and compatibility.



Snowboard cover laminates
benefits from Arnitel® are UV resistance and colour stability.

Packaging.
Arnitel® is supplied dry in airtight moisture-proof packaging, so pre-drying is not needed. The granules are supplied ready for use in standard bags of 20 or 25 kg. To obtain optimum consistency in processing, for more critical processes (like optical fiber coating), we advise to pre-dry the material to a constant moisture content. This is especially important for a running change over.

Moisture absorption.
Granules that have been exposed to ambient air for too long, will pick up a certain degree of moisture. To avoid processing problems and any adverse effect on the quality of the mouldings, moisture absorption prior to moulding must be limited as much as possible. During storage, packaging should be kept closed and undamaged.

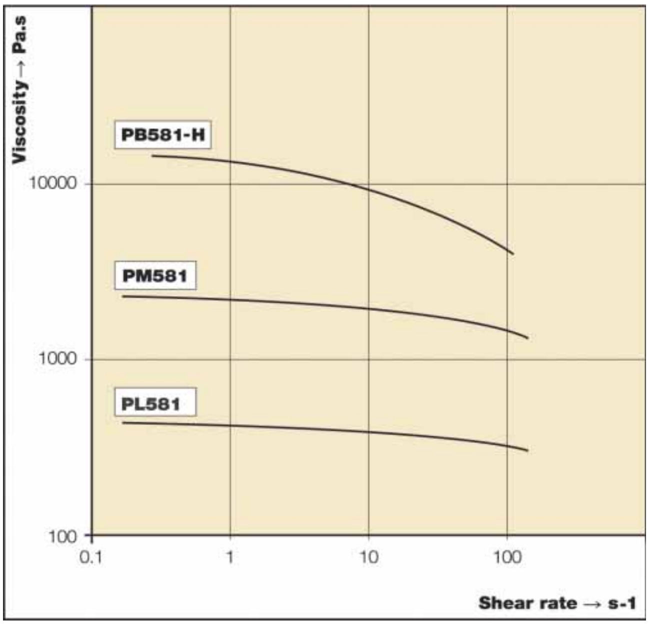
The following measures are recommended:

- bring cold granules up to ambient temperature in the processing room in closed packaging.
- open packaging just before filling.
- close packaging securely if some of the contents were not used.

A dehumidified air oven or vacuum drier may be used if drying should become necessary.

Typical drying conditions are 24 hours at 80°C in a dry air/nitrogen flow oven. Short term drying is preferred for 4 hours at 120°C.

Figure 5.
Viscosity of blow moulding (B), extrusion (M) and injection (L) grades.



Safety.
Under normal conditions, Arnitel® does not present a toxic hazard through skin contact or inhalation. During processing, avoid contact with hot or molten polymer and do not inhale fumes.

Rheology

For almost every hardness and chemical family of Arnitel®, different viscosities are available to suit the requirements of injection moulding, extrusion or blow moulding conversion processes (see Figure 5).

Lower viscosities are available for injection moulding, optimizing flow path lengths and weld lines, especially in parts with low wall thicknesses such as tear seams in airbag doors or in keypads. The higher crystallization temperatures of our Arnitel® grades combined with lower viscosities generally result in shorter cycle times. Medium viscosities are available for extrusion processes.

Melt stability of the extrudate is exceptional. Tighter tolerances are attainable at higher line speeds on semi-finished and finished extruded products.

For extrusion of electrical cable and tight buffer tubes we advise to use injection moulding grades for it will increase the line speed and the consistency of wall thickness. Blow moulding viscosities exhibit good rheological consistency for better parison reproducibility. Again, higher crystallization temperatures help minimize cycle times.

Body plugs.
Plugs produced in injection molding with large over and undercuts to seal holes in the car frame and prevent future corrosion.

Mechanical properties

The key to determining which copolyester is most suitable for an application is understanding the balance required between the mechanical load bearing capability of the material and the elasticity required for dynamic performance. The most useful data in making this determination are plots of modulus versus temperature and stress-strain curves.

The stiffness of the product depends on the composition of the amorphous soft block and the crystalline hard block. As the proportion of the hard block increases, the specific gravity, stiffness properties, chemical resistance, creep resistance and load bearing capability all increase. So does resistance to oxidative ageing.

As the proportion of the hard block decreases, the cold temperature impact, flexural fatigue, elongation at yield, and compression set properties improve. At high soft block proportions, the elastomeric properties of the soft block dominate. Hydrolysis resistance will generally improve. UV stability of Arnitel® is good, with the best performance obtained at hardness of 55-63 Shore D.

Figure 6.
Modulus versus temperature by grade for Arnitel® E-grades.

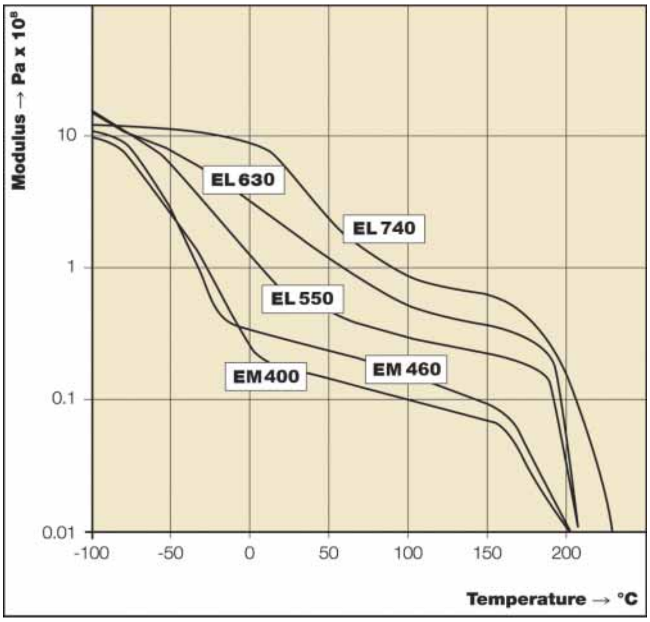
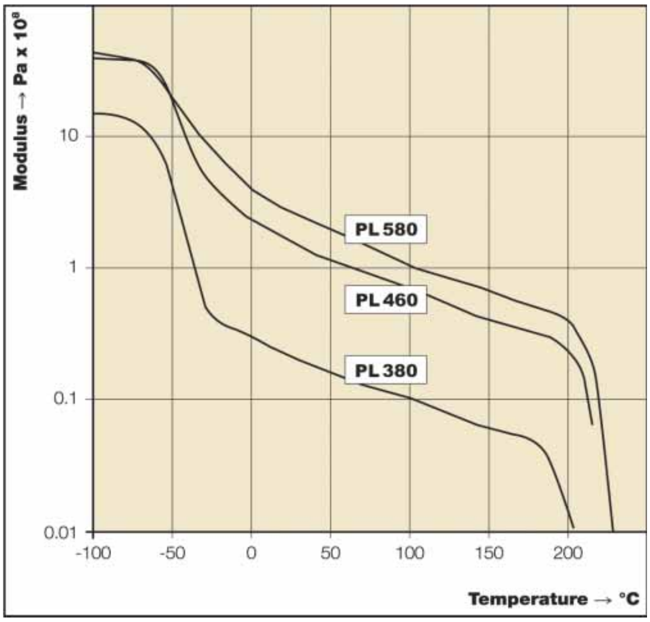


Figure 7.
Modulus versus temperature for Arnitel® P grades.



Pliers.
Pliers with Arnitel® coating providing excellent di-electrical properties that makes them suitable for working with high voltage equipment.

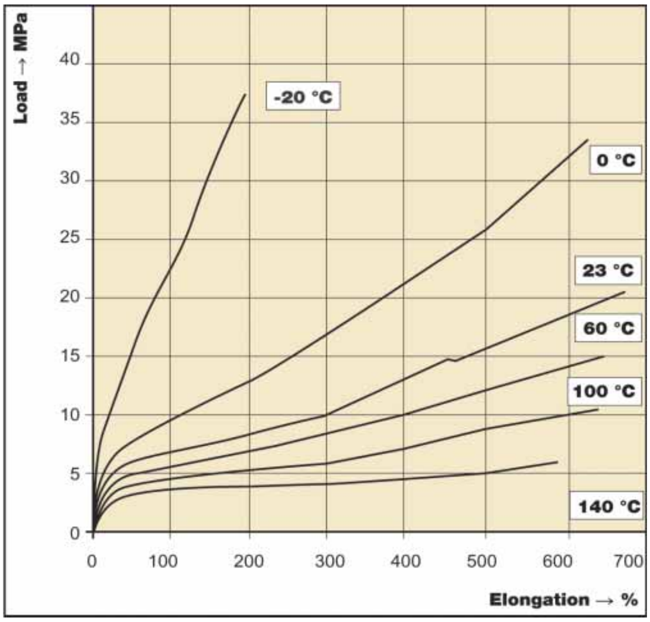


Figure 8.
Arnitel® EM 400 stress strain curves low strain (ISO 527-1BA test specimen, parallel to flow, 50 mm/min).

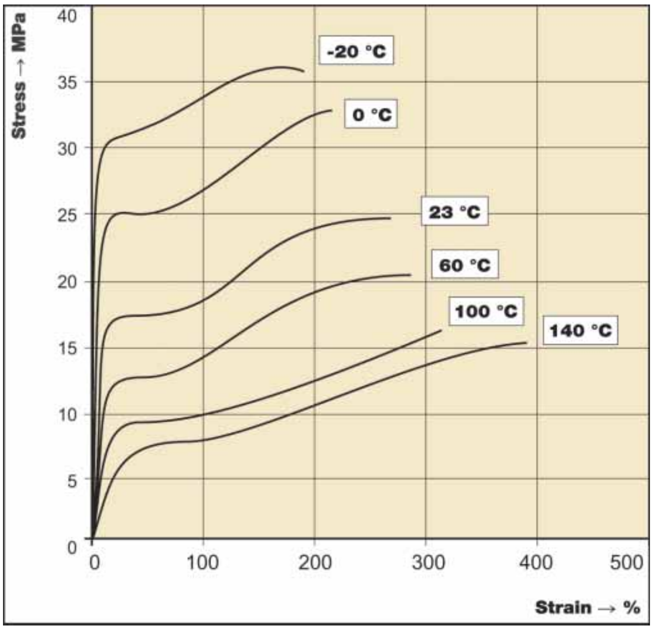


Figure 9.
Arnitel® PM581 stress strain curves (ISO 527-1BA test specimen, parallel to flow, 50 mm/min).

Copolyesters will function as elastomers as long the operating temperature is within the rubbery plateau (between glass transition and the melting point) for a given grade. This is the flatter portion of the modulus versus temperature plots (see Figures 6 and 7), typically between temperatures of -40 and 150°C. Cold temperature fatigue capabilities are excellent for the 40 Shore D and 46 Shore D materials.

The softer Arnitel® grades will also outperform the harder copolyester elastomers with respect to compression set, cold temperature impact and exhibit higher elongation at yield (high working strains).

The EL630 and EL740 materials are not as tough at cold temperatures but will show better load bearing capability at high temperatures, creep resistance and chemical resistance. The 55 Shore D materials are often preferred for their balance of both mechanical and elastic capabilities.

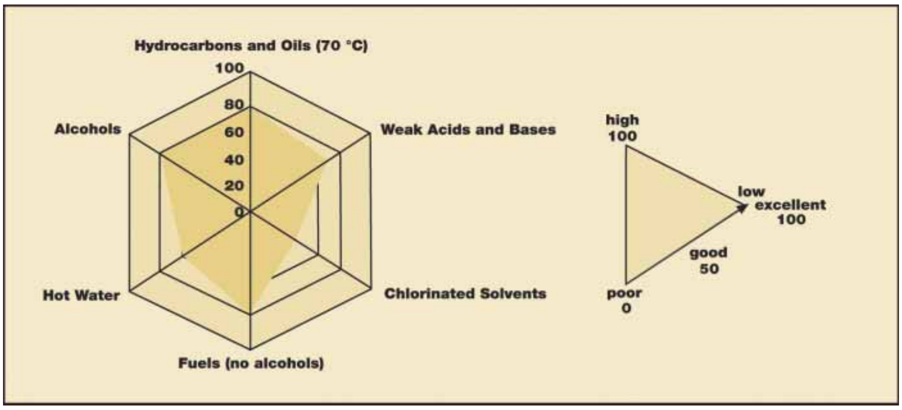
Stress-strain curves are important to understand the elastic behaviour of elastomers (see Figures 8 and 9). Usually, the lower the hardness (and stiffness) of a material, the lower the stress at yield and the higher the elongation at yield. This defines the strain range in which the material will function with elastic behaviour. Exceed the yield point, and permanent plastic deformation and dimensional change will occur in the part.

Binding strap.
Binding Straps in Arnitel® provide both excellent low temperature ductility and very high load bearing capacity resulting in excellent safety records and comfort.

Electrical properties

Copolyester elastomers exhibit good electrical properties. Surface and volume resistivities are high, as are dielectric strength, dielectric constant and dissipation factor. Due to the low moisture absorption exhibited by the Arnitel® E and Arnitel® U families of copolyesters, these materials are preferred in electrical applications over Arnitel® P. The latter is in principle only suitable for jacket material. All Arnitel® types are intrinsically stable against copper. Two flame retardant V-0 grades are available. Furthermore, Arnitel® U is available as low smoke V-2 halogen free grade. This system of FR can be used in all other Arnitel® grades as well.

Figure 10.
Arnitel® PM581 chemical resistance.



Chemical resistance

Chemical resistance improves with increasing hardness. The reason is the amorphous soft block is more susceptible to chemical attack than the crystalline hard block. As the hard block content increases, chemical resistance improves. The property retention in certain types of chemicals for a selected Arnitel® grade, PM581, is shown in general terms in Figure 10.

As a class of materials, copolyesters show excellent chemical resistance to greases, hydrocarbons, fuels and oils. As the polarity of a solvent increases, copolyesters will show less stability in the presence of hot water or strong acids or bases and alcohols at temperatures above 60°C. Highly chlorinated solvents should be avoided.

Detailed data on chemical resistance are available on request. A summary can be found in the attachment.

Handcuff holder.
This Arnitel® Hand cuff holder provides space to store 3 handcuffs. The system weighs less than one metal cuff.

Typical Arnitel® Applications Airducts

An airduct transports the air needed for combustion of the fuel in a car. It is complex system that conveys the air through a filter to the manifold on top of the engine. In the case of diesel engines, a turbocharger and an air-cooler are used (see Figures 11 and 12).

Three basic ducts can be found:

Charged airducts
(only in combination with turbochargers) that have to function at 1.8-2.2 bar and 150 -175°C with oil polluted air.

Charged airducts
that see the same pressure but lower temperatures of 60-100°C.

Clean airducts
Sometimes exposed to high temperature peaks. These airducts operate at -200 mbar pressure. Details are found in Table 5.

The processing method is usually 3-D and suction blow moulding, a shaping technique that allows fabrication of long hollow shapes with relatively simple, low cost moulds and little waste.
The combination of ease of assembly and simple processing has been the main driver for widespread use of Arnitel in these applications.

Arnitel advantages

- Light in weight due to inherent good properties at high temperature
- high continuous use temperature of 1000 hrs at 150°C.
- flexibility that allows compensation of engine movements and ease of assembly.
- high melting point allowing temperature peaks up to 205°C.
- oil resistance at high temperatures (150°C).
- blow mouldable. Blow moulding of Arnitel® reduces the number of parts and assembly operations and is thus cheaper than traditional rubber solutions.

Figure 11.
Air management systems with clean airducts from Arnitel®.

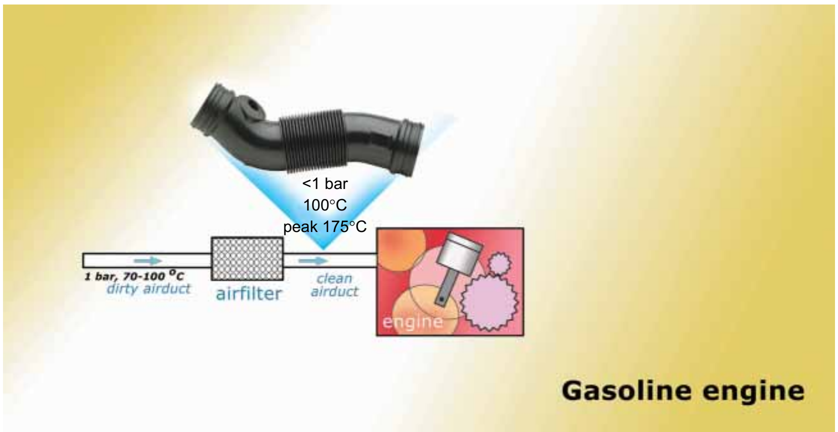


Figure 12.
Air management systems with clean and charged airducts from Arnitel®.

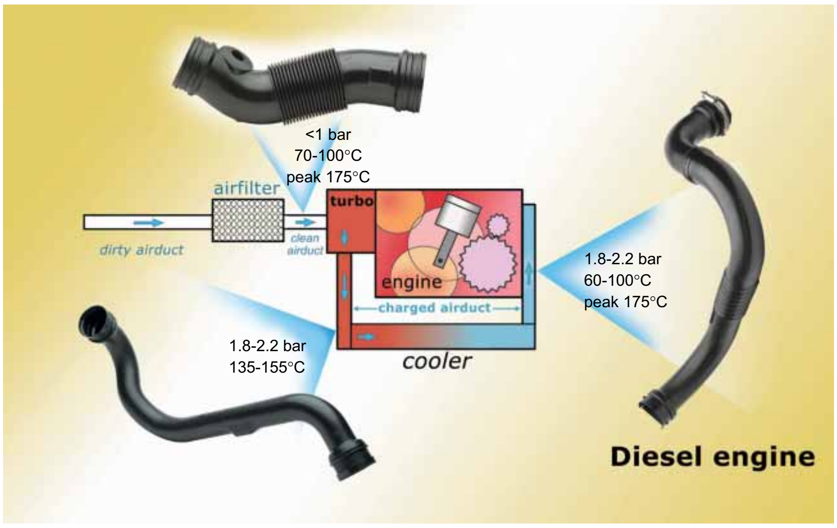


Table 5.
Performance matrix clean and charged airducts.

Type airduct (type of engine)	**Continuous temp.** (3000 hrs)(°C)	**Peak temp.** (°C)	**Material**
Charged (diesel)	155	175 (300 hrs)	Arnitel® Polyamide 6 GF, silicone rubber
	135	155 (300 hrs)	Arnitel® PB582-H
	60-100 (exit cooler)	175 (10 min)	Arnitel® PB582-H
Clean (diesel + gasoline)	70-100	175 (10 min)	Arnitel® PB582-H / EB500
		150 (10 min)	Sarlink® TPV / PP

Arnitel® grades.

Suitable airduct grades are: PB582-H, EB500

Boots for Constant Velocity Joints

Copolyester elastomers (TPE-E's) and chloroprene CR-rubbers (see Figure 13) are established as suitable materials for use in Constant Velocity Joint (CVJ) boots. In front wheel driven cars, CVJ boots retain the grease inside the joints while keeping mud, water and salt out. The number of applications for TPE-E's is expanding, as they are used increasingly to replace rubber in both fixed (wheel) and plunge (engine/ transmission) boots. TPE-E's are cost effective and offer several performance advantages over rubber including (see Table 6 for positioning):

- 50% weight savings, 90% shorter cycle times.
- better product consistency.
- improved chemical resistance.
- better flexibility and fatigue resistance
- lower centrifugal expansion at high spin rates.
- less maintenance.
- better toughness, especially at cold temperatures
- longer lifetime
- recyclable, permitting up to 30% regrind use during processing
- better ozone resistance.

Figure 13.
CAE-analysis of CR-fixed boot.

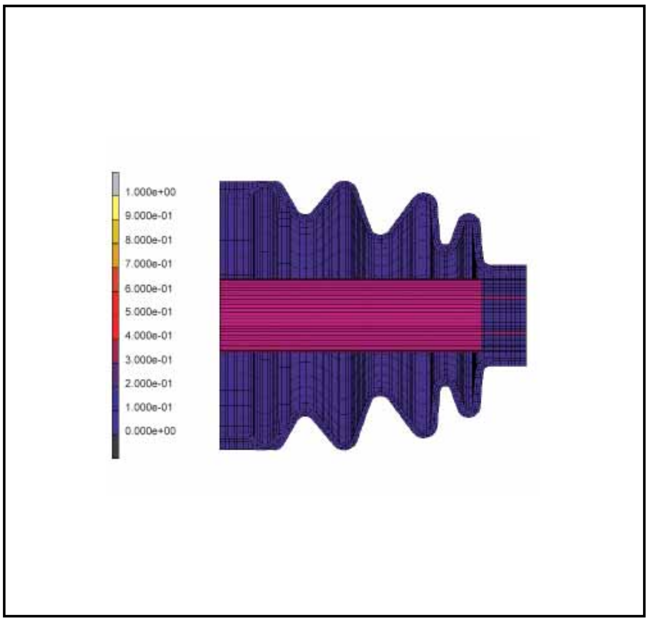
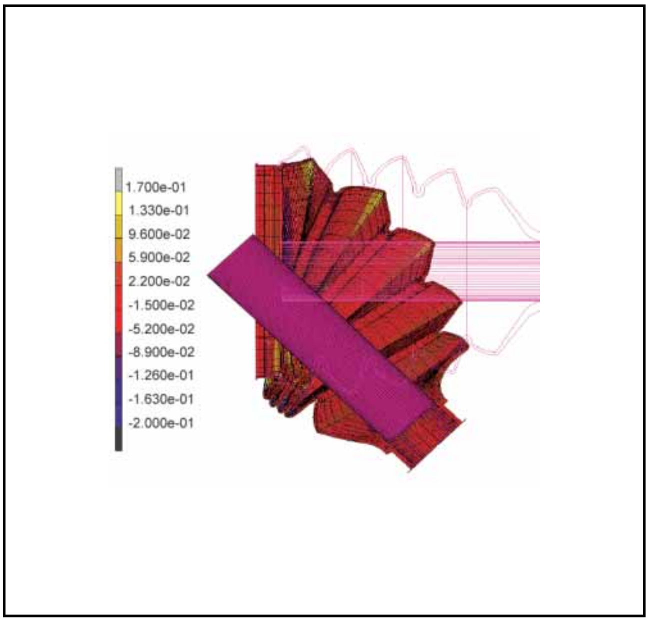


Figure 14.
Example of CVJ boot design in Arnitel®.



Constant Velocity Joint boot
CR-rubber replaced by Arnitel®.

Arnitel® is an ideal and cost effective material solution for CVJ boots, but design factors must also be taken into account (see Figure 14). These factors include:

- hinging boot to leverage TPE-E's flexural fatigue capabilities.
- eliminating kinking in the design by pressing the boot to install it and ensuring the maximum extended length in service does not exceed the original manufactured boot length.
- ensuring that the material distribution at the peaks and valleys of the convolutes is optimised to balance flexural fatigue performance and mechanical loading requirements (tear, impact and high speed spin).

DSM offers a complete Arnitel® range for CVJ boots and R&P bellows depending on the requirements of the end user, in combination with professional design support. (see Table 7)

Apart from the Arnitel® grades EB463 and EB464, new grades are offered to meet the latest requirements:

- higher turning angles up to 50 degrees
- wider temperature operating range from -45 to +140°C
- more compact designs
- new greases
- less noise generation during operation.

Table 6.
Positioning of Arnitel® in fixed CVJ boots.

Property	Arnitel®			CR-rubber
	EB464	EB463	3103	
Dynamic cold start -40°C	+	o	+	-
Dynamic abrasion resistance at 23°C	+	+	±	o
Dynamic grease resistance at 100°C	++	++	++	o
Dynamic grease resistance at 90°C	+++	+++	++	o
Ossberger process	++	++	++	n.a.
Use of regrind upon 30%	okay	okay	okay	not okay

o fair
+ good
++ very good
+++ excellent
n.a. not available

Table 7.
Portfolio for fixed CVJ boots.

Grade	Dynamic behaviour at -40°C	Grease resistance at 100°C	Processing consistency
EB463		✓	✓
EB464	✓	✓	✓

DSM also offers materials for Plunge boots. The most optimium solution is Arnitel® 3103, a material combining excellent grease stability with the heat requirements needed in this field.

For propshaft boots (4x4), we offer both EB500 and EB464 easily fulfilling specifications in this field.

Other suitable blow moulding applications for Arnitel® include turbo diesel engine air ducts, springs and other boot applications.

More detailed information can be obtained through your local DSM sales office.

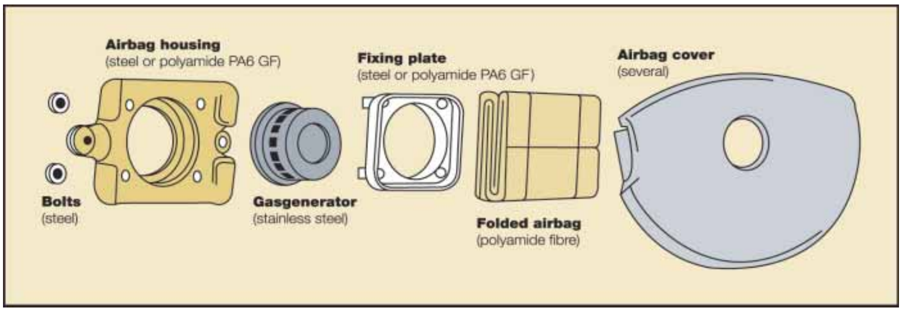
CVJ boot
in Arnitel® EB463 developed with GKN Automotive.

Airbag covers

The driver's airbag is considered as one of the most important parts of a vehicle's occupant restraint system. In combination with seat belts and other safety systems, the airbag must respond to a vehicle crash within milliseconds. Extra occupant protection is given by use of side airbags, headrest airbags, curtains, knee bolsters etc. Therefore it is crucial that the function is guaranteed under the most extreme circumstances for a period of 15 years. The cover is an essential part of the airbag system and Arnitel® is widely used as an airbag cover material. When the airbag is activated, the cover should be opened in milliseconds via a pre-programmed tear-seam line in order to release the inflating bag. The main requirements for the airbag cover material are a ductile behaviour at -35°C and significant strength at +85°C, in combination with a constant modulus over the same temperature range. The ductile behaviour of the material at -35°C is mainly needed for the drivers airbag cover to avoid face injuries due to flying splinters. The strength at +85°C is needed to keep the airbag module in place during deployment. In Figure 15, a schematic overview is shown of all components of a drivers airbag system.

Arnitel® can be used for driver- and passenger-side airbag covers, for side airbags inside door panels or seats or A-pillars, and in knee bolsters and many others.

Figure 15.
Schematic overview of all components of a drivers airbag system.



Arnitel® PL471 is the specific grade airbag cover industry. Arnitel® PL471 is a low modulus grade used for for airbag cover applications, combining the excellent low temperature properties and high flexibility of elastomers with the easy processing features of copolyester elastomers. Arnitel® PL471 can be used on its own for 1K systems, or in combination with Arnitel® EM402-L in 2K airbag cover systems.

Materials for airbag cover applications have to meet the following requirements.

Functionality

- temperature range: -35°C to +85°C (AK-LV 07)
- should not crack or splinter during deployment nor emit particles
- should stay in place during deployment
- cover should withstand frontal crash
- life time 15 years.

Aesthetics

- soft touch and compatible with the steering wheel.
- good appearance relative to the steering wheel.
- cover must be paintable, however the applied paint may not affect the performance.

Arnitel® PL471 satisfies the basic requirements of:

- minimal change in properties across the temperature range.
- required stiffness over the temperature range -35°C and +85°C.
- when painted, good adhesion and no loss in properties, and offers in addition.
- no break at -35°C notched impact testing.

Figure 16 shows the Stress-Strain plots of Arnitel® PL471 at temperatures of -40°C, 23°C and +90°C respectively. This data can be used for design purposes etc.

In Figure 17 the Shear Modulus of Arnitel® PL471 is plotted versus temperature. For airbag cover applications a relatively flat modulus curve of the material from -35°C to +85°C is required. For very low temperature deployment (actual -40°C) testing, there is a special grade offered in 46 shore D hardness being PM471.

Table 8 lists the relevant mechanical properties of Arnitel® PL471.

Audi A4 side **airbag cover**, developed by Takata-Petri AG.

Figure 16.
Stress-strain curves of Arnitel® PL471 at -40, 23 and 90°C.

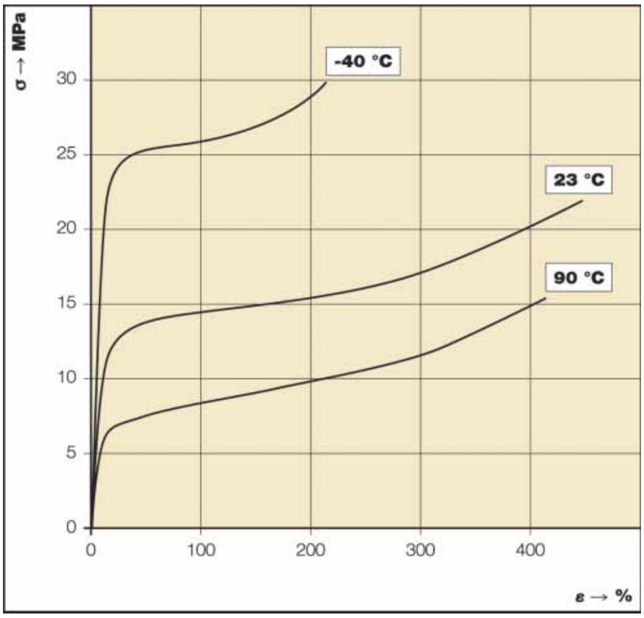
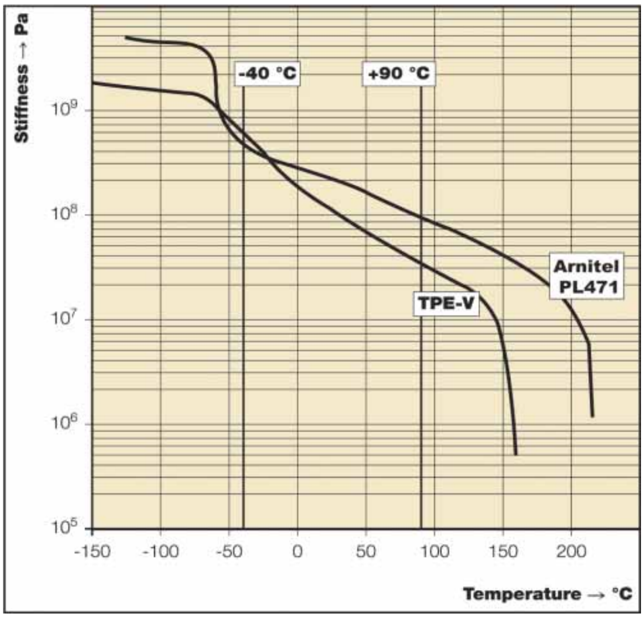


Figure 17.
Arnitel® in airbag doors: temperature versus stiffness.



Painting.
Arnitel® PL471 can be painted easily with most standard flexible PUR paints. Suitable paints are offered by paint manufacturers, in close collaboration with DSM.

Shrinkage

When molten plastic solidifies, it is accompanied by shrinkage which, in the first instance, is compensated by holding pressure. Any shrinkage which occurs after the gate(s) freeze is not compensated, nor is the shrinkage caused by after crystallization and thermal shrinkage. Designers should take into account that the finished product dimensions will be smaller than the mould dimensions. For the Arnitel® PL471 airbag grade, a mould shrinkage between 1.5% in the flow direction and 1.7% transverse to the flow is typical for parts with wall thicknesses under 2 mm.

Table 8.
Most relevant mechanical properties for Arnitel® PL471.

Arnitel® PL471		
Hardness	ISO R868	46 Shore D
Density	ISO 1183	1.20
Tensile strength 23°C - Yield stress max. - Elongation at break - Tensile modulus	ISO 527	20 MPa 15 MPa 600% 280 MPa
Tensile strength -40°C - Yield stress max. - Elongation at break - Tensile modulus	ISO 527	30 MPa 25 MPa 215% 440 MPa
Tensile strength 90°C - Yield stress max. - Elongation at break - Tensile modulus	ISO 527	15 MPa 8 MPa 410% >100 MPa
Shear Modulus at 23°C		100 MPa
Tear strength	DIN 53507	115 N/mm
Charpy notch.-40°C	ISO 179	N.B.
Vicat VST/A/50	ISO 306	170°C
MFI at 240°C and 2,16 kgs		30 g/10 min
Mould shrinkage: // and “		1.5-1.7%
CLTE (23~80°C): // and “		16-19 10^{-5}. K^{-1}
Flammability	FMVSS 302	20 mm.min^{-1}
Ozone resistance:		
48hrs/40°C/50 ppm O_3, 25% Elongation		No Cracks

Film applications

Introduction to film

From the world of construction to the medical, textile and packaging industries, there is a growing demand for high-tech films and coatings that combine a number of properties including flexibility, elasticity, permeability to water vapour, chemical resistance and thermal stability.

A more sophisticated solution than microporous films is to use monolithic films made from polyester based thermoplastic elastomers (TPE-E). These thermoplastic materials can be processed into pinhole free (pinholes are small holes that cause leakage in a breathable film. They destroy the barrier properties of such films.) coatings or films by simply extrusion coating them onto a substrate, or casting or blowing into a film and subsequently laminating onto a substrate.

In general, the typical markets and applications for TPE-E resins can be divided into breathable and non-breathable as shown in Table 9. The unique properties of TPE-E, in particular their moisture vapor transmission rate (MVTR), make them very well suited for applications requiring breathability and water impermeability. These materials also have the advantage of being elastic. Key properties of Arnitel in monolithic film and coating applications include:

Figure 18.
Schematic diagram of the moisture vapour transmission process in an Arnitel® monolithic breathable film.

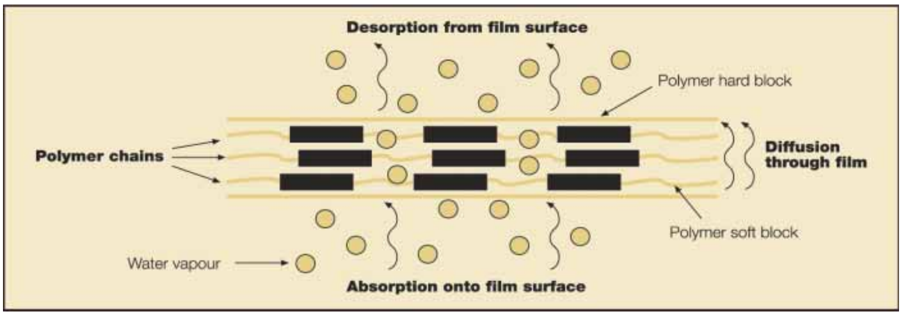


Table 9.
Markets for TPE-E's.

Breathable applications	Grade proposal	Approvals for film			
Construction	EM402-L	n.a.			
Medical disposables	PM381		PL380	PM381	EM400
		USP class	VI	IV	VI
		ISO 10993	-	pass	-
Durables	PM381				
Industrial	complete extrusion portfolio				
Other applications					
Specialty food packaging	EM400 EM460 EM550 EM630 EM740	FDA			

- high moisture vapor permeability
- waterproof
- relatively low levels of water absorption
- good mechanical properties
- high abrasion resistance
- easy to process
- high temperature stability
- good resistance to chemicals and weathering
- bacteria- and blood-impermeable for thin films (i.e. they are "monolithic" and not microporous).

MVTR measurements.
Breathability can be defined as the ability to pass water vapour. MVTR is used as a measure of breathability. Unlike microporous film, monolithic hydrophilic films breathe through a process of absorption-diffusion-desorption (see Figure 18). Water will be absorbed into the side of the film with the highest concentration of water molecules (or highest partial pressure), subsequently diffuse through the matrix, and desorb on the side with the lowest concentration of water molecules (or lowest partial pressure). The driving force is the difference in partial water vapour pressure across the monolithic film or coating.

Construction
(roofing membranes, wall coverings), Arnitel® EM402-L

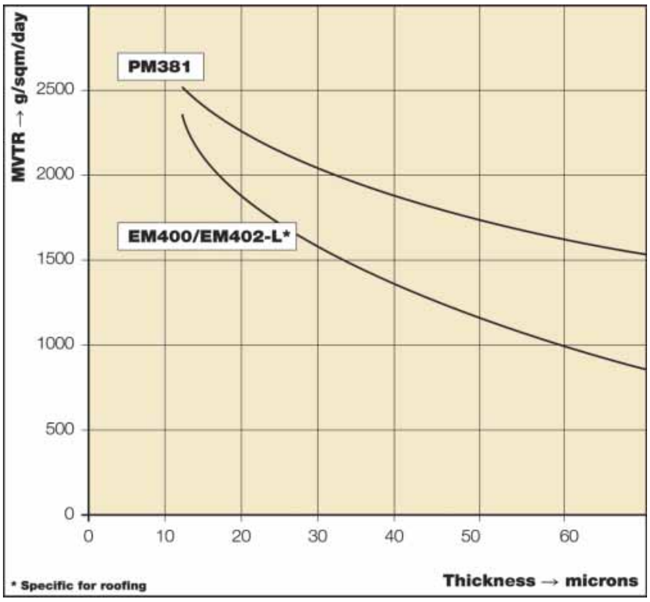


Figure 19.
MVTR versus thickness for Arnitel® according to E96B.

Figures 19 and 20 show the MVTR as determined by E96B (38°C and 50% RH) and DIN 53122 (23°C and 85% RH), respectively, for a number of Arnitel® grades. It should be noted that TPE-E show similar results for upright-cup MVTR and actually absorb less water than some of the polyurethane (TPE-U) or polyamide (TPE-A) based thermoplastic elastomers which are presently being used in breathable film applications.

Additives and masterbatches.
Arnitel® can easily be coloured with masterbatches. Although TPE-E based masterbatches are preferred, PE based masterbatches can also be used. However, one should always be cautious when choosing additives or masterbatches for materials for breathable films. Any low molecular weight material (such as mould release agents) can migrate to and block the surface of the film or coating, causing drastic decrease in MVTR.

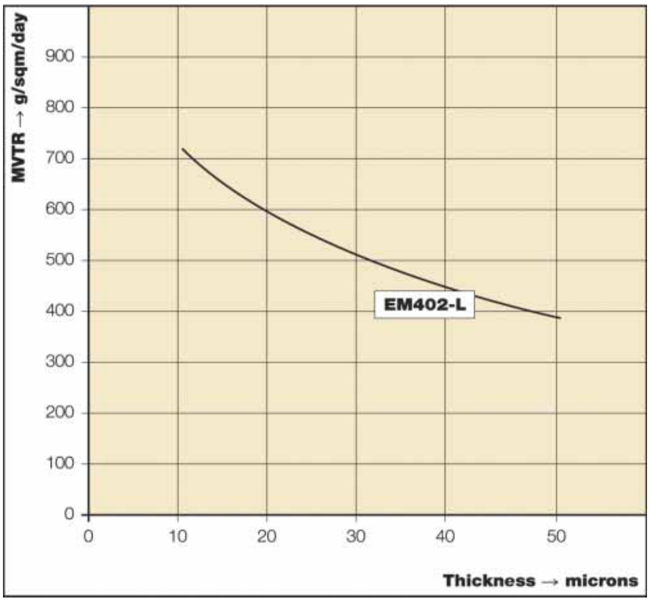


Figure 20.
MVTR versus thickness for EM402-L as a function of film thickness according to DIN-53122-D and E96A (desiccant at 23°C and 85%).

Arnitel® is well suited for disposable surgical gowns that require breathability and water impermeability.

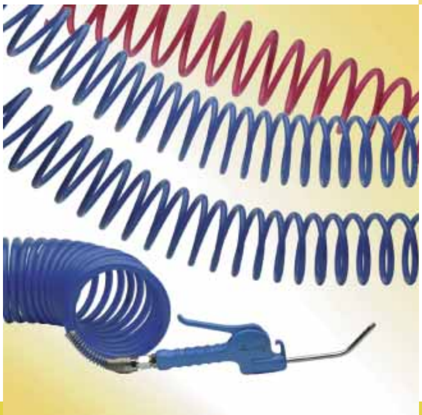
Arnitel® for tubes and hoses

Various Arnitel® grades are used in tube and hose applications due to an excellent combination of temperature resistance, flexibility and good chemical resistance. Applications, together with the recommended grades, in this area are:

Mandrels as vulcanization support.
Arnitel® has melting points in the 210-215°C range. When a rubber hose is produced, the uncured rubber needs to be supported by a mandrel during the rubber extrusion, braiding and subsequent vulcanisation step. This is often done at 180°C thus excluding thermoplastics which have lower melting points or which are too stiff when large diameters are made. Arnitel® mandrels offer a service life of 10 or more vulcanisation cycles although the exact number depends on the rubber and its vulcanisation system. This is better than the excisting solution in TPX, PA-11 and plasticized PA 6.

Fuel and Fuel Vapour tubing.
Arnitel® grades EM630 and EM740-H grades are used in fuel applications. Excellent chemical resistance and low fuel permeation are key properties for this application.

Hydraulic hose.
In this application Arnitel® is used as the inner core of a reinforced hose assembly. Excellent oil resistance allows typical lifetime of six years of uninterrupted use at 60-80°C. The performance specifications of for example SAE 100R7 are easily met.
Grades: PM581, EM550, EM630.



Pneumatic tubing.
Arnitel® grades are used for pneumatic coils. Besides an excellent pressure resistance, the coil retention properties are better than those of materials such as PA11 and TPU, due to superior creep properties. All Arnitel® E grades are food contact approved so that use of pneumatic tubing for food processing industries is no problem.
Grades PM381, EM401, EM550.

Airbrake tubing.
Trucks use compressed air to actuate the brakes. Brake tubing made from Arnitel® copolyesters is specified in the ISO7628 norm.
Grade EM630.

Other applications

Application overview

Apart from the previously described applications, Arnitel®'s broad and excellent grade range finds use in a wide range of other applications that can be broadly classified as:

- consumer products
- energy absorption
- medical/personal care
- electrical/electronic
- Fiber Optics/telecommunication

Consumer products

All around the globe Arnitel® provides special value solutions for all type of applications. In the field of consumer product. Arnitel® is used in a number of sports applications varying from Ski boots bindings straps, roller skates, heel backs and snowboard cover laminates. In all of these applications we combine the excellent low temperature ductility of Arnitel® with the very good color resistance, printability or processability.

Arnitel® is also used in several kinds of toolgrips combining a lifetime perfect grip with the excellent chemical resistance. Due to the wide portfolio there is always a solution whether it is found via gas injection molding, creating a low cost high performance suitcase grip, or in 2-K overmolding combining the best of the Xantar® polycarbonate with the Arnitel® PL581.

Energy absorption

In this field mainly heavy industries are involved, although most of the people are in contact with these issues on a daily basis.

Arnitel® railway pads provide a long service life on tracks protecting the concrete from cracking leading to better safety record and lower maintenance cost for the railway industries. For there is a wide portfolio, there are solutions for passenger tracks, where comfort is most important, as well as for freight track where the load bearing capacities is more important.
Similar background as well provides the basics for bedsprings, flexible segments warranting you a good night sleep. The combination of a wide modulus range, excellent colorability and perfect flow make that even the most difficult designs can be molded in Arnitel® co-polyester elastomers.

Medical and Personal care

For the medical care segment, where Arnitel® grades are widely used in catheter, spirellised tubes and surgeon threat, we have our Pharmacopoeia approvals in place. This is also for the applications, like dispensers for wines and oils, where our customers make use of the wide range of FDA approvals we have on our Arnitel E range.

To improve your appearance, Arnitel® co-polyester elastomers are used in hair curler systems for the excellent heat, color and hydrolysis resistance combined with a good flexibility.

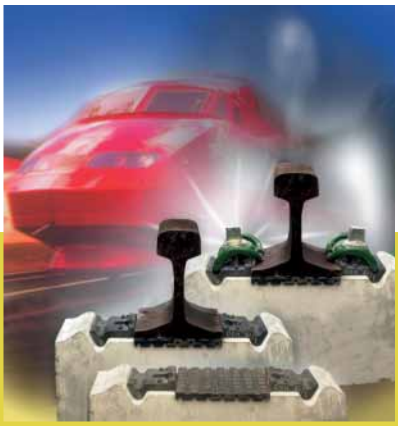
FDA food approvals

The grades generally used in food contact with a wide FDA food approval can be found in Table 13.

In all cases you can get detailed info on all approvals or listings via your local contact person.

Table 13.
Grades admitted for contact.

Arnitel® E	
EL550	EM400
EL630	EM460
EL740	EM550
	EM630
	EM740



Railway pads
in Arnitel® PL380 are used in this industry to improve dynamic track performance and decrease maintenance costs.

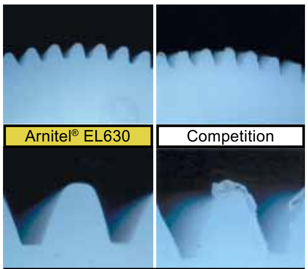
Electrical and electronics

Arnitel® co-polyester elastomers are very suitable for direct copper contact insulation, because of their excellent flexibility, creep resistance, chemical resistance and di-electrical strength. E.g. a phone cord that provides you a long term shape retention, even when it is extended on a daily base. In automotive we supply Arnitel® for truck cables, installed on the back of a truck transferring the power and signals from truck to lorry.

Low noise gears

With the Arnitel® portfolio we also service a wide variety in the field of low noise gears of noise dampening applications, mainly located of crucial importance for inside equipment consumer electronics.

Low noise gears are commonly used in CD lens pickups or tray systems, where the Arnitel® gear is installed between two POM gears to prevent that the noise generated by the gears. Important issues are also excellent mouldability of these very small and complex gears. Basic properties like crystallisation rate and dampening properties at operating temperatures make Arnitel® injection moulding grades the most suitable solution.

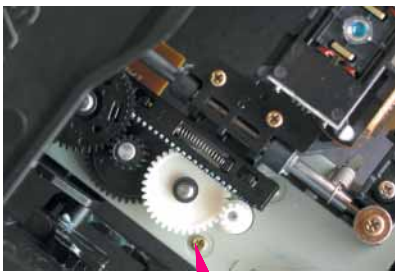


Difference in molding between Arnitel® EL630 and competition TPE 63 Shore D.

Similar issues are valid for camera gears where the Auto-focus systems for the lens are based on Arnitel®, combining excellent tooth strength with mouldability. The fact that up to 40% regrind can be used and the gears still obtain excellent properties generates a substantial cost reduction.

Fiber optics

The DSM portfolio provides complete solutions for all fiber optics systems using DSM Desotech coatings and inks to protect the glass fibers from being damaged, DSM Arnite® PBT a excellent high speed extrudable loose buffer tube material and Arnitel® as cover material for both the UV and termite resistant outer jacketing for the long distance telecom cables. Arnitel® is also an ideal solution for short distance telecom connections whether we speak about LAN cables, patch cords or the connectors needed. We provide the Ideal solution.Furthermore Arnitel® PL460-S is an excellent V0 FR grade without any blooming limiting the risks on signal loss.



Low Noise Gear.
Low Noise Gear using in the CD/DVD player.

Mobile communication

DSM Engineering Plastics has a long track record in mobile communications with their Xantar® (PC and ABS/PC) grades, Stanyl® (polyamide 46) and Arnitel®. Most of the OEM have specified Arnitel®, Stanyl® or Xantar® in applications. Xantar® being an excellent material for housing combining the excellent molding behavior with excellent ductility, Stanyl® used in quite some connector because of it mold ability and very high heat resistance. Arnitel® is for the softer applications. Major applications are in side buttons and antenna. The Arnitel® covered antenna generate less radiation to the brain) SAR meaning safer communication! This all combined with an excellent signal quality and gain (distance). Arnitel® also shows very easy mold ability and color ability required in times where people require flexibility and variation. Due to the fact that Arnitel® can easily be adhered to other polar plastics the latest developments are in the range of hard/soft combinations for keypads.

General automotive

Apart from specific applications like airbag doors and CVJ boots in automotive, Arnitel® is also used in a lot of other applications. Most of these applications are under the bonnet combining assistance to environmental oils, greases or battery acids in combination with higher temperatures.

Most of the body plugs, small caps used in a car frame to prevent water entrance in the frame holes, are molded in Arnitel® because of the very high over and undercuts it can be molded in, combined with excellent shape retention. For closure of the door Arnitel® coated door strikers and door latches are commonly used requiring excellent abrasion resistance. The latter property combined with an excellent surface after molding maker Arnitel very suitable for ball joint application as well.

Arnitel U® grades are commonly used as base material for convoluted tubing, protecting the sensitive cable harness from the external environment.

To have better phone reception, Arnitel® coatings around antenna are used, not only for automotive, but also on hand phones. Arnitel® offers a large variety in grades therefore offering flexibility, excellent performance and design freedom for all the applications you might have.

Door Latch(1)

Door Latch(2)

Door Striker

UL recognitions

Table 14.
Underwriters Laboratories yellow card file E47960 for Arnitel® grades.

Description	Grade dsignation	Colour	Minimum thickness mm	UL94	RTI ...C[1) EI]	RTI ...C[1)] WI	RTI ...C[1)] WOI	HWI[1)]	HAI[1)]	HVTR[1)]	D495[1)]	CTI[1)]
TPE-E	EL740-S	All	1.50	V-0	50	50	50	-	-	-	-	-
	PL380	NC	1.50	HB	50	50	50	-	-	-	-	-
	PL460-S	All	1.60	V-0	50	50	50	-	-	-	-	-
	UM551	All	0.75	HB	160	120	150	2	0	0	5	0
	UM552	All	0.75	HB	160	120	150	2	0	0	5	0
	EL550	NC	1.60	HB								
	EL630	All	1.60	HB								
	PL650	All	1.60	HB								
	EM460	NC	1.60	HB								

1) This data is for 3 mm thickness

Detailed and up to date UL-data can be found on the internet website of Underwriters Laboratories Inc.

http://data.ul.com

A **liquid dispenser** is used for distribution of any liquid (wine, soap, oils) from a liquid box packaging. Arnitel® EM400 and EM460.

Injection moulding

Machinery

Arnitel® can be processed on all standard injection moulding machines with screw plasticization. Do not use plunger machines. With the correct equipment, cycle times of 6 seconds can be achieved (depending on the number and size of parts, and the type of material).

Cylinder.
For best processing, the residence time of the material in the cylinder should be kept as short as possible. The machine size and cylinder diameter should be such that the product weight is within a range of approximately 40 to 70% of the maximum shot capacity. The heating elements should have sufficient heating capacity, and the temperature should be accurately controlled to avoid large melt temperature fluctuations. Generally, good product quality requires a high injection rate.

Screw.
The screw geometry determines the transport behaviour and the degree of plasticization of the granules. Standard three-zone screws with a L/D ratio from 17 to 23 and a thread depth ratio of about 1:2 yield excellent results. Conical-progressive screws (as used for PVC) are not suitable. To avoid backflow of the melt during the injection and holding pressure phases, the screw should be fitted with a non-return valve.

Nozzle.
Arnitel® is preferably processed on “decompression-controlled” machines with an open nozzle. With a short nozzle and a wide bore (3 mm or more), frictional heating and pressure losses are minimized. Injection moulding problems can be avoided in this way, particularly with flame-retardant grades. Nozzles that can be closed (hydraulically, if possible) may also be used, provided they are equipped with an effective, precision-controlled nozzle heating system. It is important to restrict the number of dead angles to a minimum.

Withdraw the nozzle from the mould after the injection/holding pressure phase to prevent it from cooling down unduly.

Hopper.
The hopper should be equipped with a tightly-closing lid which should be kept closed during processing to keep the granules dry and free from dust. It is not necessary to use nitrogen in the hopper or to exhaust air from it.

Moulds

Good mould design is essential for best injection moulding and, consequently, for a high quality product. Observe the following points when designing moulds for processing Arnitel®:

Gating systems.
All common gating systems may be used, including cone, pinpoint, tunnel, film, fan, and ring gates. Externally heated hot runner and semi-hot runner systems also qualify, but require efficient heating and very accurate temperature control to avoid freezing or overheating the material. Information about the hot-runner systems that may be used for Arnitel® grades is available from DSM Engineering Plastics Technical Service Department.

Gate locations.
Gate locations should be chosen with care to minimize deformation or warpage of the product due to anisotropic shrinkage. The gate should preferably be located on the thickest section of the product, and in such a position that the product fills as evenly as possible.

Dimensions of runners and gates.
The cross-section of the runners should preferably be circular. Where this is not feasible, the best compromise is a trapezoid. Recommended runner and gate dimensions for various wall thicknesses are given in Table 15. For products with a wall thickness exceeding 3-5 mm, a full sprue gate with a diameter of about three-quarters of the largest wall thickness is preferred. A short sprue cone with a taper of at least 1°30’ is recommended.

Table 15.
Dimensions of gates

Wall thickness *(mm)*	Gate diameter/ length *(mm)*
0.7 - 1.2	0.7 - 1.0 / 0.8 - 1.0
1.2 - 3.0	0.8 - 2.0 / 0.8 - 1.0
3.0 - 5.0	1.5 - 3.5 / 0.9 - 1.0
> 5.0*	3.5 - 6.0 / 0.8 - 1.0

(Avoid wall thicknesses larger than 5 mm).*

Screw drivers.
Screw drivers with Arnitel® grips keep the excellent grip even when exposed to oils and greases. Due to the perfect chemical these grips are resistant to almost any, chemical environment in daily use.

Venting.
Special attention should be given to effective mould venting. Venting is effected by vents (approximately 0.02 mm) in the mould faces, or via existing small channels such as those around ejector pins and cores. Vents should be located in the mould, at the end of the flow paths.

Ejection.
Moulded products are removed from the mould using ejector pins, plates or rings. The design and number of ejectors is dictated by product design and stiffness. Ejection must not cause damage or deformation. In view of Arnitel®'s flexibility (particularly the softer types), that part of the product in contact with the ejector should be under uniform load. A fairly large ejector face is therefore required.

Cooling.
The cooling system is an important part of the mould and needs to be configured with scrupulous care. The product must be cooled rapidly and uniformly to prevent warpage and long cycle times.

Here are some recommendations for an effective cooling system design:

- plan a sufficient number of generously dimensioned cooling channels, configuring them symmetrically around the moulding cavity and in the closest possible proximity to it. The distance between channels and to the mould cavity should be within 1 to 1.5 times the channel diameter
- avoid long cooling circuits. Compact, independent circuits are most effective, and parallel cooling is superior to stepped cooling
- incorporate one or more thermocouples or sensors in both mould halves to provide a check on mould temperature.

Material handling

When processing Arnitel®, the moisture content of the material must not exceed a given limit. Too much moisture present in the molten phase will cause the polymer chain to break down, degrading the mechanical properties of the injection-moulded product.

To spare the expense and time involved in pre-drying, Arnitel® granules come with a moisture content low enough to permit immediate processing. However, the material quickly picks up moisture from ambient air once the moisture- and air-sealed package is opened, so take the following precautions:

- allow material that has been stored in a relatively cold room to adapt to the temperature of the processing room, starting at least 24 hours before use. This will prevent condensation of atmospheric humidity onto the granules when the package is opened.
- handle packages carefully during internal transport, so the packages remain airtight
- do not open the package until the injection moulding machine is sufficiently heated and ready to start production.
- always feed the entire contents of one or more bags into the hopper, and then close the hopper tightly
- do not refill the hopper until there is sufficient room for the entire contents of a bag
- always try to refill the hopper to the top
- ensure that the hopper is not larger than strictly necessary to limit the residence time of the material.

Note: Even in a tightly closed hopper the material will absorb a slight amount of moisture. The residence time of the material in the hopper should not exceed 5 to 6 hours.

Open bags.
Some hoppers may be too small to hold the entire contents of a bag of Arnitel® granules. To avoid long exposures of the remaining material to ambient air, use the following methods (in order of effectiveness):

- press the bag to remove air and subsequently reseal it with a sealing device. You can then store it indefinitely.
- remove air and reseal bag with tape. As the moisture barrier will not be perfect, process the remaining material within 12 hours
- remove air and carefully fold bag tight. Since the granules will absorb moisture rapidly, it is not advisable to use this method for Arnitel U grades. For the other Arnitel grades it is only acceptable if the residence times of the material in the folded bag and the hopper together do not exceed 12 hours.

Moist granules.
Granules that have been exposed to ambient air for too long must be assumed to have picked up too much moisture. These granules can be dried in an oven with hot, pre-dried air circulation, or in a rotary vacuum drier. Drying conditions for the various grades in vacuum with nitrogen leakage are given in Table 16.

Table 16.
Drying conditions for various grades.

Grade code	Time (hours)	Temp. (°C)
EM400	10	100
EM460	10	100
EL550	10	110
EL630	8	110
EL740	6	120
PL380	3	120
PL460	3	120
PL471	3	120
PL581	6	120
UM551	3	120

Material dried this way will soon reabsorb moisture during cooling. So, adopt one of the following procedures:

- leave the hot, dried granules to cool down in a moisture- and air-tight (sealed) package. After cooling down to ambient temperature, these granules can be processed as earlier described
- alternatively, if you don't have the proper equipment, for this transfer the hot dried granules immediately in the hopper, close the lid tightly and process at once. If the temperature of the granules does not drop below 80°C, moisture absorption will not be excessive. At temperatures below 80°C the granules will reabsorb humidity. Too rapid a cooling of the granules can be prevented by hopper insulation or by using hopper driers set to 100°C.

Processing

Automatic feed of granules.
Pneumatic granule-feeding equipment may be used for processing Arnitel®. Cut a hole in the package that will just fit around the suction pipe. The opened bag should be emptied within 5 hours to limit moisture absorption.

Colouring granules.
Arnitel® can be coloured during processing by a variety of techniques. The simplest method is to mix the pigment powder the granules prior to introducing to the hopper. This can be done by dusting the granules in drum mixers, approximately 0.2% of dusting oil may be found necessary.

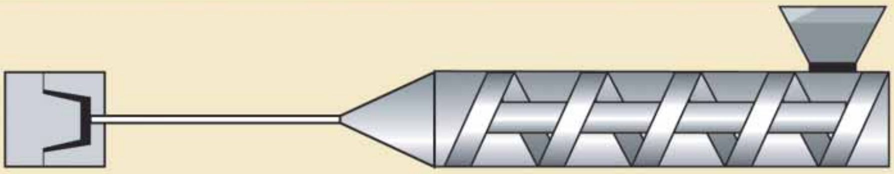
DSM recommends using masterbatches (colour concentrates) for colouring, preferably those based on chemically identical polymers. Masterbatches based on LDPE and EVA may also be used if heat resistance is not a requirement.

Processing scrap.
The excellent heat stability of Arnitel® permits the use of regrind from sprues, runners and rejects as long as it does not contain impurities, and was properly processed in the first place. Predrying is necessary.

Depending on the demands on the mouldings, up to 50% regrind can be added to the fresh granules, although we recommend a maximum of 20%.

Steering wheel.
Arnitel® EM400, a polyether-ester injection grade, chosen for its physical property performance over wide range of temperatures, provides structural integrity for steering wheels.
The use of Arnitel® eliminates plasticizers that might attack the leather wrap on a steering wheel. DSM supported the development of compatible foaming agents to enhance mould filling characteristics and reduce density without losing performance.
In addition, Arnitel® provides superior adhesion to foam layers and leather lending a great surface appearance to the steering wheel. DSM conducted multiple trials at the customer's production facility and provided test specimens moulded internally to help this project meet target costs.

Table 17.
Cylinder temperatures.



Arnitel® E	Mould	Melt	Nozzle	3	2	1
	°C	°C	°C	°C	°C	°C
EM400	20 - 35	220	215	210	205	200
EM460	20 - 35	220	215	210	205	200
EL550	20 - 50	235	230	225	220	220
EL630	20 - 50	240	235	230	225	220
EL740	20 - 50	245	240	235	230	225
Arnitel® P						
PL380	20 - 35	230	230	225	220	215
PL460	20 - 40	235	235	230	225	215
PL471	20 - 50	240	235	235	235	225
PL581	20 - 50	240	240	230	225	215

Cylinder temperatures.
In accordance with their respective melting points, Arnitel® grades are processed between 220-250°C.

A rising temperature profile will normally yield the best results. The optimum temperature depends on the injection moulding grade, type of machine and product to be injection moulded. Typical cylinder temperatures are shown in Table 17. For some materials peaks of 260°C are allowed.

The residence time of the material in the cylinder is an important processing parameter. To avoid thermal degradation of the melt as a result of prolonged residence times, it is best to observe the lower limit of the recommended temperature range.

Too high melt temperatures should be avoided because thermal degradation adversely affects mechanical properties. Processing (= polymer) temperatures are generally in the 220-260°C range. Cylinder temperature settings should be in a range from 200 to 250°C (see Table 17). Temperatures of 255°C (250°C for EM400 and EM460) may be used where high flow is needed, but the residence time in the equipment must then be very short. Polymer temperatures of 230°C (Arnitel® EM400 and EM460) and 260°C (EL550, EL630 and EL740) are the maximum values for longer residence times in the cylinder.

Mould temperature.
A mould temperature of 50°C is recommended for thin-walled products, while thick-walled products can be moulded at 20°C. Higher mould temperatures improve flow but add to the cycle time.

Tensioner ski-binding
is a 2-component moulded part combining the excellent ductility of Xantar® polycarbonate with the pleasant feeling and appearance of Arnitel® without any special treatment.

Conditions

Injection pressure.
Injection pressure is primarily determined by the wall thickness of the product, the flow path length, and the flow behaviour of the injection moulding grade. In general, Arnitel® grades have excellent flow properties. Injection pressure should be high enough for uniform mould filling (see Figures 22, 23 and 24).

Injection rate.
Fill the mould quickly to avoid premature freezing during injection. A relatively high injection rate is usually possible, but a moderate rate may be necessary under certain conditions.

Holding pressure and time for follow-up pressure.
Shortly before the mould is completely filled, the injection pressure is usually stepped down to the holding pressure, which in most cases is 40 to 70% lower. The volume shrinkage of the cooling melt is compensated for during the holding pressure phase.

The holding pressure should therefore be set high enough to prevent sink marks. Excessively high holding pressures should be avoided since they may cause residual stresses in the product or visible burning.

The holding pressure should be sustained until the gate freezes. The appropriate holding pressure time is best determined by weighing the product. Sink marks or shrinkage voids indicate that the holding pressure time is too short. The holding pressure time should be prolonged proportionally as wall thicknesses and gate dimensions increase.

Figure 22.
EM400 - EM460 – flow lengths as a function of injection pressure.

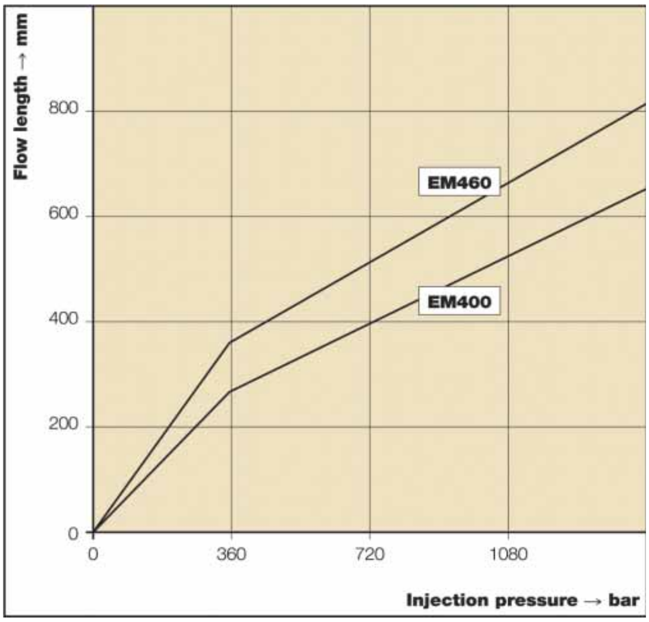
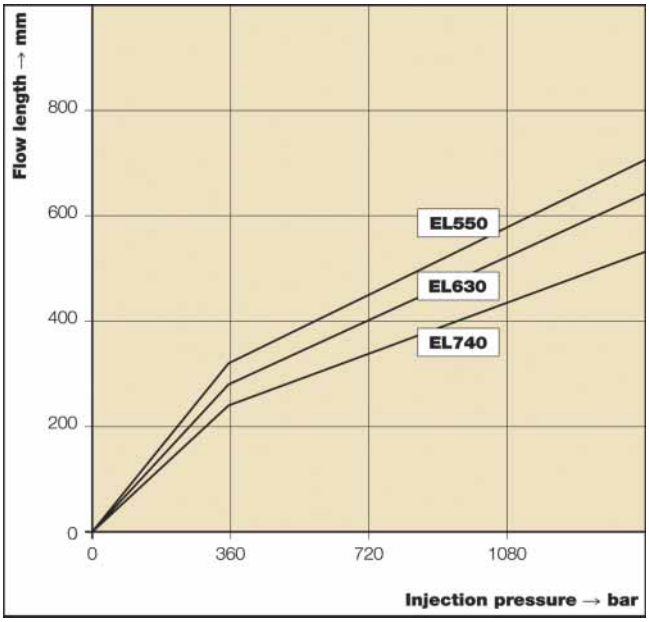


Figure 23.
EL550 - EL740 – flow length as a function of the injection pressure.



Back pressure and screw speed.
In general, back pressure and screw speed should be set as low as possible to avoid excessive heat generation through friction, and the reduction of glass fibre length in reinforced grades. Back pressure promotes the homogeneity of the melt. It should be set just high enough to ensure that the melt is free from air bubbles, that the screw plasticizes evenly, and that the product weight is constant.

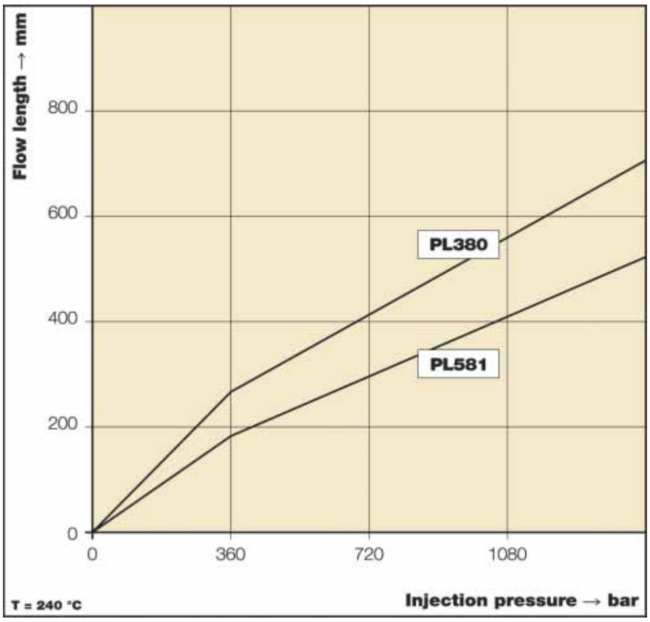
A hydraulic back pressure of approximately 3 to 6 bar is sufficient. The screw speed should be such that the plasticizing time remains just within the cooling time. Low screw speeds (from 30 to 100 rpm) will limit heat generation through shear.

Clamping pressure.
The clamping pressure should be matched to the injection pressure and the projected surface of the product.

Metering.
The screw-metering rate should be controlled so that, during holding pressure, a sufficiently large buffer of molten material remains in front of the screw to serve as after-filling material. A small buffer of 2 to 5 mm is recommended, since a large buffer might lead to loss of pressure and to prolonged residence of the melt in the cylinder.

Cooling/cycle time.
The cycle time is primarily determined by the injection/after pressure time and the cooling time. The nucleating agent, crystallization accelerator, and glass fibre reinforcement (if any) bring about rapid crystallization of Arnitel® grades.

Figure 24.
PL380 - PL581 – flow lengths as a function of the injection pressure.



Production stops.
We recommend the following procedure if injection moulding is interrupted:

- if the interruption is expected to be shorter than 15 minutes, retain the temperature settings and purge the cylinder. Upon resumption of processing, recharge with fresh polymer
- if the interruption is likely to exceed 15 minutes, empty the cylinder, purge with HDPE or PP and switch off heating. After the interruption, reheat the machine and purge with Arnitel.

Changing to a different material. Before changing from Arnitel to a different thermoplastic material (or vice versa), purge the cylinder with HDPE or PP.

Flow behaviour

A material's flow behaviour depends on several factors:

- melt temperature
- mould temperature
- melt viscosity
- injection pressure and injection rate
- dimensions of runners and gates.

The influence of these factors depends on the wall thickness of the product: the minimum wall thickness is lower for low-viscosity than for high-viscosity materials. Figures 22 to 24 illustrate the relation between path and injection pressure for various Arnitel® grades. The flow paths were determined by means of a 15-mm-wide flow spiral at a thickness of 2 mm.

Shrinkage

When molten plastic solidifies, it shrinks which, in the first instance, is compensated by holding pressure. Any shrinkage which occurs after the gate(s) freeze is not compensated, nor is the shrinkage caused by after crystallization and thermal shrinkage. Designers should take into account that the finished product dimensions will be smaller than the mould dimensions.

Table 18 gives an indication of the mould shrinkage for some Arnitel® grades.

Table 18.
Mould shrinkage (%).

Unfilled grades	Flow direction	Across flow direction
Arnitel® E		
EM400	1.50	1.50
EM460	1.25	1.50
EL550	1.55	1.55
EL630	1.75	2.00
EL740	1.75	2.00
Arnitel® P		
PL380	1.55	1.75
PL460	1.60	1.80
PL471	1.70	1.70
PL581	1.70	1.80

These shrinkage figures should be used with care, as the degree of shrinkage not only depends on the type of material, but also on the extent to which shrinkage in the mould can be compensated for by the holding pressure. The degree of shrinkage is determined by:

$$\textbf{Shrinkage (in \%)} = \frac{\text{mould cavity length - product length}}{\text{mould cavity length}} \times 100\%$$

Product-dependent factors:

- wall thickness
- flow path length
- gating system

Process-dependent factors:

- gate dimensions
- melt and mould temperature
- holding pressure and time of hold pressure
- injection rate

Material-dependent factors:

- grade

Product-dependent factors.
Increases in wall thickness produce fairly steep increases in shrinkage, while smaller gates and longer flow paths result in a higher shrinkage. The gate location is also important: injecting the material at the thickest section is most effective in controlling shrinkage. The shrinkage figures in Table 18 were established with a moulded bar of the following dimensions:

Wall thickness	2 mm
Length	250 mm
Width	30 mm
Gate	Film gate on short side

Process-dependent factors.
Shrinkage decreases with mould temperature. An increase in holding pressure or an extension of the hold pressure time will also reduce shrinkage.

After-treatment

Coating.
Arnitel® is easily coated provided that no silicone-containing mould release agents or other products with an adverse effect on adhesion were used during the injection moulding process. No special adhesion promoters are necessary. Paint system suppliers offer coatings to match the hardness - or rather stiffness - of the Arnitel® grade used to the flexibility of the coating.

Metallising.
Vacuum-metallising is the best procedure to use on Arnitel®. Because of the low flexibility of the metal film, it is best not to use soft Arnitel grades. Always run a test first.

Printing.
Arnitel® is easy to print. Polyester printing film allows the use of standard equipment, and it is a relatively simple method. It offers a wide choice of coatings adapted to the specific properties of the end product. Arnitel® is also very suitable for sublimation-, screen- and lasermarking techniques. For detailed information, please link to the website on this topic.

Pencilgrip.
Arnitel® EM400 over moulded on ABS.

Miscellaneous

Gas injection.
Arnitel® is suitable for gas injection processes for producing hollow grips, tubes etc.

2-K injection moulding.
Arnitel® shows excellent adhesion to other plastics, in particular to ABS, polycarbonate, PVC, polystyrene and other polyester based materials. In general: the warmer the inlay, the better the adhesion. If thicker layers (>1 mm) are injection moulded, differences in shrinkage can warp the object. Annealing can for the major part prevent this. Table 19 gives an impression of the tear force (ISO4578), a measure for adhesion, necessary for separating the layers.

Table 19.
Adhesion found after 2-K injection moulding of Arnitel®.

Inlay	Melt	T_{melt}	T_{inlay}	G_n	T_{inlay}	G_n
		°C	°C	J/m²	°C	J/m²
EM400	PBT	240	23	50	90	500
		260	23	25	100	2000
EM460	PBT	240	23	25	100	500
		260	23	25	100	1750
PBT	EM400	260	23	500	105	6000
		280	23	1250	105	5500
PBT	EM460	260	23	1000	105	2500
		280	23	1000	105	3500
EM400	PC	240	23	500	80	4500
		260	23	1250	80	> 9000*
EM460	PC	240	23	500	90	> 8500*
		260	23	1250	80	> 6500*
PC	EM400	300	23	> 6500*	100	> 5000*
		320	23	> 6500*	100	> 6500*
PC	EM460	300	23	> 7000*	100	> 6500*
		320	23	> 7000*	100	> 6500*
ABS	EM400	240	23	1000	n.a.	n.a.
ABS	PL380	240	23	850	n.a.	n.a.
PVC	EM400	220	23	30	n.a.	n.a.
Polystyrene	EM400	220	23	n.a.	n.a.	n.a.
Polystyrene	PL380	220	23	n.a.	n.a.	n.a.

* *Cohesive fracture.*

Foaming

Products made of Arnitel® thicker than 1 mm can generally be foamed on injection moulding machines provided with a shut-off nozzle.

Remarks.
Density reductions of approximately 25% can be achieved.

A HYDROCEROL-Compound CLM 70 (2%) is used as foaming agent. To ensure a uniform cell structure, add 0.2% VS 103 (fluid) or calcium carbonate. Other chemical blowing agents which can be used are Expandex and different Genitron types.

The mixture must be tumbled for approximately 15 minutes, and can then be injection moulded immediately. The following conditions ensure best injection moulding:

Shut-off nozzle.
A hydraulically or pneumatically operated valve is recommended.
The residence time in the nozzle must be kept as short as possible to reduce loss of gas from the melt due to pressure decay in the barrel.Other recommended processing conditions are:

- high injection speeds but low injection pressures
- no holding pressure
- increased back pressure during plasticizing
- minimum clamping force
- adequate mould venting to prevent cell collapse
- gate and runner dimensions should not be too small, to avoid shear heating

Processing temperatures.
A rising temperature profile from the hopper to the nozzle is normally used.**Example:** Arnitel® EM400: 190-200-210-240°C Mould temperature: 50°C

Physical blowing agents may be used, but crystallization enhancers must be added to obtain a good foam structure.

Although the performance of Arnitel® TPE is more than satisfactory for most applications, some may need additional heat, UV or hydrolysis stabilization. DSM offers a complete package of master batches for creating the ideal properties. (details in table 3)

Extrusion

Machinery

Arnitel® is as easy to extrude as other polymers. Good results are obtained with most conventional single screw extruders.

Extruder barrel.
Extruder barrels for polyamide, polyester and polyolefins are usually suitable for Arnitel®. Barrels with axial grooves and intense cooling of the intake zone are not suitable. If an intake zone with relatively short and shallow grooves (< 1.5 mm) is used, good results can be obtained only by avoiding intensive cooling.

Screw design.
Good results are obtained with conventional single screw extruders equipped with a 3-zone screw (see Figure 25). Length to diameter ratios of 24 or higher provide the best melt quality. The clearance between screw flights and barrel should be small:

- 0.08-0.10 mm for extruders up to 45 mm in screw diameter
- 0.1-0.15 mm for larger extruders

The compression ratios should be between 1 : 2.4 and 1 : 3.2, determined by the depth of the feed section divided by the depth of the metering section.

The channel depth of both the feed and metering sections is important; if the feed channel is too deep and not long enough, particularly with large diameter screws, poor feeding and loss of output can result.

If the metering channel is too deep, insufficient pressure will be built up resulting in irregular output, particularly with low-viscosity grades. A metering channel which is too shallow can result in overheating of the melt due to high shear, particularly with high-viscosity types.

Figure 25.
Three-zone screw.

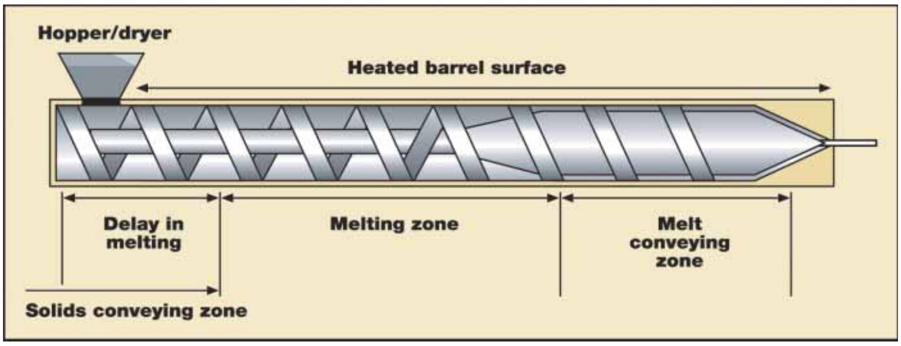


Table 20.
Design parameters.

Characteristic design parameters three-screw					
Screw length **Pitch**	24 - 27 1D				
Extruder diameter	mm	**30**	**45**	**60**	**90**
Length of section					
Feed section	D	7 - 10	7 - 10	7 - 10	7 - 10
Compression section	D	4 - 6	4 - 6	4 - 6	4 - 6
Metering section	D	8 - 11	8 - 11	8 - 11	8 - 11
Channel depth					
Feed section	mm	5	6.5	8	10
Metering section	mm	2	2.5	3.5	4

Many factors affect selection of the correct screw design. Characteristic design parameters and approximate values are listed in Table 20.

Certain designs of barrier screw have been found to be effective in extruding Arnitel®.

The energy required for melting is supplied by two sources; the heater bends and the electric motor driving the screw. Arnitel® has a high heat capacity and a high heat of fusion, so high engine power is needed for the high temperatures required to extrude it. On the two heating zones situated directly downstream from the hopper, the heater bands should have a power of 4-5 W/cm^2.

For the remaining zones, a power of 1.5 W/cm^2 is sufficient. Extruder startup needs an engine power of approximately 0.3 kW per kg output, after which an engine power of 0.15-0.2 kW per kg output is sufficient.

Heating blends and thermocouples should be installed at strategic positions to avoid overheating of the melt. All positions that are not directly heated, should be avoided.

Material handling

Arnitel® is supplied pre-dried, in moisture-proof bags. The moisture content is low enough to permit immediate extrusion for most applications but pre-drying will improve the performance of the final polymer even more.

Moisture absorption.
When exposed to air, Arnitel® granules absorb moisture. Small quantities of absorbed moisture in the Arnitel® granules cause degradation in the extruder. This results in varying molecular weights, leading to a decrease in mechanical performance and to irregular throughput.

Take the following precautions:

- allow material that has been stored in a relatively cold room to adapt slowly to the temperature in the processing room
- do not open the packages until the extruder is heated and ready for production
- always feed the entire contents of one or more bags into the hopper and close the hopper tightly immediately
- do not refill the hopper until there is room for the entire contents of a bag
- always try to refill the hopper to the top
- ensure that the hopper is not larger than necessary in order to limit residence time of the material

Drying.
For critical extrusion operations such as monofilaments, profiles and vacuum calibrating tubes with small tolerances, we recommend drying the granulate in a desiccant dryer to assure a constant moisture level. The hopper of the dryer should preferably be mounted directly on the extruder. The residence time in the hopper should be at least three hours at a temperature of 90 to 105°C, depending on Arnitel® grade. For longer residence times in the hopper, use lower temperatures.

Table 21.
Drying conditions.

Arnitel® grades		Drying conditions	
Base grade	Hardness Shore D	Time (hours)	Temperature (°C)
E	40	10	100
E	46	10	100
E	55	10	110
E	63	8	110
E	74	6	120
P	38	3	120
P	58	6	120

Granules that have been exposed to ambient air for too long must be assumed to have picked up moisture. These granules can be dried in desiccant drier or in a rotary vacuum drier. The recommended drying conditions are shown in Table 21.

Materials dried in this way will reabsorb moisture quickly during cooling. So, adapt one of the following procedures:

- leave the hot, dried granules to cool in a sealed moisture- and air-tight package. After cooling to room temperature, these granules can be processed like Arnitel® that has just been delivered
- if sealing equipment is not available, the hot and dry granules should be transferred immediately to the hopper and the lid closed tightly. If the temperature of the granules does not go below 80°C the amount of moisture absorbed will not be excessive. Rapid cooling of the granules can be prevented by insulating the hopper or by using hopper dryer set to 100°C.

Use of regrind.
The excellent heat stability of the Arnitel® melt permits the use of regrind as long as the material was properly processed during the initial extrusion. Depending on the demands to be met in service, up to 20% regrind can be used. The scrap should be chopped into granules approximately the same size as the original pellets. The regrind must be blended with virgin polymer and dried to ensure uniform quality.

Colouring of granules.
The standard colour of all materials is natural white. Colour can be added by using colour concentrates (masterbatches), preferably based on chemically identical polymers. DSM can help customers choose the correct masterbatch.

Processing

Depending on grade and application, the processing temperatures for Arnitel® range from 200 to 250°C. The optimum temperature profile depends largely on the grade and its application. Some guidelines and other important information are given in Table 22.

Temporary shut down.
No special measures are required when the extrusion process is interrupted for less than 30 minutes. The normal temperature settings can be maintained. When production is resumed, however, the extruder should be purged until the residual material has been replaced.

Equipment cleaning.
Occasional dismantling and cleaning of the extruder screw, adapter and die components is recommended.

The frequency of these strip downs depends on the application, number of start up/shut down operations and number of resin changes which have occurred.

The clean-out procedure consists of purging the extruder with PE or PP and removing the adapter and die from the extruder. With the die removed, the screw and barrel may be cleaned using a purge compound such as high-viscosity polyolefin or cast acrylate.

Complete removal of the screw for thorough cleaning is necessary from time to time. This is the only way to ensure that hard particles of degraded polymer and other residue are properly removed from the screw and barrel surfaces.

Larger quantities of the resin can be removed by scraping the screw while still hot, followed by wire brushing.

Table 22.
Extrusion guidelines

Arnitel® Grades	Melting point (°C)	Melt flow index at:			Processing temp.	
		220 °C (dg/min)	230 °C (dg/min)	240 °C (dg/min)	mininum (°C)	maximum (°C)
EM400	195	25	-	-	205	240
EM401	-	-	12	-	-	-
EM402-L	-	25	-	-	-	-
EM460	185	38	-	-	195	240
EM550	202	7	-	-	215	260
EM630	213	-	-	6	225	260
EM740	221	-	-	7	230	260
EL740	221	-	-	30	230	260
PM381	218	-	4	-	225	260
PM581	218	-	-	6	225	260

The adapter and die components can be burned off in an oven. A better method is to immerse parts in a hot fluidised bed which is designed for this purpose. This equipment uses hot-air fluidized aluminium oxide, into which the parts to be cleaned are lowered in a wire basket. With suitable fume extraction, this method is fast and thorough, and leaves parts ready for reinstallation.

Residues attached to extruder parts may be removed from die components by burning with a propane torch. However, this method is not generally encouraged, since flammable and toxic gases may be formed.

Arnitel® tubing extrusion equipment.

DSM Engineering Plastics product portfolio

Arnitel® copolyester elastomers	High performance elastomers based on polyester.
Stanyl® 46 polyamide	High temperature polyamide which bridges the price-performance gap between traditional polyamides and high-performance materials.
Stanyl® High Flow 46 polyamide	High flow and high temperature polyamide which bridges the price-performance gap between traditional polyamides and high-performance materials.
Akulon® polyamides	Polyamide 6 and 66 in both unreinforced and reinforced grades, including flame retardant products.
Akulon® Ultraflow™ polyamide	Polyamide 6 reinforced grades, easy flowing, lower processing temperatures, faster crystallization speed, shorter injection and holding time, reduced cycle time.
Arnite® thermoplastic polyester	PBT and PET based materials, including unreinforced, reinforced, and flame retardant grades, offering excellent dimensional stability and low creep with good chemical resistance.
Stapron® PC/ABS-blend PC/PET-blend	Unreinforced and reinforced PC-blends with optimized balance between flow and impact resistance. Flame retardant grades based on halogen free systems.
Xantar® polycarbonate	Unreinforced, reinforced, and flame retardant grades with outstanding impact resistance, dimensional stability, and high heat deflection temperature.

Arnitel® chemical resistance

Chemicals	EM400 EM460	EL550 EM550	EL630 EM630	EL740 EM740	PL380	PL460	PL581 PM581	UM551(-V) UM552(-V)	UM622
Water	+	+	+	+				+	+
Acetic acids 10%		+	+	+	-			+	+
Hydrochloric acids 10%		+	+	+	-		+	+	+
Nitric acids 10%					-			-	-
Phosphoric acids 30%		+	+	+	-	-			
Sulfuric acids 30%	+	+	+	+	-	-			
Ammonium hydroxide 10%					-	-	+	+	+
Sodium hydroxide 10%	+	+	+	+	-		+	+	+
Hydrogen peroxide 30%	-		+	+	-				
Calcium chloride 10%							+		
Zinc chloride 10%		+	+	+		-			
Toluene	+	+	+	+	-			+	+
Acetone		+	+	+	-			+	+
Diethylether					-			+	+
1, 1, 2, 2-Tetrachloro ethane		+	+	+	-	-	-	-	
Ethyl acetate	-				-	-	-		
Ethyl alcohol			+	+	-			+	
Chloroform	-	-	-		-	-	-	-	
Tetrachloro ethylene	-	-			-	-	-	-	
Trichloro ethylene	-	-	-		-	-	-	-	
Transformer oil (Palatonil C)	-	-	-		-			+	+
Diesel oil		+	+	+		+	+	+	+
Four star petrol, with lead		+	+	+	-	+		+	+
Four star petrol, unleaded			+	+	-	+		+	+
Test fluid (GM L0003)	-				-	-	-		
Oil (ASTM-1) at 100°C			+	+				+	+
Oil (ASTM-3) at 100°C	-		+	+				+	+
Brake fluid (DOT-4) at 100°C	-	-	-	-	-	-			+
Coolant (Glysantin)	-							+	+

+ *excellent*
good
- *poor*

Arnitel® typical data

Notes
1) Most properties are in accordance with the Campus statemers
2) HDT-B, at 0.45 MPa.
3) According to UL94, at test specimen of 1.6 mm thickness.
4) NB = no break.

Properties [1]	Units								
Injection moulding					**EM400**			**EL550**	**EL630**
Extrusion						**EM401**	**EM460**	**EM550**	**EM630**
Blow moulding		**EB463**	**EB464**	**EB500**					
Physical properties									
Relative density	-	1.15	1.15	1.18	1.12	1.12	1.16	1.20	1.23
Melting point	°C	203	205	216	195	194	191	207	212
Coefficient of linear thermal exp.		-	-	-	220	-	160	150	140
Deflection temperature under load [2]	°C	-	-	-	-	-	-	110	115
Vicat softening temperature:									
at 10 N	°C	-	-	-	130	-	150	180	200
at 50 N	°C	-	-	-	-	-	50	85	115
Moisture absorption:									
equilibrium in air	%	-	-	-	0.30	0.30	0.30	0.20	0.20
equilibrium in water	%	-	-	-	0.75	0.70	0.70	0.65	0.60
Flammability [3]	-	-	-	-	HB	-	HB	HB	HB
Merchanical properties									
Tensile modulus	MPa	95	113	223	55	45	110	220	375
Tensile stress:									
at 5% elongation	MPa	3.9	3.9	8.1	4.0	1.8	7.1	13.2	20.2
at 10% elongation	MPa	6.1	6.2	11.5	5.4	3.1	9.0	15.7	23
at 50% elongation	MPa	10.9	10.8	17.3	8.4	6.1	11.4	16.6	20.0
Tensile strength	MPa	17	20	23	17	15	21	32	40
Elongation at break	%	260	320	200	700	800	800	600	600
Izod impact strength:									
unnotched, at +23°C	kJ/m²	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]
unnotched, at -30°C	kJ/m²	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]
notched, at +23°C	kJ/m²	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]
notched, at -30°C	kJ/m²	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	20	4
Hardness Shore D	-	41	42	50	38	34	45	55	63
Electrical properties									
Dielectric strength	MV/m	-	-	-	-	-	-	-	-
Volume resistivity		-	-	-	$5x10^{14}$	-	10^{14}	10^{14}	10^{14}
Surface resistivity	N	-	-	-	$>10^{15}$	-	10^{14}	10^{14}	10^{14}
Dielectric constant ( ):									
at 50 Hz	-	-	-	-	4.1	-	-	-	3.8
at 1 MHz	-	-	-	-	4.0	-	4.4	4.0	3.4
Dissipation factor									
at 50 Hz	$x10^{-4}$	-	-	-	10	-	-	-	3.9
at 1 MHz	$x10^{-4}$	-	-	-	170	-	350	400	350
Tracking resistance									
CTI	-	-	-	-	600	-	600	600	600
CTI(M)	-	-	-	-	600	-	600	600	600

									Test methods
EL740	EL740-S	PL380		PL460	PL460-S	PL471	PL581		
EM740(-H)			PM381				PM581		
								PB582-H	
1.27	1.40	1.16	1.16	1.20	1.39	1.20	1.23	1.23	ISO R 1183
221	222	212	210	216	217	223	218	218	ASTM D2117
110	-	150	1.5	130	-	-	110	-	
120	-	-	-	-	-	-	100	108	ISO 75
									ISO 306
205	-	145	145	-	-	-	205	209	ISO 306/A
150	-	-	-	-	70	-	95	-	ISO 306/B
0.15	-	0.40	0.40	0.45	0.40	0.30	0.40	-	
0.60	-	7.00	7.00	4.00	3.50	-	2.50	-	
HB	V-0	HB	FH-3	HB	V-0	-	HB	-	UL94
900	1300	60	69	190	240	300	275	345	ISO 527
									ISO 527
26.9	-	3.5	2.6	6.0	7.9	8.9	17.0	10.6	
33.6	-	5.2	4.4	9.0	10.6	11.6	19.5	16.0	
26.3	-	8.5	8.8	12.5	14.1	14.4	21.0	20.6	
45	40	15	13	22	16	20	22	25	ISO 527
360	25	450	183	365	180	500	300	187	ISO 527
									ISO 180
NB[4]	NB[4]	NB[4]	NB[4]	NB[4]	-	NB[4]	NB[4]	NB[4]	ISO 180/1C
200	70	NB[4]	NB[4]	NB[4]	-	NB[4]	NB[4]	NB[4]	ISO 180/1C
9	12	NB[4]	NB[4]	NB[4]	-	NB[4]	NB[4]	NB[4]	ISO 180/1A
4	6	NB[4]	NB[4]	NB[4]	-	NB[4]	25	12	ISO 180/1A
74	74	38	34	47	51	47	58	57	ISO 868
-	-	-	-	-	-	-	1.0	-	IEC 243
10^{15}	-	10^{12}	10^{12}	-	-	-	10^{14}	-	IEC 93
10^{15}	-	10^{13}	10^{13}	-	-	-	10^{14}	-	IEC 93
									IEC 247
-	-	4.7	-	-	-	-	-	-	
3.3	-	4.4	-	-	-	-	4.0	-	
									IEC 247
-	-	310	-	-	-	-	-	-	
300	-	350	-	-	-	-	400	-	
									IEC 112
600	-	600	600	600	-	-	600	-	
600	-	600	600	600	-	-	600	-	

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