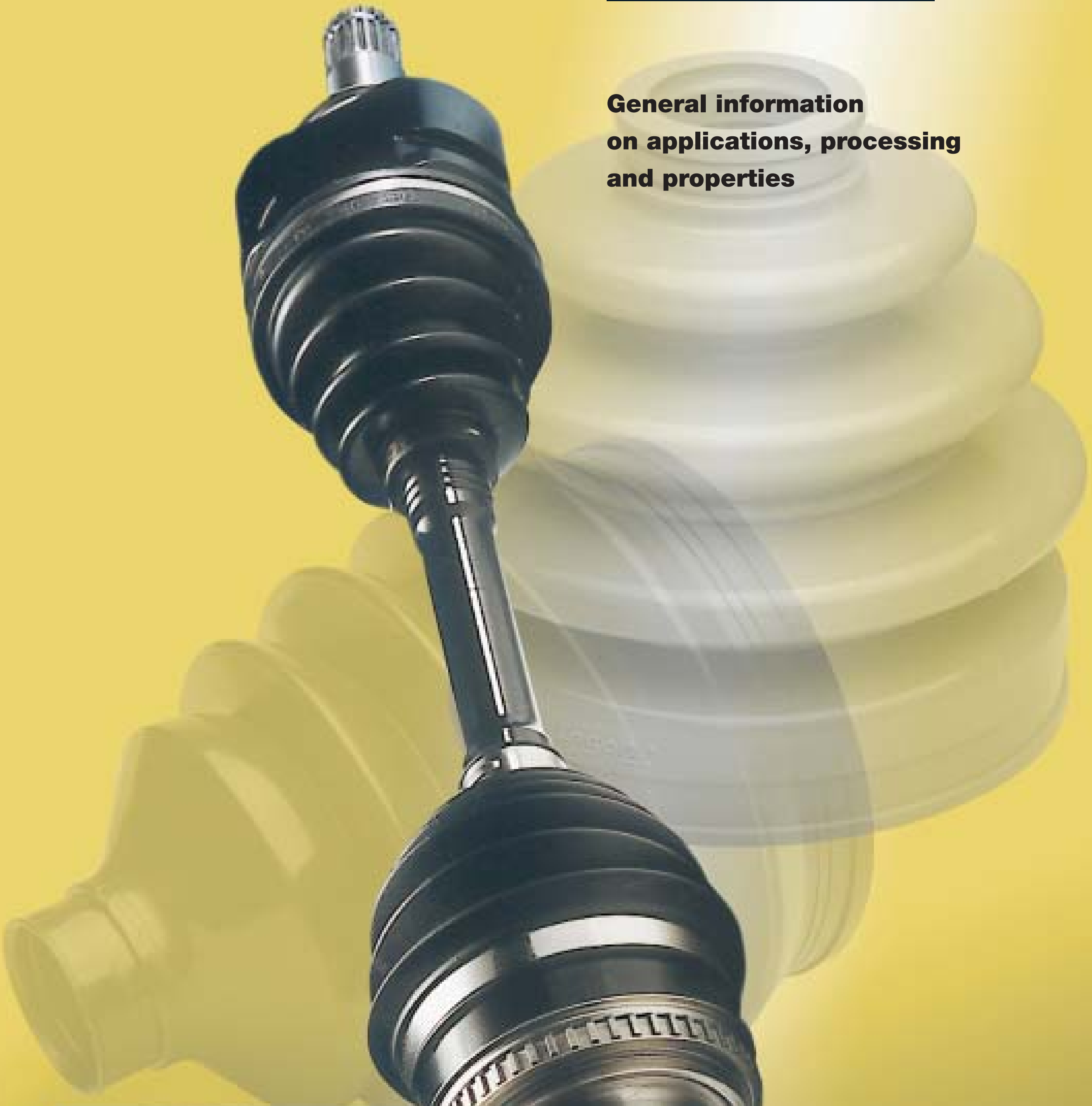
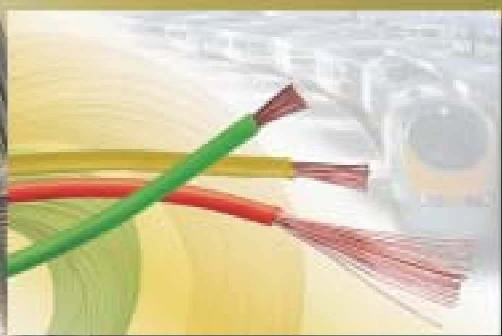
Arnitel



General information on applications, processing and properties



DSM

DSM ENGINEERING PLASTICS

Contents

Arnitel® team - dedicated to you

Our organisation is dedicated to our customers. We have Arnitel dedicated sales representatives in all major countries, backed up by Technical Marketing and Technical Field Service Engineers who visit customers regularly. These people are headed by a Regional Product Manager and supported by a Global Research department. The Arnitel organisation has the same structure in Europe, USA, and South East Asia/Japan. This allows us to establish synergy across the regions.

DSM

DSM is active worldwide in life science products, performance materials and industrial chemicals. The group has annual sales of close to EUR 5.6 billion and employs about 18,500 people at more than 200 sites across the world. DSM ranks among the global leaders in many of its fields. The company's strategic aim is to grow its sales - partly through acquisitions - to a level of approx. EUR 10 billion by 2005. By that time at least 80% of sales should be generated by specialties, i.e. advanced chemical and biotechnical products for the life science industry and performance materials. This strategy represents a continuation of the company's ongoing transformation and concentration on global leadership positions in high-added-value activities characterized by high growth and more stable profit levels.

DSM Engineering Plastics is a Business Group in the performance materials cluster of DSM, with sales in 2002 of EUR 579 million and 1300 employees worldwide. It is one of the world's leading players in the field of engineering thermoplastics offering a broad portfolio of high performing products.

DSM Engineering Plastics operates in all major markets of the world including the Americas, Asia, 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 a 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. Access to polycarbonate was secured under a long term capacity sharing agreement with Dow Chemical.

All our compounding facilities in the world (in the Netherlands, Belgium, USA, Canada, China 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:
Akulon® (PA6 and PA66)
Akulon® Ultraflow™
(high flow Akulon PA6)
Akulon® XP
(Xtreme Performance PA6 for film)
Arnite® (PBT, PET)
Arnitel® (TPE-E)
Stamylan® UH (UHMWPE)
Stanyl® PA46 (PA46)
Stanyl PA46 High Flow™
(high flow PA46)
Stapron® (PC-blends)
Xantar® (PC)
Yparex® (extrudable adhesive resins)

Complemented in some regions by products as:
Electrafil® (conductive products)
Fiberfil® (reinforced polypropylene)
Nylatron® (PA66 specialties)
Plaslube® (lubricated products)

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's 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 brings 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

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)

Asia Pacific
Jiangsu - China
(compounding)
Pune - India
(compounding)
Tokyo - Japan
(M/S joint venture and toll compounding)

Introduction

Arnitel overview

Arnitel is a family of thermoplastic copolyester based elastomers (TPE-E's 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".
E and P types are more traditional polyether-ester formulations, while U grades are based on unique polyester-ester technology that extends the traditional temperature range of thermoplastic elastomers.
Arnitel copolyester elastomers fall in the middle to 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.

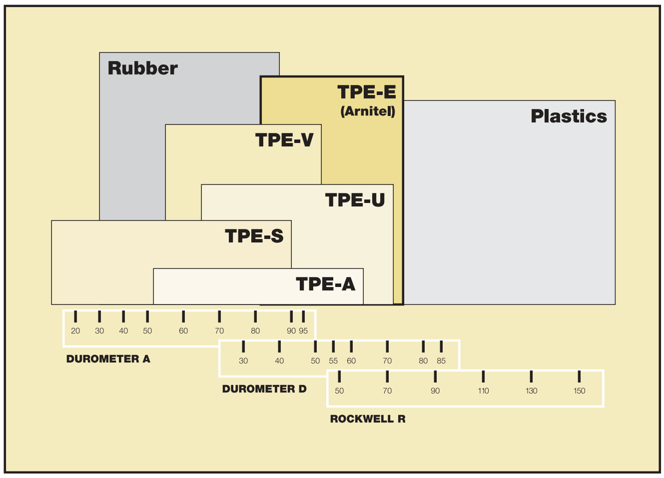


Figure 2. Positioning of thermoplastic elastomers versus thermoset materials.

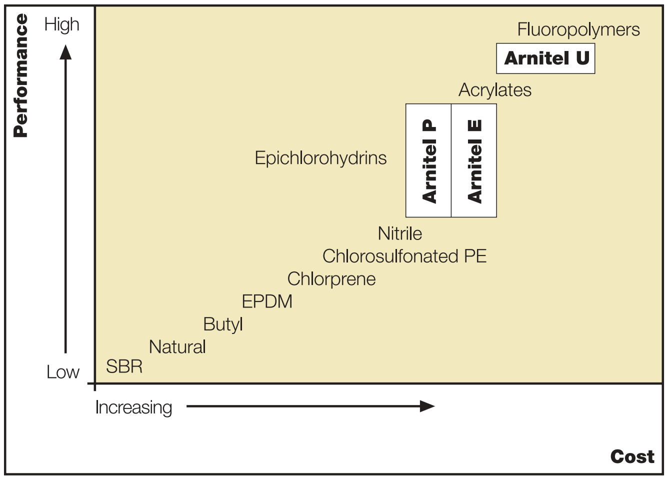
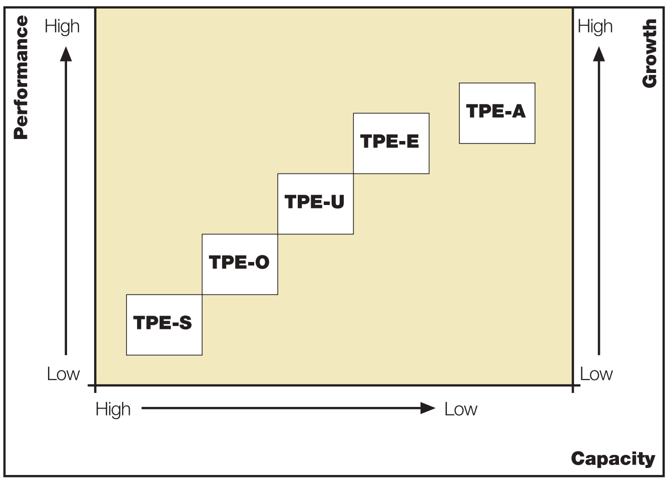


Figure 3. TPE's positioning in performance capacity/growth.



Copolyester elastomers product scope

Table 1. Arnitel product range.

Shore D	38/42	46/47	50	55/58	63	69	74
Arnitel E	EM400 EM401 EM402-L	EB460 EB463 EB464 EM460 EM460-H	EB500	EL550 EM550	EL630 EM630	EL695-G2 EL695-G4	EL740 EM740 EM740-H
Arnitel P	PL380 PL380-M0 PL420-H PM381	PL460 PL460-S PL471		PB581-H PL581 PM581			
Arnitel U				UM551 UM551-V UM552	UM622		

Table 2. Arnitel product coding.

	U	M	55	1	-V
Thermoplastic elastomer type E = polyether-ester P = polyether-ester U = polyester-ester	U				
Indication of viscosity range or processing technique L = injection moulding M = extrusion B = blow moulding		M			
Hardness (Shore D)			55		
Serial number				1	
Specific properties S = flame retardant (V-0), halogen containing G = glass fibre reinforced V = flame retardant (not V-0), halogen free					-V

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 of any grade 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 weight (%)
Heat ageing for E or P	Arnitel E - Heat	0.5 - 3.0
UV for E or P	Arnitel E - UV	1.25 - 2.5
Hydrolysis for E or P	Stabaxol® KE9514*	2.5 - 7.5
Hydrolysis for U	Stabaxol® KE9464*	8.0 - 10

**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.

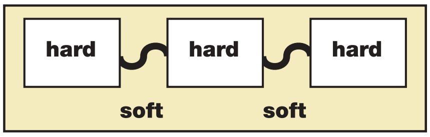


Table 4. Arnitel property profile.

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.*

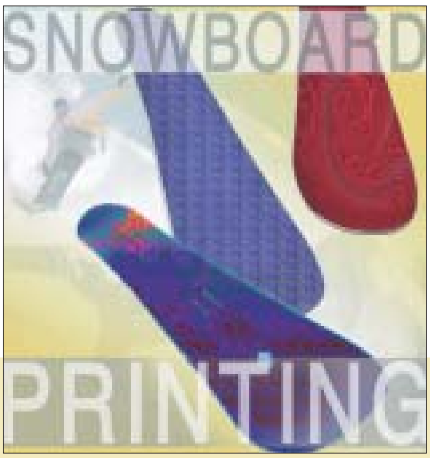
Arnitel properties. The ratio of soft to hard block and the composition of the soft segment can be varied, creating a wide range of properties. Main characteristics of Arnitel include:
- excellent flexural fatigue endurance
- high peak temperature resistance
- high impact strength, even at low temperatures
- 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
- Urethane-like abrasion resistance
- inherent resistance to copper poisoning.

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 benefit from Arnitel 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, 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.

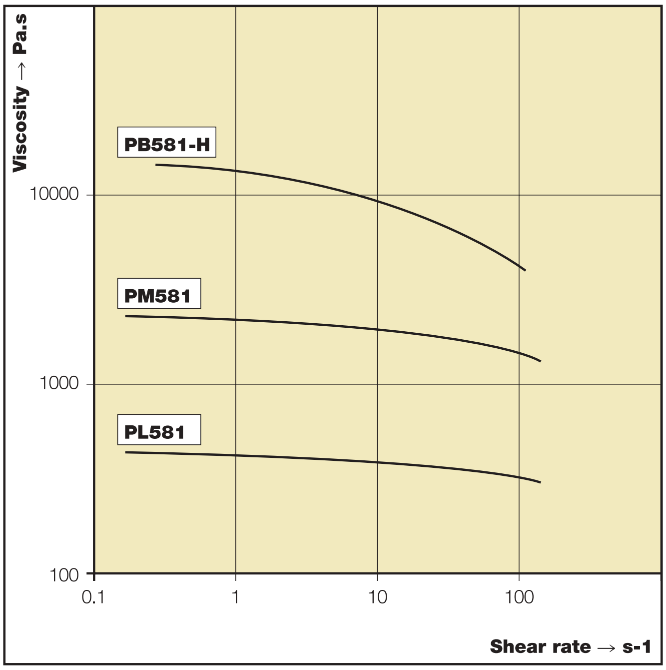
The following measures are recommended:
- bring cold granules up to ambient temperature in the processing room in closed packaging
- open packaging just before filling
- close packaging securely if all of the contents have not been used.

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

Typical 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

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.

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



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 length and weld lines, especially in parts with low wall thicknesses such as tear seams in airbag doors or in keypads. The higher crystallization temperatures and 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.
The excellent productivity and process capability attainable make Arnitel the material of choice within the processing community for copolyester elastomers.

Body plugs, Arnitel PL581, PL380, PL460.

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. The UV resistance of 55 Shore D and 63 Shore D materials is good but then decreases for both lower and higher hardness products.

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

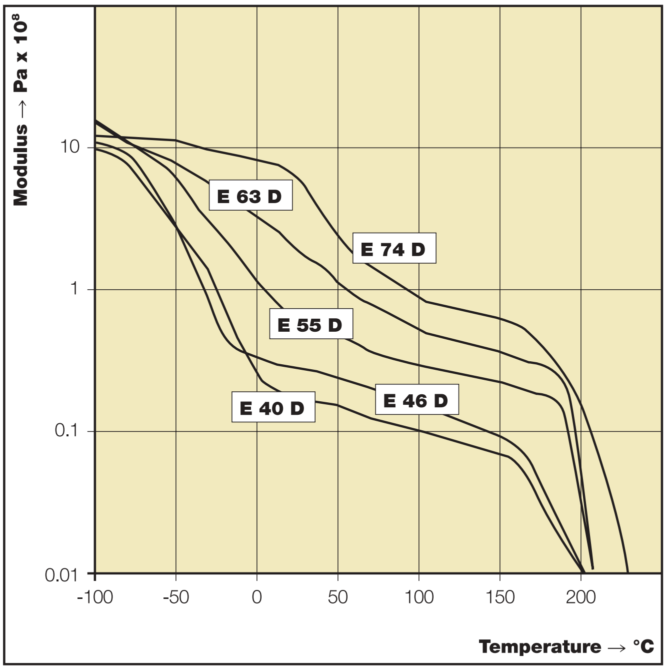
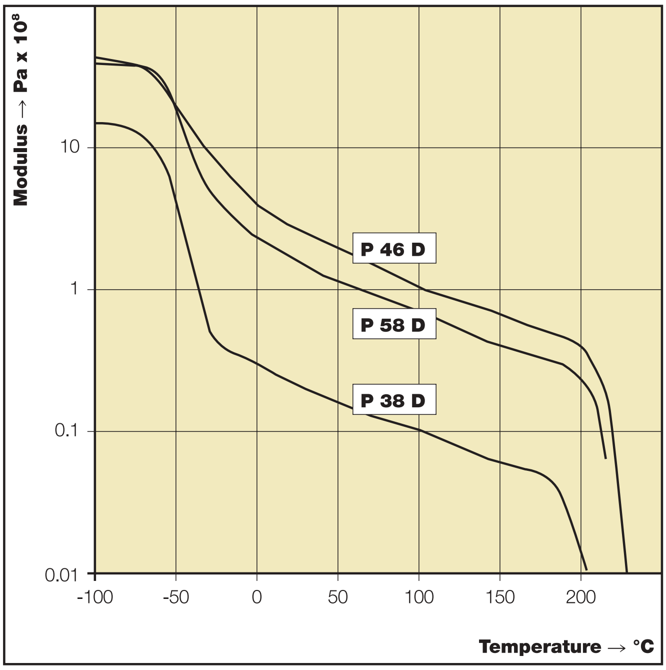


Figure 7. Modulus versus temperature for Arnitel P-grades.



Plyers, Arnitel EM460, EM400.

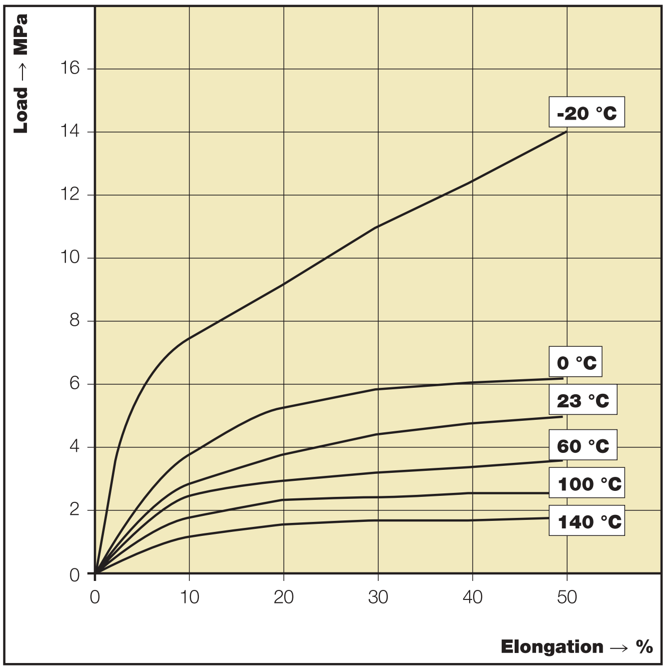


Figure 8. Arnitel E 40D stress strain curves low strain (ISO 527-1BA test specimen, parallel to flow, 50 mm/min).

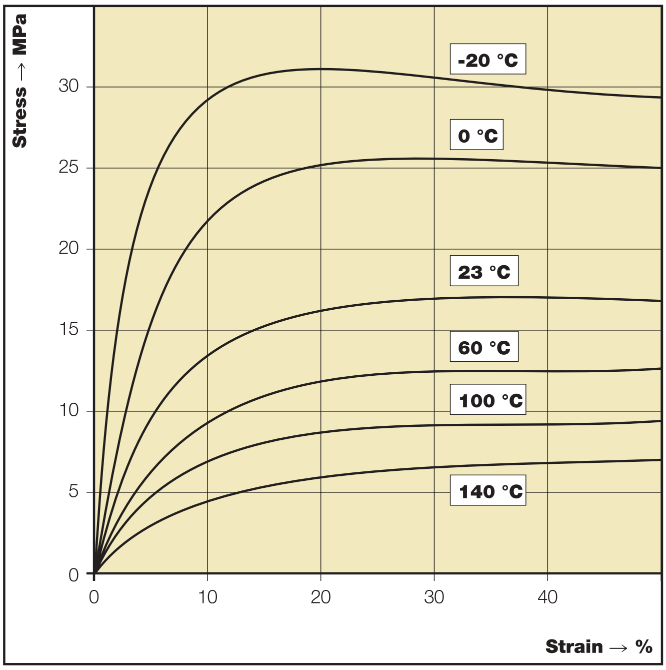


Figure 9. Arnitel PM581 stress strain curves (ISO 527-1BA test specimen, parallel to flow, 50 mm/min).

Copolyesters will function as elastomers as long the operating temperature is within the rubbery plateau 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.

They 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 63D and 74D 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.

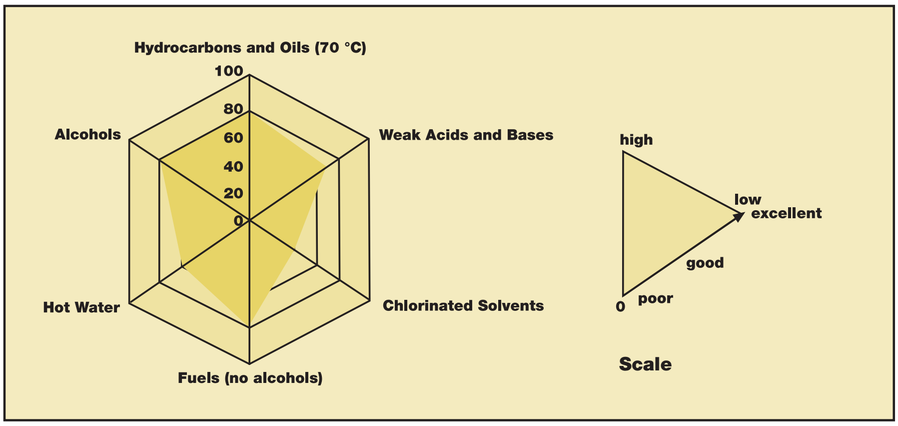
Stress-strain curves are important to understand the elastic behaviour of elastomers (see Figures 8 and 9). Usually, the lower the hardness (and stiffness) of a material, then the lower the stress at yield and the higher the elongation at yield. This defines the strain range in which the material will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

The bindingstrap fixes the shoe to the binding system.

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 jacketting material. All Arnitel types are intrinsically stable against copper. One flame retardant V-0 grade is available.

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 increase, 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.

Airducts

An airduct transports the air needed for combustion of the fuel in a car. It is a 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 see sometimes 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.

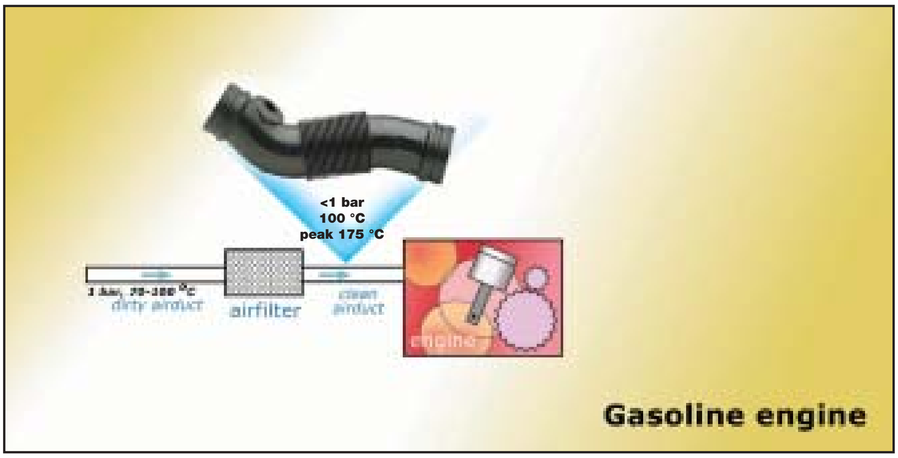


Figure 12. Air management systems with clean and charged airducts from Arnitel.

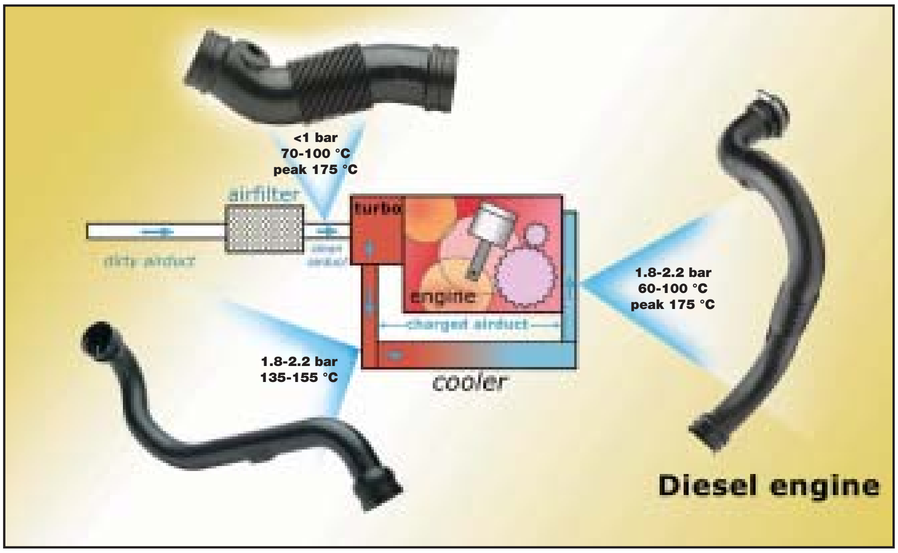


Table 5. Performance matrix clean and charged airducts.

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

Arnitel grades. Suitable airduct grades are: PB581-H, PB582-H, EB464

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 (CV) Joint boots. In front wheel drive 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) CVJ 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.

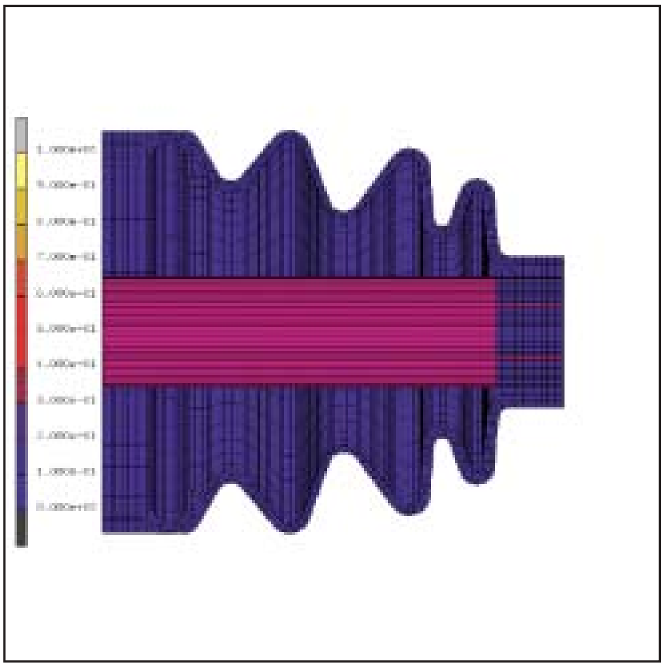
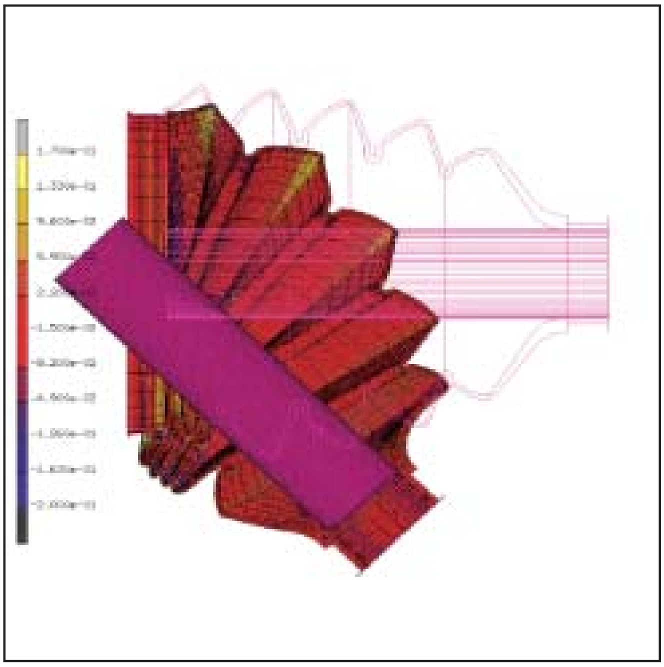


Figure 14. Example of CVJ boot design in Arnitel.



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

Apart from the Arnitel grades EB460, EB463 and EB464, new grades are under development 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.

Plunge boot grades are also under development with similar requirements.

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.

Table 6. Positioning of Arnitel in fixed CVJ boots.

Property	Arnitel			Other	CR-
	EB464	EB463	EB460	TPE-E	rubber
Dynamic cold start -40 °C	+	o	o	+	-
Dynamic abrasion resistance at 23 °C	+	+	++	o	o
Dynamic grease resistance at 100 °C	++	++	o	o	o
Dynamic grease resistance at 90 °C	+++	+++	++	+++	o
Ossberger process	++	++	+++	o	na
Use of regrind upto 30%	okay	okay	okay	okay	not okay

o *fair* + *good* ++ *very good* +++ *excellent*

Table 7. Portfolio for fixed CVJ boots.

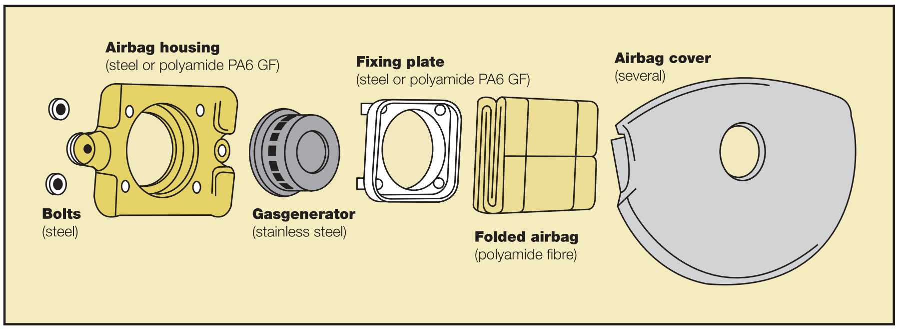
Grade	Dynamic behaviour at -40 °C	Grease resistance at 100 °C	Processing consistency
EB460			✓
EB463		✓	✓
EB464	✓	✓	✓

CVJ boot in Arnitel EB463 developed by GKN Automotive GmbH.

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 positioned 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, preferably 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 15a 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 developed for airbag cover industry. Arnitel PL471 is a low modulus grade developed specifically 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 the ideal situation would be that the modulus curve of the material is horizontal from -35 °C to +85 °C.
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.

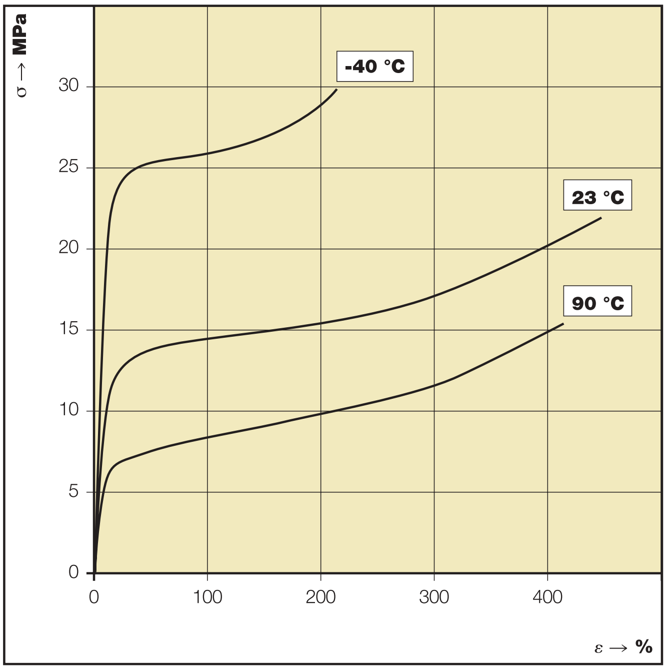
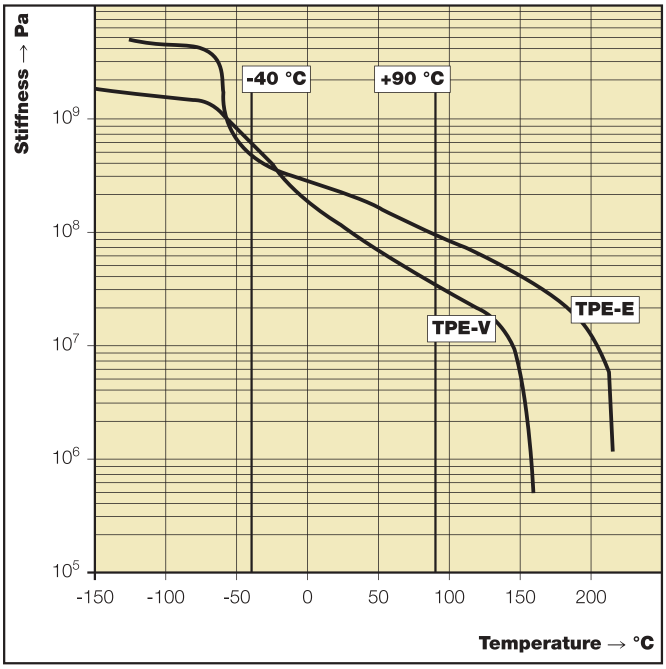


Figure 17. Arnitel in airbag doors: temperature versus stiffness.



Painting. Arnitel PL471 can be painted easily with most standard flexible PUR paints. Suitable paints are developed 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	ISO 527	20 MPa
- Yield stress max.		15 MPa
- Elongation at break		600%
- Tensile modulus		280 MPa
Tensile strength -40 °C	ISO 527	30 Mpa
- Yield stress max.		25 MPa
- Elongation at break		215%
- Tensile modulus		440 MPa
Tensile strength +90 °C	ISO 527	15 MPa
- Yield stress max.		8 MPa
- Elongation at break		410%
- Tensile modulus		> 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 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 extremely 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:
- high moisture vapor permeability (MVTR)
- 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).

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

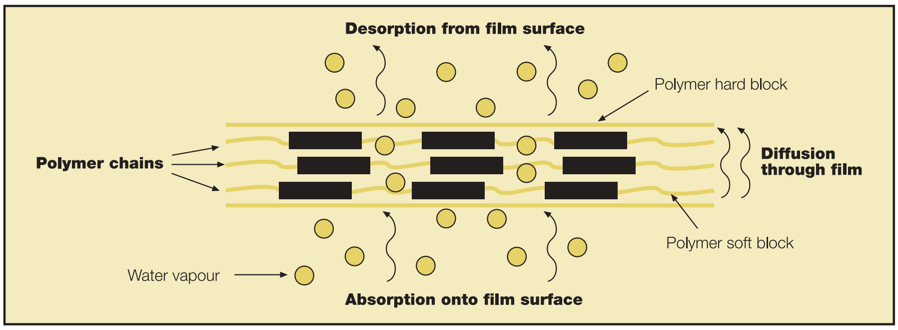


Table 9. Markets for TPE-E’s.

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	See grade portfolio				
Other applications					
Specialty food packaging	See grade portfolio	FDA			
High heat resistant film	UM552, PM581	n.a.			

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

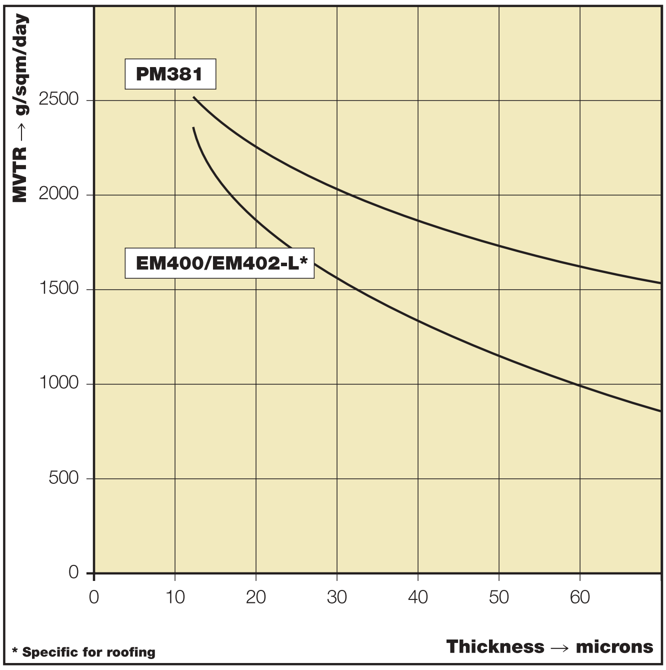


Figure 19. MVTR versus thickness for Arnitel according to E96B.

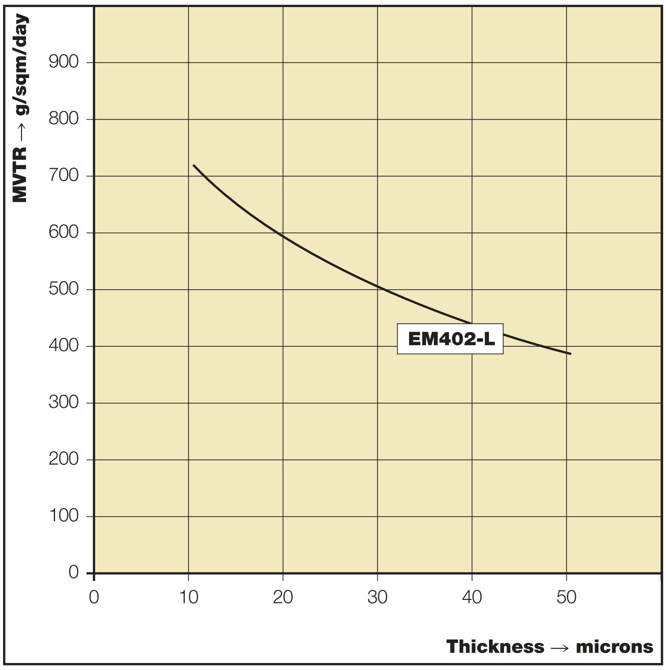


Figure 20. MVTR versus thickness for EM402-L as a function of film thickness according to DIN-53122-D and E96A (desiccant at 23 °C and 85%).

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 a drastic decrease in MVTR.

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

Arnitel U

Arnitel U is a high heat thermoplastic elastomer based on PBT and an aliphatic polyester soft block whereas Arnitel E and P grades use polyether soft blocks. This polyester soft block is the reason that Arnitel U has unsurpassed heat ageing results.
In Figure 21 this heat ageing result is shown.

Grade Range. The material is available either as a base polymer or as a compound for specific end use applications. Table 10 lists the different grades.

Chemical resistance. Arnitel U shows good chemical resistance. In the attachment an overview is given of all Arnitel grades. The resistance of Arnitel U against water is listed in Table 11.

The water resistance can be improved by using a stabilization system, Staboxol®, available through Rhein Chemie Germany. Using 1.6 to 2% of this stabilizer (8-10% MB) gives 2-3 times the lifetime over unstabilized Arnitel U.

Figure 21. Heat ageing capability Arnitel U.

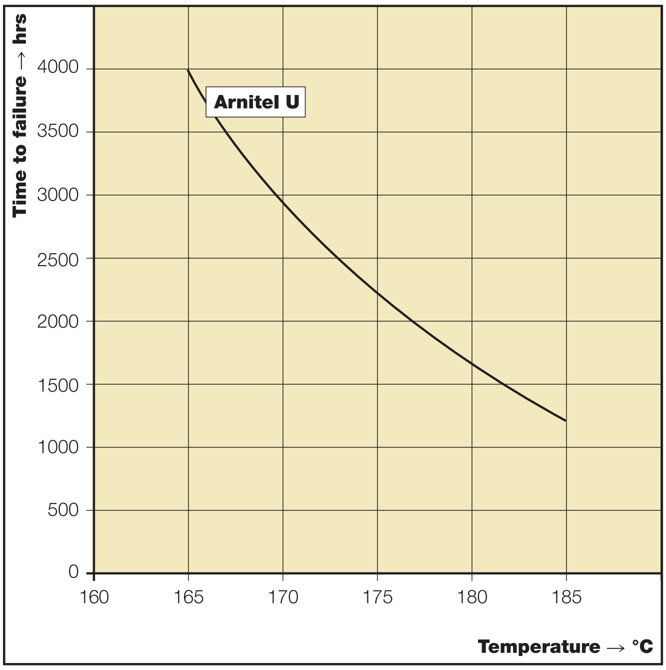
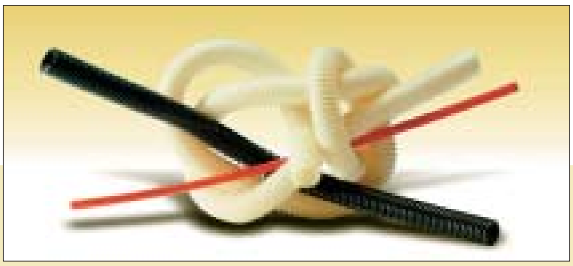


Table 10. Arnitel grades and applications.

Grade	Description	Melting point (°C)	MFI (T = 230 °C)
UM551	Base polymer 55 Shore D	198	14
UM552	Base polymer 55 Shore D with MFI of 7	198	7
UM551-V	Compound with halogen free flame retardant MFI 14	198	14
UM622 Blk	Black compound also for peak temperature performance	220	-

Table 11. Water resistance results.

Temperature (°C)	Relative Humidity (%)	Lifetime (days)	Note
27	80	3000	Tropical climate
150	0.1% RH	100	Air from tropical climate heated to 150 °C
80	100	13	"Microclimate" conditions



Arnitel offers excellent flexibility and heat resistance for convoluted tubing.

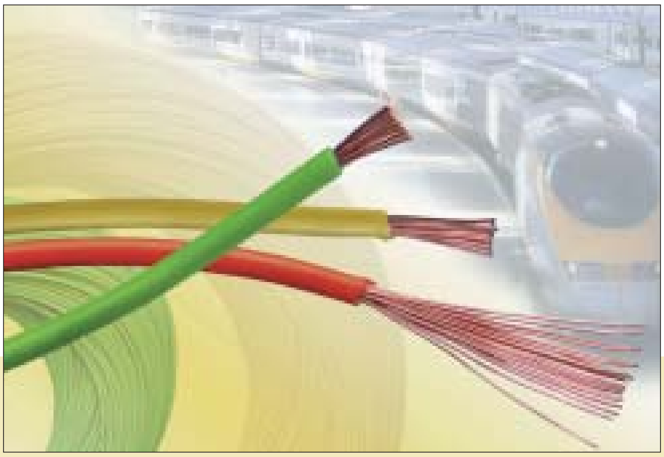
Typical applications. An application overview is given in Table 12. Arnitel is normaly chosen for one or more reasons from the list on the right.

Customer benefits are:

- superior heat ageing
- good wear resistance
- halogen free flame retardant package V-2 rating at 1.6 mm for flame retardant grades
- flexible, with a modulus of 200 Mpa
- easy processing with viscosities tailored to the shaping process.

Table 12. Application overview.

Application	Grade	Customer benefit
Cable insulation for public transportation	UM551-V	Halogen free formulation gives low smoke and low toxic performance during fires.
Automotive convoluted tubing	UM622 Blk UM552 UM551-V	Excellent heat ageing properties with, if applicable, a halogen free flame retardant package. Flexibility allows easy cable insertion.
Convoluted tubing for the construction industry	UM551-V	Halogen free formulation gives low smoke and low toxic performance during fires.
Film industry	UM552	Excellent heat ageing properties, combined with high peak temperature.
Miscellaneous injection moulding	UM551	Excellent long term heat ageing with 55 shore D hardness. Improved UV resistance. Improved compression set.



Low fire hazard thin wall wires and cables for control units in trains.

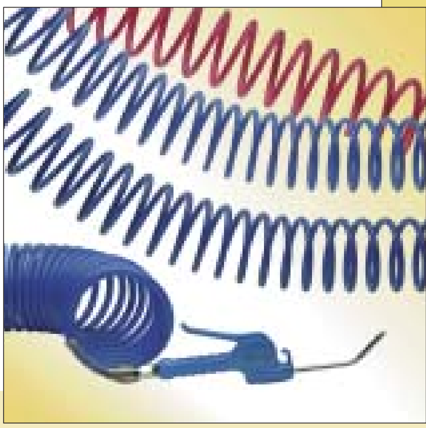
Arnitel for tubes and hoses

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 vulcanisation 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 can offer a service life of 10 or more vulcanisation cycles although the exact number depends on the rubber and its vulcanisation system.

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 a 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 brake. Brake tubing made from 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.

In the consumer product area, typical Arnitel applications are those where the need for excellent oil or grease resistance is combined with excellent processing, perfect surface appearance, good abrasive properties etc. Examples are suitcase handles for better grip and load bearing capacity, tools that always give the optimum performance, antenna covers for mobile or low-noise gears for silent operation in electrical appliances or equipment.

For energy absorption related applications, excellent fatigue resistance is the main feature combined with issues such as colourability, chemical resistance and outdoor performance. Examples are industrial applications (railway pads and train buffers) and consumer products (bedsprings for improved sleep comfort).

In medical and personal care applications, Arnitel is used for its excellent food contact behaviour and Pharmacopoeia approvals. These approvals have led to applications in sterilisable catheters, surgical threads for cleaner and better looking wound sutures and flexible components in all types of dispensers.

The last major application area uses the excellent dielectrical properties of the Arnitel copolyester elastomer with other important properties like resilience, creep resistance, heat/UV resistant and/or flexibility. These applications include optical fibre cables for high-speed data transmission, electrical wiring for medical equipment or specific types of automotive wiring.

In case of cable applications quite often UL flame retardancy listmaps are requested. These are listed in Table 14.

FDA food approvals

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

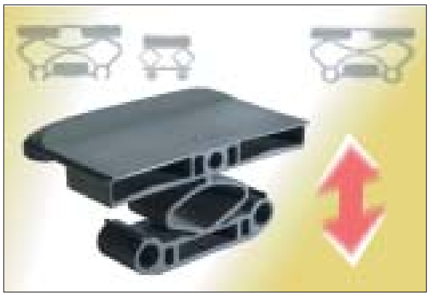
Table 13. Grades admitted for contact with foods stuff.

Arnitel E	
EL550	EM400
EL630	EM460
EL740	EM550
	EM630
	EM740

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

Car antenna, Arnitel PL380.

Suitcase handle, Arnitel PL380 (gas injection moulding).



Bedflex is a part that supports the wooden lats in a bedframe. Arnitel E- and P-types.

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

UL recognitions

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

Description	Grade designation	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	1.5	V-0	50	50	50	-	-	-	-	-
	PL380	NC	1.5	HB	50	50	50	-	-	-	-	-
	PL460-S	All	1.6	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

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.

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 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
1.2-3.0	0.8-2.0 / 0.8-1
3.0-5.0	1.5-3.5 / 0.9-1
> 5.0*	3.5-6.0 / 0.8-1

(Avoid wall thicknesses larger than 5 mm).*

Screw drivers, Arnitel PL381.

Venting. Special attention should be given to effective mould venting. Venting is effected by vents (approximately 1.5 x 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 if they were fresh
- alternatively, if you don't have the proper equipment, 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 go 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.

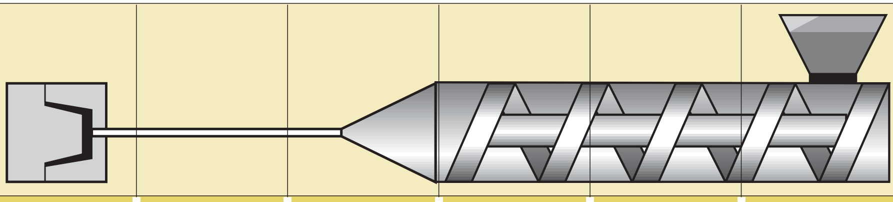
Colouring granules. Arnitel can be coloured during processing by a variety of techniques. The simplest method is to mix the pigment powder with the granules prior to introducing to the hopper. This can be done by dusting the granules in drum mixers, approximately 0.2% of dusting oil may be found necessary.

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 extrusion grade, chosen for its physical property performance over a 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, Arnitel PL581.

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 length as a function of injection pressure.

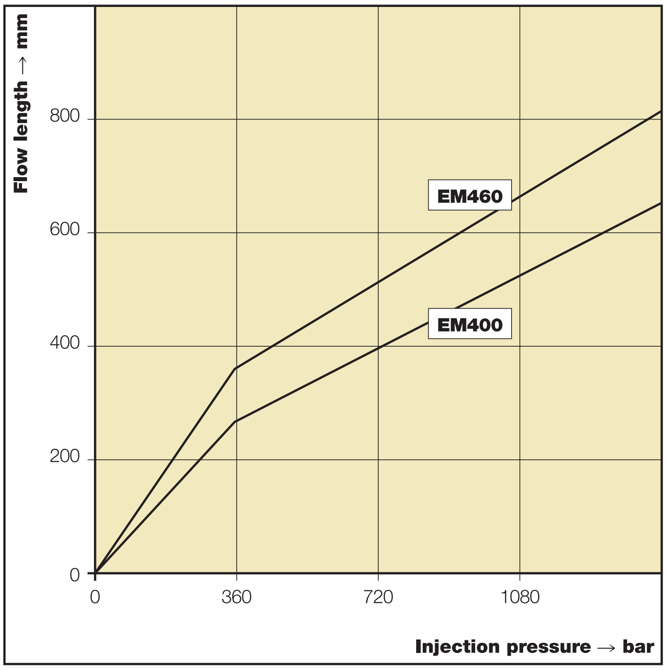
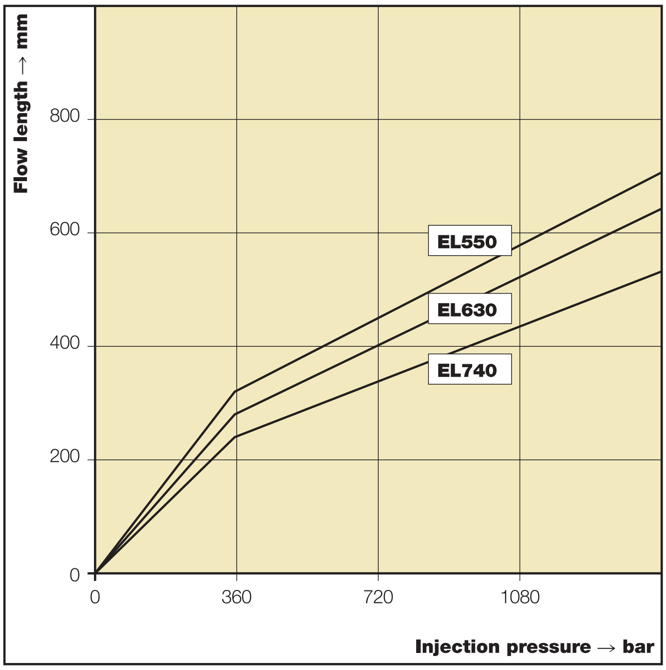


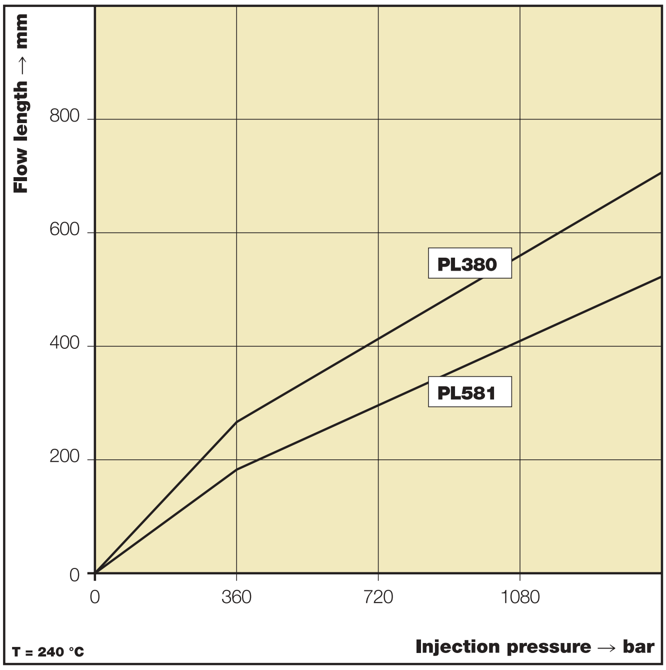
Figure 23.
EL550 - EL740 – flow length as a function of the injection pressure.



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 has in practice been found to be 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 both heat generation through shear and the reduction in glass fibre length.

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



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.

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 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.

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:

Product-dependent factors:
- wall thickness
- flow path length
- gating system.

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

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 will be pleased to tell you whether the flexibility of the coating you have selected matches the hardness - or rather stiffness - of the Arnitel grade used.

Metallizing. Vacuum-metallizing 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 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 request the brochure on this topic.

Pencilgrip, Arnitel EM400.

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)*
PBT	EM400	240	23	50	90	500
		260	23	25	100	2000
PBT	EM460	240	23	25	100	500
		260	23	25	100	1750
EM400	PBT	260	23	500	105	6000
		280	23	1250	105	5500
EM460	PBT	260	23	1000	105	2500
		280	23	1000	105	3500
PC	EM400	240	23	500	80	4500
		260	23	1250	80	>9000*
PC	EM460	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	-	-
ABS	PL380	240	23	850	-	-
PVC	EM400	220	23	30	-	-
Polystyrene	EM400	220	23	-	-	-
Polystyrene	PL380	220	23	-	-	-

** 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.

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

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

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.

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 and
- 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.

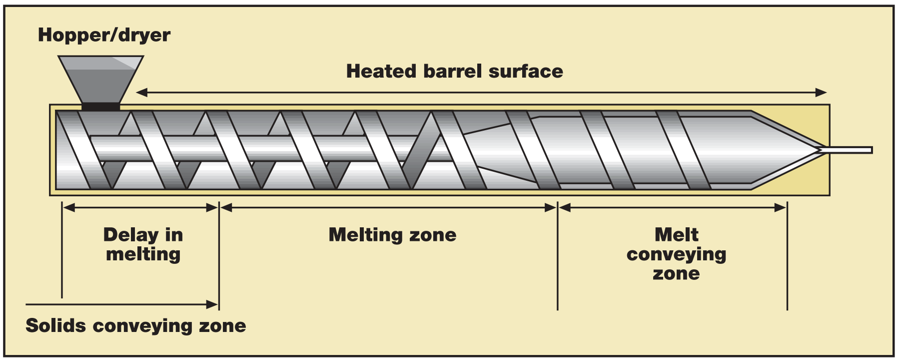


Table 20. Design parameters.

Characteristic design parameters three-zone screw					
Screw length	24-27				
Pitch	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
U	55	3	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 a 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 a 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 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.

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 fluidised 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.

Table 22. Extrusion guidelines

Arnitel Grades	Melting point (°C)	Melt flow index at: 220 °C (dg/min)	230 °C (dg/min)	240 °C (dg/min)	Processing temp. minimum (°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
UM551	200	-	14	-	210	260
UM551-V	200	-	14	-	210	260
UM552	195	-	7	-	210	260
UM622	220	-	25	-	210	240

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.

Foaming

Laminates made of Arnitel with wall thicknesses ranging from 0.3 to 10 mm can generally be foamed in extruders, but the chemical blow agent must be dosed at the extruder end.

A HYDROCEROL-Compound CLM 70 (2%) is used as foaming agent. A 0.2% VS 103 (fluid) or calcium carbonate is added to ensure a uniform cell structure. Other possible chemical blowing agents include Expandex, and different Genitron types.

Arnitel tubing extrusion equipment.

DSM Engineering Plastics product portfolio

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.
Akulon® XP polyamide	Xtreme Performance PA6 for film
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.
Arnitel® copolyester elastomers	High performance elastomers based on polyester.
Stamylan® UH ultra high molecular weight polyethylene	A high performance polymer having outstanding abrasion resistance in combination with excellent impact and chemical resistance, low coefficient of friction and very good electric and dielectric properties.
Stanyl® PA46 46 polyamide	High temperature polyamide which bridges the price-performance gap between traditional polyamides and high-performance materials.
Stanyl® PA46 High Flow™ 46 polyamide	An innovative PA46 which combines excellent mechanical performance with (LCP-like) high flow and low warpage resulting in cost-savings for demanding high-end applications.
Stapron® PC/PET-blend	Unreinforced and reinforced PC-blends. 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.
Xantar® C PC/ABS-blend	A new generation PC/ABS-blend providing improved flow, simultaneously increasing impact and stress-crack resistance, while optical appearance and stability are on a very high and consistent level.
Yparex® adhesive resin	This family of extrudable adhesive resins consists of polyolefins with incorporated functional groups, which provide the necessary bond between polyolefins and polar materials (e.g. PA, EVOH, glass) or metals (e.g. steel, aluminium, brass, copper).

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