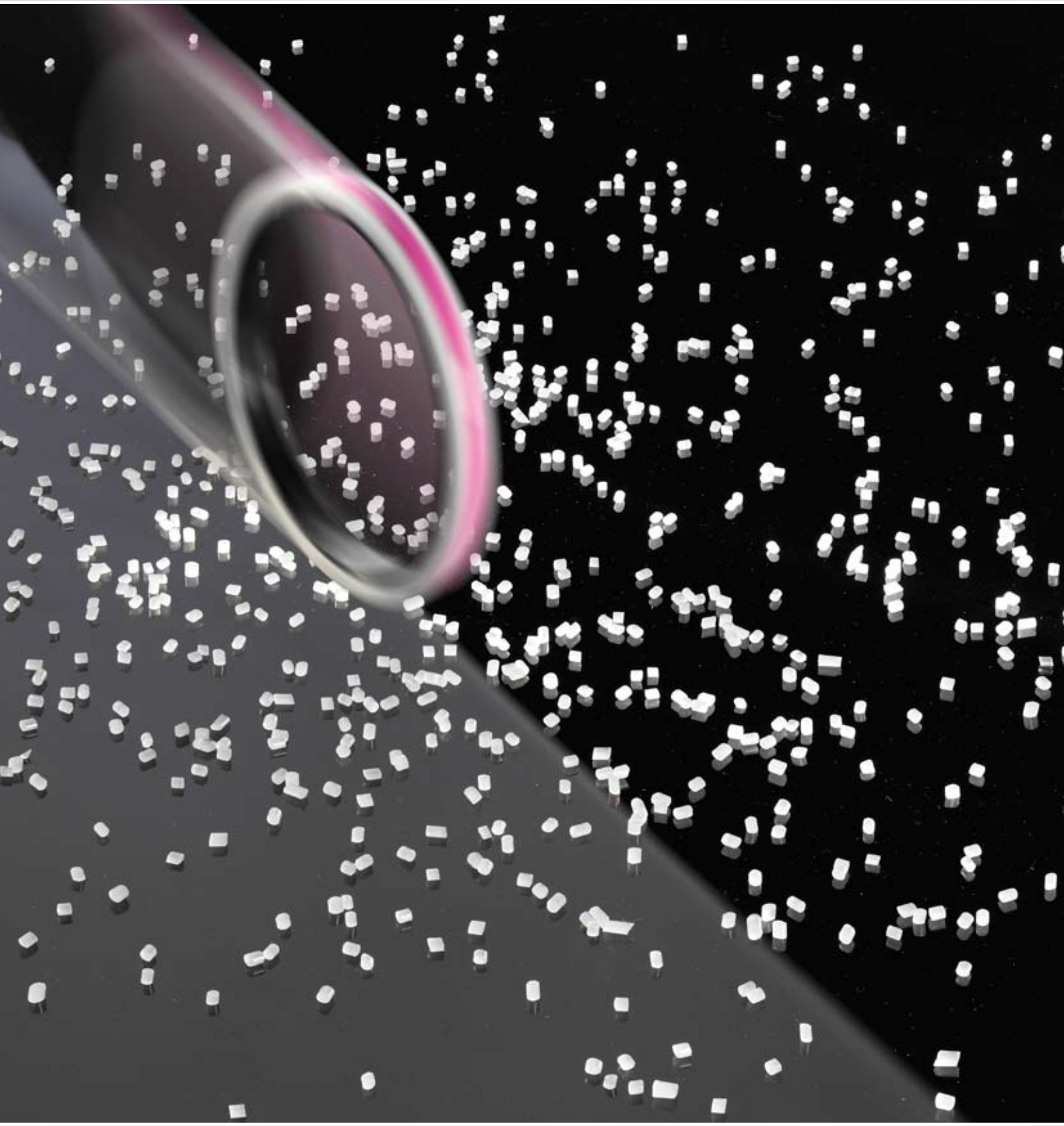
ARTIC SEALS™

TPU Guide Line



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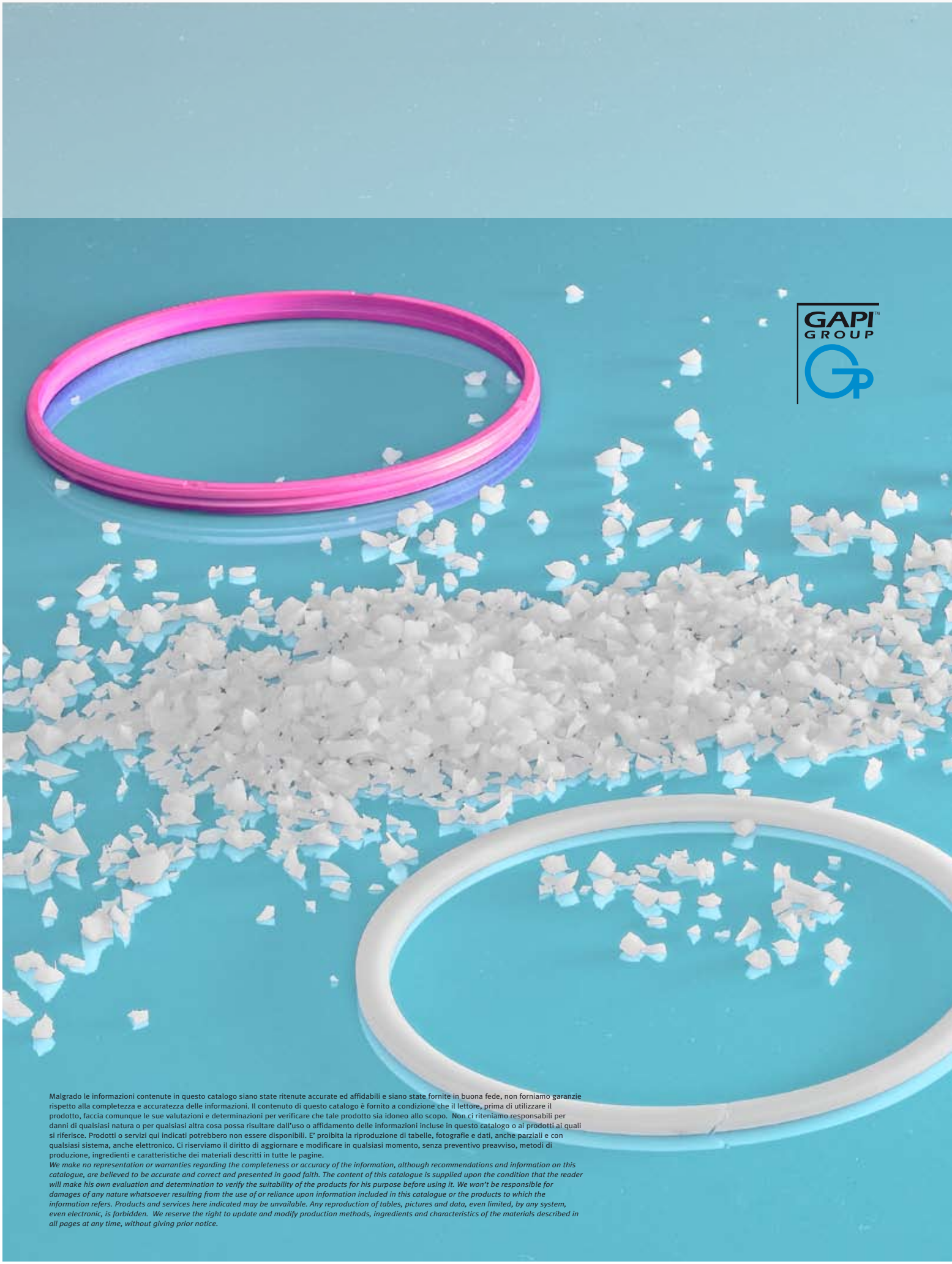

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What is TPU

Thermoplastic polyurethanes (TPUs) offer exciting possibilities for meeting the manufacturing challenges of a fast-changing world. Well-known for their outstanding versatility, Artic Seals's TPUs can improve the production and enrich the performance of our wide range of seals. Building on years of experience, we have selected a large number of TPUs with limitless potential to meet customer application requirements.

Thermoplastic polyurethane (TPU) is a unique category of plastic created when a polyaddition reaction occurs between a diisocyanate and one or more diols.

First developed in 1937, this versatile polymer is soft and processable when heated, hard when cooled and capable of being reprocessed multiple times without losing structural integrity.

Used either as a malleable engineering plastic or as a replacement for hard rubber, TPU is renowned for many things including its: high elongation and tensile strength; its elasticity; and to varying degrees, its ability to resist oil, grease, solvents, chemicals and abrasion.

These characteristics make TPU extremely popular across a range of markets and applications. Inherently flexible, it can be extruded or injection molded on conventional thermoplastic manufacturing equipment to create solid components typically for seals, footwear, cable & wire,hose and tube, film and sheet or other industry products. It can also be compounded to create robust plastic moldings or processed using organic solvents to form laminated textiles, protective coatings or functional adhesives.

There are three main chemical classes of TPU: polyester, polyether and a smaller class known as polycaprolactone.

Polyester TPUs are compatible with PVC and other polar plastics. Offering value in the form of enhanced properties they are unaffected by oils and chemicals, provide excellent abrasion resistance, offer a good balance of physical properties and are perfect for use in polyblends.

Polyether TPUs are slightly lower in specific gravity than polyester and polycaprolactone grades. They offer low temperature flexibility and good abrasion and tear resilience. They are also durable against microbial attack and provide excellent hydrolysis resistance – making them suitable for applications where water is a consideration.

Polycaprolactone TPUs have the inherent toughness and resistance of polyester-based TPUs combined with low-temperature performance and a relatively high resistance to hydrolysis. They are an ideal raw material for hydraulic and pneumatic seals.

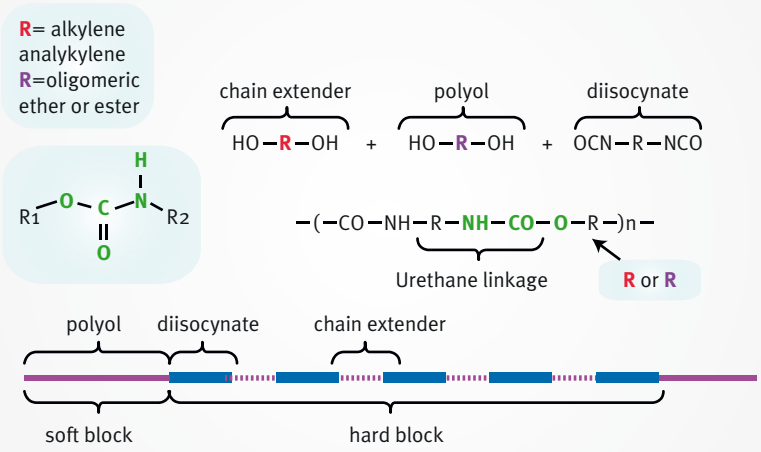
TPU Chemistry

A TPU is a multi-phase block copolymer that is created when three basic raw materials are combined together in a specific way. The individual components required to produce a TPU are:

- A polyol or long-chain diol
- A chain extender or short-chain diol
- A diisocyanate

Figure 1.0 shows the basic chemistry of TPU. The soft block, built out of a polyol and an isocyanate, is responsible for the flexibility and elastomeric character of a TPU. The hard block, constructed from a chain extender and isocyanate, gives a TPU its toughness and physical performance properties.

Fig. 1

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Physical Properties

Material Resistance

The mechanical properties of a TPU can be evaluated in a number of different ways. Detailed below are some of the standard assessments used to measure a TPU's characteristics and define what can be expected in terms of physical performance and longevity.

Shore hardness

Shore hardness is an empirical measurement used to test a TPU's resistance to indentation or penetration under a defined force. Two letters are used to categorize the type of TPU being appraised: 'A' denotes a flexible type of TPU while 'D' refers to more rigid varieties. These two categories can sometimes overlap. On both scales measurements range from zero to 100 with zero being very soft and 100 very hard.

Tensile strength

Tensile strength is an indicator of TPU behavior and the tendencies that will be exhibited when a specimen cross section is placed under short-term, uniaxial stress. In other words, the strain it will endure before any sort of deformation starts to occur. Guidelines for undertaking tests are specified in the standard DIN 53504 or ASTM D412. Results are usually documented in a stress strain diagram. See Figure 3 as an example.

Tear strength Tensile

Tear strength denotes a TPU's ability to counter break and distortion. The higher the tear strength, the greater the number of utilization options there are likely to be.

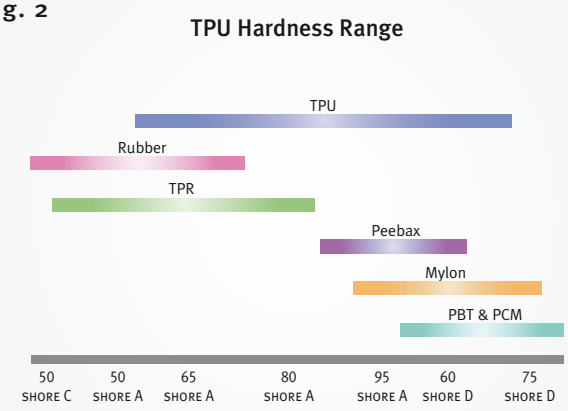
Compression set

A TPU's compression set can be defined as the permanent deformation that remains after compressive stress has been released. It is calculated as a percentage of the original deflection after the material has been allowed to recover at standard conditions for 30 minutes. The compression set of a TPU is normally tested over a period of 24 hours at a specified temperature. Guidelines for standard deformation tests are defined in DIN ISO 815 or ASTM D395. To ensure that TPU materials can offer the very best compression resistance, heat treatments like post curing is required.

Abrasion

The abrasion resistance of plastic materials like TPU is measured by applying coarse paper to a substrate under pressure via a rotating cylinder. This sort of test typically takes place as per DIN 53516 (ISO 4649) guidelines. The weight of the TPU specimen is measured before and after the abrasion assessment to gauge how much wear has occurred. The original density of the material is considered alongside the roughness of the paper with results typically expressed in terms of volume loss of the substrate in mm3.

Fig. 2



Highlights the diversity of TPU chemistry and the broad spectrum of materials that can be created ranging from soft rubbers to rigid thermoplastics.

Fig. 3

Strength characteristics:

The yield stress is the tensile stress at witch the slope of the stress-strain curve become zero

Tensile strength is the tensile stress at maximum force

Tear strength is the tensile stress at the moment of rupture of the specimen

Deformation characteristics:

The yield strain is the elongation corresponding to the yield stress

Maximum force elongation is the elongation corresponding to the tensile strength

Elongation at break is the elongation corresponding to the tear strength

Chemical resistance

Recognizing that certain applications require TPUs that demonstrate chemical resistance, Artic Seals offers a technical service that can help gauge the resistance of its TPU grades in relation to specific substances – particularly those employed in industrial, laboratory and medical projects. These can take place at Artic Seals R&D facilities on request.
For other more general projects involving TPU, see our catalogue - pag. 12-13 – Tab. 1 Chemical Resistance of materials.

Solvents

Depending on the type of alcohol-based solvent used, the effect on a TPU may differ. Aliphatic alcohols such as ethanol and isopropanol can trigger slight swelling. More obvious levels of distortion can occur with exposure to aliphatic esters and ketones including acetone, methyl ethyl ketone (MEK) and cyclohexanone. Strong polar organic solvents like dimethyl formamide (DMF) and dimethyl sulfoxide (DMSO) can dissolve TPU altogether.

Microbial resistance

In applications where a TPU is in regular contact with soil in either hot or humid environments, its ability to resist microbial attack will need to be considered. Polyether-based TPU grades – often used in the cable industry – are resistant to microbial degradation. The saponification value according to DIN 57472 (VDE 472-804) is below 200mg KOH/g for ether grades meeting VDE 0282-10 requirements. Flexible polyester-based TPUs can be vulnerable to damage from fungi and bacteria. The enzymes present in microorganisms can split ester bonds causing the TPU to discolour and crack – thereby affecting load-bearing capabilities.

Hydrolysis resistance

Polyester-based TPU may be put at risk by hydrolysis when exposed to high temperature levels and in humid environments. Problems typically start to occur when water molecules cause ester groups to split. With hydrolysis resisting abilities, polyether-based TPU can be used in underwater applications as well as humid and damp situations. Where increasing temperatures would normally cause hydrolytic degradation, the graph indicates good hydrolysis resistance at a high temperature. This makes polyether-based TPU a good solution for applications including ABS cables located on the anterior of automobiles, which come into constant contact with dirt and water.

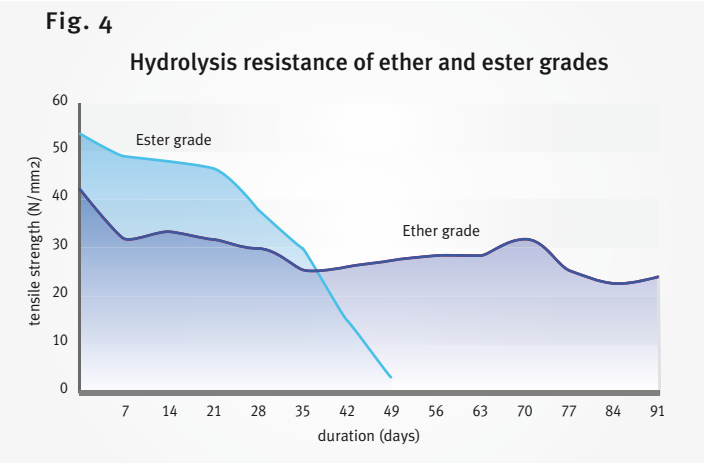
Oil, grease and lubricant resistance

As a general rule, TPU remains stable when it comes into contact with greases, lubricants and test oils in tests like ASTM 1, IRM-902 and IRM-903. This is true even at high temperatures up to 100°c and over a period of several weeks. However, some oil-based fluids may be prepared with additives that could damage TPU. Compatibility testing is therefore recommended.

Ozone Resistance

Ozone is a powerful oxidizing agent that can break down the double bonds present in some elastomers. All grades of TPU from Huntsman are ozone resistant and meet VDE 472-805
requirements

Fig. 4



Artic Seals TPU's Range

STANDARD TPU's							
Material colour		Material Ref.	Description	Appications	Chemical Base (*)	Hardness	Temperature range
	Light violet	**A0**	TPU POLYETHER (80%) AND POLYESTER (20%)	Pneumatic / rod seals, piston seals, wipers	MDI TPU	85 ShA	(TR10) -40°C +90°C
	Grey	**B0**	TPU POLYETHER	Pneumatic / rod seals, piston seals, wipers	MDI TPU	90 ShA	(TR10) -40°C +90°C
	Violet	**C0**	TPU POLYESTER CAPRO-LACTONE	Hydraulic / rod seals, piston seals, wipers	MDI TPU	93 ShA	(TR10) -30°C +100°C
	Fucsia	**D0**	TPU POLYESTER	Hydraulic / piston seals	MDI TPU	98 ShA	(TR10) -30°C +100°C
	Natural white	**E0**	TPU ETHER BASED POLYE-THER	Hydraulic / piston seals	MDI TPU	60 ShD	-25°C +100°C
	Brown	**F0**	TPU ETHER BASED POLYE-THER	Hydraulic / special appli-cations	MDI TPU	72 ShD	-20°C +100°C

SPECIAL TPU's							
Material colour		Material Ref.	Description	Appications	Chemical Base (*)	Hardness	Temperature range
	Dark Grey	**G0**	TPU POLYCAPROLACTON	Hydraulic higt tempera-ture / rod seals, piston seals, wipers	PPDI TPU	93 ShA	-29°C +135°C
	natural	**X1**	TPU POLYETHERE	Low Temperature applica-tions / Brittle point - 52°C	MDI TPU	93/95 ShA	-50°C + 90°C
	natural	**X7**	TPU POLYESTER & POLYCARBONATE	High Hydrolysis resistence applications / water 100° C/100h	MDI TPU	98 ShA	-20°C +100°C

* MDI : DIPHENYLMETHANE DIISOCYANATE
*PPDI : POLYDIPHENYLENE DIISOCYANATE

Co–Standard Hydraulic TPU Casting material

Exceptional performance as standard answer

PHYSICAL PROPERTIES			
Original Physical Properties	**Method**	**Unit**	**Specimen**
Colour		Violet	
Hardness	DIN 53505	Shore A	**93**
Specific gravity	DIN 53479	g/ cm3	**1,20**
Elastic modulus 100%	DIN 53504	MPa	**11,9**
Elastic modulus 300%	DIN 53504	MPa	**22**
Tensile strength	DIN 53504	MPa	**Min 40**
Elongation	DIN 53504	%	**520**
Compression-set 24h/70°C	DIN 53517	%	**18**
Compression-set 70h/70°C	DIN 53517	%	**22**
Compression-set 70h/100°C	DIN 53517	%	**35**
Tear Strength	DIN 53515	KN/m	**90**
Rebound resistance	DIN 53512	%	**58**
Abrasion	DIN 53516	mm3	**40**

Co – TPU 93ShA

is a caprolactone-based thermoplastic polyurethane. The material is produced by casting process in order to maximize it's physical properties. It has been developed for Hydraulic applications requiring exceptional performance in terms of compression set, wear resistance and hydrolysis resistance over conventional polyester-based TPUs.

PERFORMANCE FEATURES

- High wear resistance
- Low compression set
- Short cycle times
- Exceptional hydrolysis resistance
- Resistant to high dynamic loads

Go – Special High Temperature TPU

No compromise: the best choice for the best performace

PHYSICAL PROPERTIES			
Original Physical Properties	**Method**	**Unit**	**Specimen**
Colour		Dark Gray	
Hardness	DIN 53505	93°A±3	**93**
Specific gravity	-	1.18±0.03	**1,20**
Tensile strength	DIN 53504	350 min	**11,9**
Elongation	DIN 53504	500 min	**22**
Tensile strength at 100% elongation	DIN 53504	130 min	**Min 40**
Tensile strength at 300% elongation	DIN 53504	185 min	**520**
Rebound Resilience	-	60 min	**18**
Tear strength	DIN 53515		**22**
Tear strength with nick	DIN 53515	90 min	**35**
Tear strength without nick	DIN 53515	110 min	**90**
Compression set at 70 hrs at 70°C	-	20 max	**58**
Compression set at 70 hrs at 100°C	-	35 max	**58**
Compression set at 70 hrs at 125°C	-	65 max	**58**
Service Temperature Range**		**- 29°C to 135°C °C**	

An important addition to our TPU's range is G0, TPU based on the **isocyanate PPDI** – Polycaprolactone. This Product offers a combination of properties not previously obtained with polyurethane. Resistance to abrasion, flex cracking, cutting and tearing are all taken to a significantly higher level together with rebound resilience and very low compression set at elevated temperatures. The upper continuous-use temperature limit has for some PPDI elastomers been raised from 90ºC for conventional TPU to a remarkable **135°C.**

X1 - Special Low temperature TPU

Extreme conditions become feasible

PHYSICAL PROPERTIES			
Original Physical Properties	**Method**	**Unit**	**Specimen**
Colour		Transparent	
Hardness	ISO 7619	Shore A	**94**
Tensile strength	DIN 53504	MPa	**50**
Elongation @ break	DIN 53504	%	**580**
20% modulus	DIN 53504	MPa	**7.6**
50% modulus	DIN 53504	MPa	**10**
100% modulus	DIN 53504	MPa	**12**
200% modulus	DIN 53504	MPa	**14.6**
300% modulus	DIN 53504	MPa	**17.4**
Tear Resistance	ISO 34-1	N/mm	**84**
Abrasion	DIN 53516	mm3	**25**
Compression set at 70 hrs at 23°C	ISO 815	%	**17**
Compression set at 24 hrs at 70°C	ISO 815	%	**31**
Compression set at 24 hrs at 100°C	ISO 815	%	**36**
Compression set at 70 hrs at 100°C	ISO 815	%	**41**
Vicat Softening Point	ISO 306	°C	**160**
Density	ISO 1183-1	g/cm3	**1.13**
Bayshore Rebound	ASTM D-2632	%	**40**
Brittle Point	ASTM D 746	°C	**- 52**
Tg	DSC	°C	**-54**

X1 TPU is a polyether-based thermoplastic polyurethane. The material has been developed for injection moulding applications requiring exceptional performance in terms of compression set, wear resistance, hydrolysis resistance and behaviour at very low temperature, over conventional TPUs.

X1 is the preferred material for Hydraulic seals where Low temperature is the most relevant requirement, with it's extreme characteristics like Tg -54 and Brittle Point **– 52.**

X7 - Special Hydrolysis Resistant TPU

Modified TPU invade new areas

PHYSICAL PROPERTIES			
Original Physical Properties	**Method**	**Unit**	**Specimen**
Colour		Natural	
Density	DIN 53479	g/c3	**1.1**
Hardness	DIN 53505	Shore A	**97°A**
Tg Glass Transition Temp.	DIN 53479	°C	**-20**
100% modulus	DIN 53504	MPa	**23.5**
300% modulus	DIN 53504	MPa	**59.5**
Tensile Strength	DIN 53504	MPa	**59.5**
Elongation	DIN 53504	%	**320**
Tear Resistance	ASTM 624 – DIE B	KN/m	**163.5**
Tear Resistance	ASTM 624 – DIE C	KN/m	**140.0**
Compression set at 23 hrs at 70°C	DIN 53517	%	**25**
Abrasion Resistance	DIN 53516	mg	**58.0**
Abrasion Resistance	DIN 53516	mm3	**38.0**
Max Service Temperature	DIN 53479	°C	**+ 110**

The TPU X7 has been developed in order to join together excellent mechanical characteristics to hydrolysis, synthetic oils and gasoline, acid and basic environment, High Temperature and UV resistance,
Great ultimate tensile strength, the best possible abrasion resistance for polyurethane elastomers (also at high temperature), make it particularly fit for seals in water contact, protection for mining and sea field, mining screens, shock absorbers, bumpers, belts, anti-abrasion articles, high performances engineering and robotics. Test conducted on several applications demonstrate the exceptional hydrolysis resistance in contact with **boiling water**.

Artic Seals other Thermoplastic Materials

TPE							
Material colour		Material Ref.	Description	Appications	Che-mical Base	Hardness	Temperature range
	Yellow	**L1**	TPE - HYTREL	Hidraulic/ Antiextrusion Rings	TPE	55 ShD	-30°C + 130°C (Peaks till -50° and +150°)
	Light violet	**L2**	TPE - HYTREL	Hydraulic/ Piston seals components	TPE	63 ShD	-30°C + 130°C (Peaks till -50° and +150°)

ACETALIC RESINS & NYLON							
Material colour		Material Ref.	Description	Appications	Che-mical Base	Hardness	Temperature range
	Black	**R0**	POM H+GLASS FIBER	Hydraulic/ Wearrings - Antiextrusion rings	POM	-	-40°C +115°C
	Black	**R1**	PA6+PTFE+GLASS FIBER	Hydraulic higt temperature/ wearrings	PA6	-	-40°C +130°C
	White	**R2**	POM H	Pneumatic/ wearrings	POM	-	-40°C +115°C
	White	**R3**	POM H + PTFE + SILICON	Pneumatic/ wearrings	POM	-	-40°C +115°C
	Dark Grey	**R4**	PA6 + MOS2	Special Applications	PA6	-	-40°C +130°C
	Black	**R5**	PA6 + GLASS FIBER (CATERPILLAR APPROVED)	Customized items Caterpillar	PA6	-	-40°C +130°C

Gapi Group

Centri di distribuzione e uffici commerciali - Sales and logistic centers

GAPI S.p.A.
Via Molinaretti, 2
I - 24060 Castelli Calepio (BG)
ph +39 030 7438 511
fax +39 030 7438 550
sales@gapigroup.com

MIROS s.r.l.
Via Gallarate, 221
I - 20151 Milano
ph +39 02 33 400 480
fax +39 02 33 400 615
e-mail: miros@gapigroup.com

GAPI USA Inc.
300 Huls Drive, Clayton
Ohio, OH 45315-8982, US
ph +1 (937) 836-0080
800 442 8030
fax +1 (937) 836-7499
gapi@gapiusa.com

GAPI Ltd
Centurion Business Park
Bessemer Way - Templeborough
Rotherham - Sheffield - S60 1 FB - UK
ph +44 (01709) 378 181
fax +44 (01709) 378 182
sales@gapi.co.uk

GAPI GmbH
Hans Böckler Str. 14
Postfach 200265 - 51503 Rösrath
ph +49 (02205) 90494-0
fax +49 (02205) 90494-33
verkauf@gapi.de

Gapi Sealing System
Calle Gramil,15 Poligono
Industrial P29
Collado Villalba - 28400 Madrid
ph +34 918517 187
fax +34 918517 195
e-mail: vescor@vescor.es

Stabilimenti di produzione - *Production plants*

GAPI S.p.A.
Rubber Division
Via Marconi, 108
24060 Castelli Calepio (BG)
ph +39 035 847 084
fax +39 035 848 467
gapisede@gapigroup.com

GAPI S.p.A.
Rubber Division
Via Molinaretti, 2
24060 Castelli Calepio (BG)
ph +39 030 7438 511
fax +39 030 7438 550
gapisede@gapigroup.com

GAPI S.p.A.
Compounds Division
Via L. Da Vinci, 11
24060 Grumello del Monte (BG)
ph +39 035 4420 880
fax +39 035 4420 432
gapicompounds@gapigroup.com

GAPI S.p.A.
PTFE semifinished products Div. (LANZA)
Via Tolari, 12
24060 Gandosso (BG)
ph +39 035 834 268
fax +39 035 834 275
lanza@gapigroup.com

GAPI S.p.A.
PTFE machined components Div. (MG)
Via Francesca, 19/D
25030 Coccaglio (BS)
ph +39 030 7701210
fax +39 030 7705721
mg@gapigroup.com

GAPI S.p.A.
PTFE machined components Div. (FLUORIL)
Via europa, 47
25036 Palazzolo s/o (BS)
ph +39 030 7300221
fax +39 030 7300366
info@fluoril.it

ROLF S.p.A.
Oil seals Division
Via Campania, 24
20093 Cologno Monzese (MI)
ph +39 02 27 300 700
fax +39 02 25 47 788
rolf@gapigroup.com

ROLF S.p.A.
Polyurethane Division (MACMA)
Via Lab. Olivetti, 38
20010 Pregnana Milanese (MI)
ph +39 02 9359 0625
fax +39 02 9359 0625
rolf@gapigroup.com

PRADELLA & MATEGO S.p.A.
Braking systems seals div.
Regione Crocetta
14018 Villafranca D'asti (AT)
ph +39 0141 943 544 - 942 061
fax +39 0141 943 046
pradella@gapigroup.com

ARTIC SEALS s.r.l.
Hydraulic & Pneumatic Division
Via Vettigano, 11
42010 Rio Saliceto (RE)
ph +39 0522 649 764
fax +39 0552 649 496
info@articseals.it

GAPI GmbH
Technopolymers Division
Hans Böckler Str. 14
Postfach 200265 - 51503 Rösrath
ph +49 (02205) 90494-0
fax +49 (02205) 90494-33
verkauf@gapi.de

www.gapigroup.com