

# Contents of CAMPUS<sup>â</sup>

## 2 Single-Point Data

## 2 Single-Point Data

According to clause 1, the acquisition of the single-point data generally shall be in accordance with ISO 10350-1. With respect to the high number of properties and thus of test methods and test standards involved, it was split up into the following two parts.

Part 1: Moulding materials

Part 2: Long-fibre-reinforced plastics

The indicated symbols were introduced into CAMPUS from version 4.1 onwards. This paper therefore gives the symbols according to ISO 10350-1 commonly for all languages.

In ISO 10350-1 the properties additionally are numbered. These numbers however depend on the exclusion or inclusion of properties and thus differ between the versions of ISO 10350, whereas the symbols represent a permanent designation system. The numbers therefore have not been introduced into CAMPUS.

For the injection or compression molding of test specimens see clause 2.2.7.

For machining specimens from compression molded plates see ISO 2818.

For the conditioning of the test specimens see clause 1.3.

## 2.1 Summary of Test Conditions

### 2.1.1 Thermoplastic Materials

#### Rheological Properties

Property		Symbol	Standard	Specimen (Dimensions in mm)	Unit	Supplementary Instructions	Test conditions
Melt volume-flow rate		MVR	ISO 1133	Material	cm <sup>3</sup> /10 min	Test conditions according to the relevant material standard	
Molding shrinkage	parallel (p)	S <sub>MP</sub>	ISO 294-4 (Th.-plast)	60 * 60 * 2	%		parallel to flow direction
	normal (n)	S <sub>MN</sub>	ISO 2577 (Th.-sets)				normal to flow direction

## Mechanical Properties

Property		Symbol	Standard	Specimen (Dimensions in mm)	Unit	Supplementary Instructions	Test conditions
Tensile modulus		$E_t$	ISO 527-1 and -2	ISO 3167 injection molded: type A, machined: type B.	MPa	Determined in the range 0,05- 0,25% strain	1mm/min
Yield stress		$\sigma_Y$				%	
Yield strain		$\epsilon_Y$					If Yield stress exists.
Nominal strain at break		$\epsilon_{tB}$				If Yield stress does not exist.	If Strain break $\leq$ 10%, then 5mm/min
Stress at 50% strain		$\sigma_{50}$				If Yield stress and Stress at 50 % strain don't exist.	
Stress at break		$\sigma_B$					If 10% < Strain at break $\leq$ 50%, then 50mm/min
Strain at break		$\epsilon_B$				If Yield stress and Stress at 50 % strain don't exist	
Tensile creep modulus	1h	$E_{tc1}$	ISO 899-1		MPa	All strains $\leq$ 0.5%.	1h
	1000h	$E_{tc}10^3$				All strains $\leq$ 0.5%.	1000h
Charpy impact strength	unnotched	$a_{cU+23}$	ISO 179/1eU	80 * 10 * 4	kJ/m <sup>2</sup>	Using conventional impact pendulums and respecting their individual application ranges, that with the largest value of its potential energy possible shall be selec- ted, see ISO 179 (Charpy), 8256 (tensile impact) and 13802 (pendulums). For instrumented Charpy tests see ISO 179-2 Notched: Reliable if Charpy impact strength shows "NB".	+23°C
		$a_{cU-30}$					-30°C
	notched	$a_{cA+23}$	ISO 179/1eA				+23°C
		$a_{cA-30}$					-30°C
Tensile impact strength		$a_{t1}$	ISO 8256-1			Recommended if Charpy- notched impact strength shows "NB".	+23°C
Puncture impact properties	Max. Force	$F_{M+23}$	ISO 6603-2	60 * 60 * 2	N	Up to the deflection at which the force has dropped down to half the maximum force.	4,4m/s $\pm$ 0,2m/s (***)
		$F_{M-30}$					
	Punct. Energy	$W_{P+23}$			J		
		$W_{P-30}$					
Transition temperature		$T_{db}$			°C		

Footnotes:

(\*) e: Edge wise blow according to ISO 179: 1993

(\*\*) u: unnotched

(\*\*\*) This bar may be taken from the central region of the multi- purpose- test specimen according to ISO 3167

## Electrical Properties

Property		Symbol	Standard	Specimen (Dimensions in mm)	Unit	Supplementary Instructions	Test conditions	
Relative permittivity	100 Hz	$\epsilon_r100$	ISO 60250	60 * 60 * 2	-		100 Hz	
	1 MHz	$\epsilon_r1M$					1 MHz	
Dissipation factor	100 Hz	$\tan\delta100$				E-4		100 Hz
	1 MHz	$\tan\delta1M$						1 MHz
Volume resistivity		$\rho_e$	IEC 60093	60 * 60 * 2	$\Omega$ m	Use contact electrodes voltage 500V.		
Surface resistivity		$\sigma_e$		Plaque with thickness: 1.0mm +/- 0.1mm(*)	$\Omega$	Use contact electrodes voltage 500V. Use contacting line electrodes, 50 mm long and with a gap of 5 mm, and a grounded contacting electrode at the back side of the plate.		
Electric strength		$E_B1$	IEC 60243-1		kV/mm	Short- time test, voltagerate 2kV/s Immersion in transformer oil according to IEC 60296.		
Comparative tracking index		CTI	IEC 60112	$\geq 15$ * $\geq 15$ * 4	-	Test liquid A		

## Thermal Properties

Property	Symbol	Standard	Specimen (Dimensions in mm)	Unit	Supplementary Instructions	Test conditions	
Melting temperature	$T_m$	ISO 11357-1 and -3	Material	°C	C 1 b)(DSC or DTA)	10°C/min	
Glass transition temperature	$T_g$	ISO 11357-1 and -2			Method A (DSC or DTA) Only for amorphous, single-phase thermoplastics.		
Temperature of deflection under load (flexural softening temperature)	$T_{f1,8}$	ISO 75-1 and -2			80 * 10 * 4 or 110*10*4 (*)	For both rigid and less rigid materials	
	$T_{f0,45}$					For rigid materials only	
$T_{f8,0}$							
Vicat softening	$T_{V50/50}$	ISO 306	$\geq 10 * 10 * 4 (**)$			50°C/h; 50N	
Coefficient of linear thermal expansion	Parallel (p)	$\alpha_p$	(**)	$10^{-6} \cdot K^{-1}$		23 °C - 55 °C, Normal to the flow direction	
		$\alpha_{p-40}$				-40 °C - 100 °C, Normal to the flow direction	
	Normal (n)	$\alpha_n$				23 °C - 55 °C, Parallel to the flow direction	
		$\alpha_{n-40}$				-40 °C - 100 °C, Parallel to the flow direction	
Burning behavior	1.5 mm thick	B50/1.5	UL 94 IEC 60695-11-10 IEC 60695-11-20	Class	Indicate class from the following sequence B50:HB, V-2, V-1, V-0 B500: N, 5VA or 5VB		
		B500/1.5				$125 * 13 * 1.5$	
	-.- mm thick	B50/-.-				$\geq 150 * \geq 150 * 1.5$	
		B500/-.-				$125 * 13 * -.-$	
		$\geq 150 * \geq 150 * -.-$					
Flammability by oxygen index	OI23	ISO 4589-1 and-2	80 * 10 * 4	%	Method A		
Burning Rate (automotive)	FMVSS	ISO 3795	356 * 102 * 1	mm/min			
Thermal stability in air (Charpy, 50% property retention at 3000 h)	$TS_{3000}$	IEC 60216-1	80 * 10 * 4	°C	unnotched / notched: state described with symbol $T_{stSp}$		

Footnotes:

(\*) This bar may be taken from the central region of the multi- purpose- test specimen according to ISO 3167.

Test specimen	Loading direction	Span
80 mm x10 mm x 4 mm	flatwise	64 mm
110 mm x 10mm x 4 mm	edgewise	100mm

(\*\*) can be taken from the central region of the multipurpose - test specimen according to ISO 3167

### Electrical Properties

Property	Symbol	Standard	Specimen (Dimensions in mm)	Unit	Supplementary Instructions	Test conditions	
Relative permittivity	100 Hz	$\epsilon_r$ 100	60 * 60 * 2			-	
	1 MHz	$\epsilon_r$ 1M					
Dissipation factor	100 Hz	$\tan\delta$ 100		IEC 60250	$10^{-4}$		
	1 MHz	$\tan\delta$ 1M			$10^{-4}$		
Volume resistivity	$\rho_e$	IEC 60093			$\Omega$ m		Use contact electrodes voltage 500V
Surface resistivity	$\sigma_e$				$\Omega$		Use contact electrodes voltage 500V. Use contacting line electrodes, 50 mm long and with a gap of 5 mm, and a grounded contacting electrode at the back side of the plate
Electric strength	$E_B$ 1	IEC 60243-1	$\geq 60 * \geq 60 * 1$	kV/mm	Short- time test, voltage rate 2kV/s Immersion in transformer oil according to IEC 60296.		
Comparative tracking index	CTI	IEC 60112	$\geq 15 * \geq 15 * 4$	-	Test liquid A		

### Other Properties

Property	Symbol	Standard	Specimen (Dimensions in mm)	Unit	Supplementary Instructions	Test conditions
Water absorption	$W_W$	ISO 62 and ISO 15512	Thickness $\geq 1$	%	Saturation values	23°C immersion in water
Humidity absorption	$W_H$					
Density	$\rho$	ISO 1183	$\geq 10 * \geq 10 * 4$ (*)	kg/m <sup>3</sup>		

(\*) can be taken from the central region of the multipurpose - test specimen according to ISO 3167

## Material Specific Properties

Property	Symbol	Standard	Specimen (Dimensions in mm)	Unit	Supplementary Instructions	Test conditions
Viscosity number	VN	depending on material	material	cm <sup>3</sup> /g	Test conditions according to the relevant material standard	
Indicative density	$\rho_l$	ISO 1872-1		kg/m <sup>3</sup>	Applicable to PE only	
Luminous transmittance	$\tau_t$	ISO 13468-1, -2	60 * 60 *2	%	it is a matter of total transmission, the registration of non-diffuse and possibly diffuse parts of transmission from colorless transparent material	calculation for illuminant D65, CIE standard observer, alternatively C2°

## 2.1.2 Film Grades

### Mechanical Properties

Property	Symbol	Standard	Specimen (Dimensions in mm)	Unit	Supplementary Instructions	Test conditions
Stress at yield	parallel	$S_{Yp}$	strip, 15 mm wide, clamping distance 100 mm	MPa	nominal strains only, relative to clamping distance	
	normal	$S_{Yn}$				
Strain at yield	parallel	$e_{Yp}$				
	normal	$e_{Yn}$				
Maximum stress	parallel	$S_{Mp}$		MPa		
	normal	$S_{Mn}$				
Maximum strain	parallel	$e_{tBp}$		%		
	normal	$e_{tBn}$				
Elmendorf tear resistance	parallel	$F_{tp}$	ISO 3167			work spent in tearing the specimen shall be between 20% and 80% of the pendulum energy
	normal					
Trouser tear resistance	parallel		rectangular, 50mmx150 mm, cut perpendicular to shorter edge, length of cut (75 ± 1)mm, thickness d ≤1 mm			v=200 mm/min
	normal					

### Optical Properties

Property		Symbol	Standard	Specimen (Dimensions in mm)	Unit
Gloss	20°	Gloss20	ISO 2813		-
	45°	Gloss45			
	60°	Gloss60			
Haze		Haze	ISO 14782	~ 50 * 50	%

### Barrier Properties

Property		Symbol	Standard	Specimen (Dimensions in mm)	Unit
Water vapor transmission rate	23°C; 85% r.h.	WVTR2385	ISO 15106-1 and -2		g/(m <sup>2</sup> *d)
Oxygen transmission rate	23°C, 0% r.h.	OTR23/0	ISO 15105-1 and -2		cm <sup>3</sup> /(m <sup>2</sup> *d*bar)
	23°C, 85% r.h.	OTR23/85			
Carbon Dioxide transmission rate	23°C, 0% r.h.	CDTR23/0			
	23°C, 85% r.h.	CDTR23/85			

### 2.1.3 Thermoplastic Elastomers (TPE)

#### Mechanical Properties

Property		Symbol	Standard	Specimen (Dimensions in mm)	Unit	Supplementary Instructions	Test conditions
Stress at 10% strain		$S_{10}$	ISO 527-1 and -2	ISO 527-1/1BA	MPa	If yield stress does not exist	200 mm/min
Stress at 100% strain		$S_{100}$					
Stress at 300% strain		$S_{300}$					
Nominal strain at break		$e_{tB}$			%	If strain at break is greater than 300%: indicate '>300'	
Stress at break		$S_B$			MPa		
Compression set under constant strain	23°C	CS23	ISO 815	type B: plate $\varnothing = 13$ mm, d = 6.3 mm	%	Specimens may be stacked if initial thickness is smaller than 6.3 mm. Time of measurement after relief of compression 30 min ISO 815 refers to IRHD in order to define the strain to be applied.  IRHD strain (%) 10 - 95 25 80 - 89 15 90 - 95 10 >95 not covered -> indicate: '*'  Determination of IRHD acc. ISO 48	23°C, 25% strain, 22 -24 h
	70°C	CS70					70°C, 25% strain, 22 -24 h
	100°C	CS100					100°C, 25% strain, 22 -24 h
Tear strength		TearS	ISO 34-1	angle test specimen with nick	kN/m	Method B, procedure b. Loading in parallel direction, the cut (nick ) is in the normal direction	500 mm/min
Abrasion resistance		AbrRes	ISO 4649		mm <sup>3</sup>		
Shore A hardness (3s)		ShrA/3	ISO 868	$\geq 6 * 25 * 25$	-		Indenter Typ A, reading after 3s
Shore D hardness (15s)		ShrD/15					Indenter Typ D, reading after 15s

## 2.2 Thermoplastic Materials

### 2.2.1 Rheological Properties

#### 2.2.1.1 Melt Volume-Flow Rate

ISO 1133

Specimen: Material

Property	Symbol	Unit
Melt volume-flow rate	<i>MVR</i>	cm <sup>3</sup> /10 min

Number values for the test conditions temperature and load are given in the International Standard for the relevant material, see table 6.

Material	Standard	Temperature in °C	Load in kg	
PS	ISO 1622-2	200	5	
PE	ISO 1872-1	<sup>1)</sup>		
PP	ISO 1873-1	230	2,16	
PA	ISO 1874-2	<sup>2)</sup>		
ABS	ISO 2580-2	220	10	
PS-I	ISO 2897-2	200	5	
EVAC	ISO 4613-1	<sup>3)</sup>		
SAN	ISO 4894-2	220	10	
ASA, AEPDS, ACS	ISO 6402-1	220	10	
PC	ISO 7391-2	300	1,2	
PET, PBT, PCT, PEN	ISO 7792-2	<sup>2)</sup>		
PMMA	ISO 8257-1	230	3,8	
PB	ISO 8986-1	<sup>4)</sup>		
POM	ISO 9988-2	190	2,16	
MABS	ISO 10366-2	220	10	
TPC	ISO 14910-2	<sup>5)</sup>		
PPE	PPE+PS, unfilled	ISO 15103-2	250	10
	(PPE+PS)-Mineralf.		350	5
	PPE+PA		280	5
PK	ISO 15526-1			
LCP				
PES				
PPS				
PPSU				
PSU				
TEEE				

Table 3: Conditions for testing melt volume-flow rate, MVR

- 1) A temperature of 190 °C and four loads are indicated in the standard. Please refer to ISO 1872-1, which load shall be used.
- 2) This material standard does not provide MVR in the standard property table. Record \* (not relevant) for these materials and property.
- 3) Three temperatures and two loads are indicated in the standard. Please refer to ISO 4613-2, which combination shall be used.
- 4) A temperature of 190 °C and two loads are indicated in the standard. Please refer to ISO 8986-1, which load shall be used.
- 5) Three temperatures and load of 2,16 kg are indicated in the standard. Please refer to ISO 14910-2, which temperature shall be used.

### 2.2.1.2 Molding Shrinkage

ISO 294-4 for Thermoplastics

ISO 2577 for Thermosets

Specimen: 60 \* 60 \* 2 mm<sup>3</sup>

Property	Symbol	Unit
Molding shrinkage		
parallel (p)	$S_{Mp}$	%
normal (n)	$S_{Mn}$	%

For **specimens** prepared by injection molding use mold type D1 for 1 mm thickness and type D2 for 2 mm thickness, respectively, see ISO 294-3 for thermoplastics and ISO 10724-2 for thermosets.

Where specimens are prepared by injection molding, record property values both parallel (p) and normal (n) to the flow direction into the mold. For compression molded specimens record \* (not applicable) for the normal direction.

Round robin tests have provided recommended molding parameters for the preparation of test specimens to be used in the determination of shrinkage. These are given in table 7.

<b>Material</b>	<b>Cavity pressure <math>p_{CH}</math> / MPa</b>
ABS	50
LCP-GF30	50
PC, PC-GF20	50
PEBA	50
PES, PSU	50
PPE	50
PPS-GF40	50
PS, PS-HI	50
PVDF	50
SAN	50
PA11	60
PA12	60
PA46	60
PA6, PA6-GF15, -GF30, -GF50, -BM230	60
PA612	60
PA63T	60
PBT, PBT-GF10, -GF15, -GF20, -GF30, -GF50, -GK30	60
PET-GF30	60
PP	60
PMMA	70
PA6/6T	90
POM	90

Table 4: Conditions for determination of molding shrinkage

### 2.2.2 Mechanical Properties

The tests are generally carried out at the standard laboratory conditions 23 °C / 50 % r.h.. For testing the properties of moisture sensitive materials in the dry state (as molded) see clause 1.4.2. For testing low-temperature-conditioned specimens at room temperature see clause 1.4.3.

ISO 3167 describes two types of **specimens** for tensile tests. The type A specimen has a lower value for the radius of the shoulders of 20 mm to 25 mm (recommended: 24 mm  $\pm$  1 mm), which thereby enables a central region to be obtained of length at least 80 mm. The standard ISO bar having dimensions 80 mm x 10 mm x 4 mm can thus be cut from the central region of this type of test specimen which is therefore demanded for directly molded specimens. The type B specimen has a larger shoulder radius of >60 mm (recommended: 60 mm  $\pm$  0,5 mm) and is provided only for specimens machined from compression molded plates.

### 2.2.2.1 Tensile Test

ISO 527-1 and -2

Specimen: ISO 3167 A, see 2.2.2

Property	Symbol	Unit
Tensile modulus	$E_t$	MPa
Yield stress	$S_Y$	MPa
Yield strain	$e_Y$	%
Nominal strain at break	$e_{tB}$	%
Stress at 50% strain	$S_{50}$	MPa
Stress at break	$S_B$	MPa
Strain at break	$e_B$	%

ISO 527-1 demands, that the **prestress** at the start of the tensile test shall be less than the stress at 0,05 % strain, which corresponds to the lower limit of the modulus-testing interval. The clamping procedure, however, generally generates higher values of prestress, positive or negative. These shall be equilibrated to the above given limit before starting the test.

The **tensile modulus** is defined as the secant modulus taken between the strains of 0,05 % and 0,25 %, using the test speed of 1 mm/min.

Instead of using the two distinct stress/strain points the tensile modulus can be determined also by a linear regression procedure applied on the part of the curve between these mentioned points.

Record value of **nominal strain at break** only for specimens that show yielding or a breaking **strain beyond 10 %** when tested at a speed of 50 mm/min. The test speed shall be 50 mm/min, see Figure 1 and Table 5.

After the measurement of the tensile modulus at the test speed of 1 mm/min, the **same test specimen** can be used for testing the other relevant tensile properties. It can be deloaded however intermediately, i.e. starting a second test with the speed of 5 mm/min or 50 mm/min, respectively, at zero point load. Using the one test specimen at both 5 mm/min and 50 mm/min are not allowed.

The **nominal strain** shall be used beyond yielding, see Table 5. Its determination is based upon the relative change of the grip separation L, see Figure 1, upper abscissa, instead of the change of the gauge length  $L_0$ , see Figure 1, lower abscissa.

Note that the nominal strain at break can be only half the strain at break formerly used.

The nominal strain at break is additively composed by the strain at yield and the part of nominal strain between yield and break.

If break occurs **above 50 % nominal strain**, record it as >50.

Record  $S_{50}$  value for specimens only that show no **yielding up to 50 % strain**, see Table 5.

Record  $S_B$  and  $e_B$ -values for specimens only that show **break without yielding**. For a strain at break of less than or equal to 10 % when tested at a speed of 50 mm/min the test speed shall be 5 mm/min, see Figure 1. For a strain at break greater than 10 % and up to 50 % when tested at a speed of 50 mm/min the test speed shall be 50 mm/min. See Table 5.

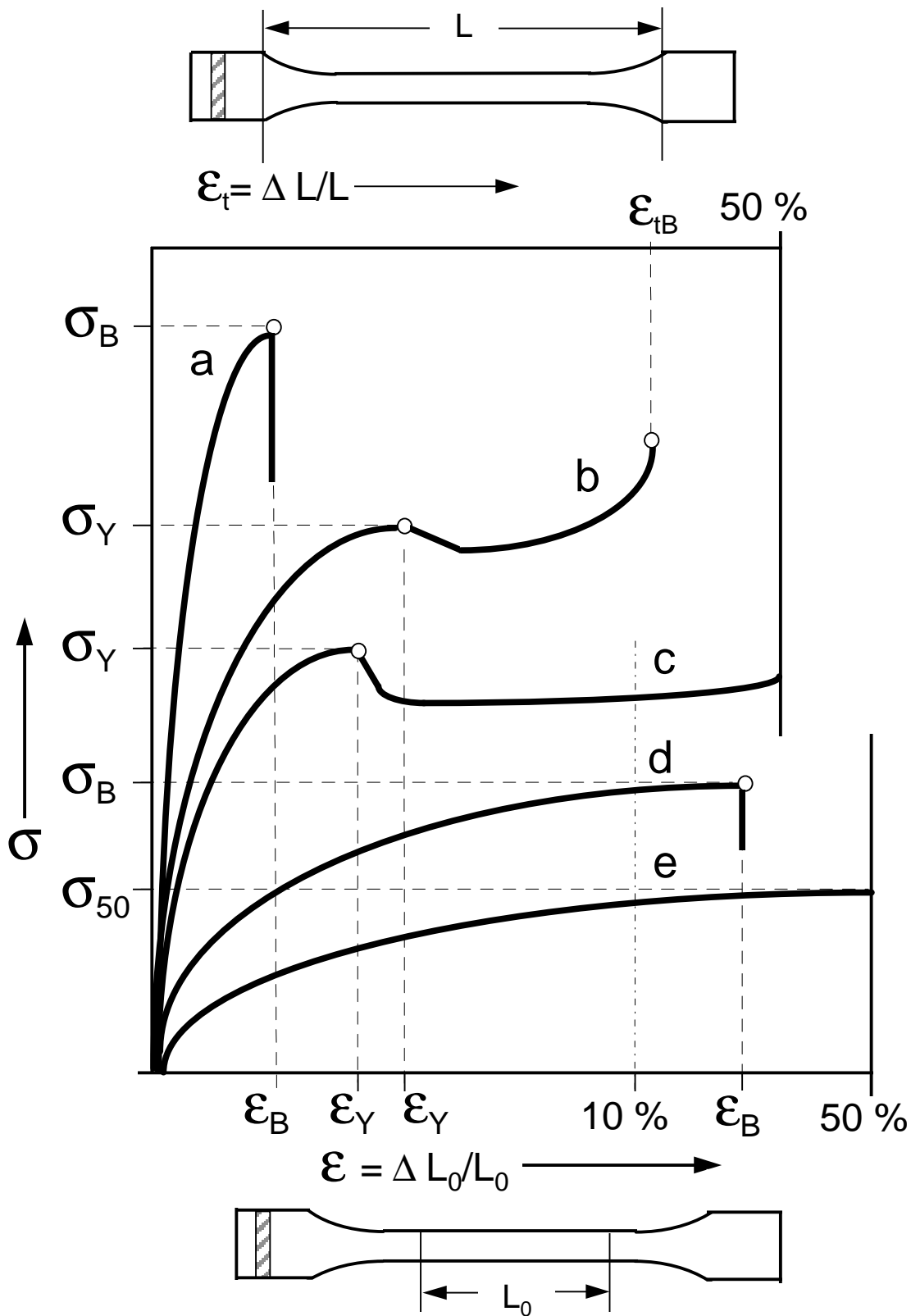
Stress-strain characteristic <sup>1)</sup>	Property						Test speed in mm min <sup>-1</sup>
	S <sub>Y</sub>	e <sub>Y</sub>	e <sub>tB</sub>	S <sub>50</sub>	S <sub>B</sub>	e <sub>B</sub>	
a	*	*	*	*	n	n	5
b	n	n	n	*	*	*	50
c	n	n	> 50	*	*	*	50
d	*	*	*	*	n	n	50
e	*	*	*	n	*	> 50	50
f	n	n	-	*	*	*	50

<sup>1)</sup> Type of stress/strain curve according to Figure 1, if tested at the testing speed of 50 mm min<sup>-1</sup>.

\* Property not relevant

n Number value of the mean property to be recorded

Table 5: Scheme for recording tensile properties and the testing speed to be used



- $\sigma_Y$  yield stress
- $\epsilon_Y$  yield strain
- $\sigma_B$  breaking stress
- $\epsilon_B$  breaking strain
- $\epsilon_{tB}$  nominal strain at break
- $\sigma_{50}$  stress at 50 % strain

Figure 1: Tensile stress/strain curves

### 2.2.2.2 Tensile Creep Test

ISO 899-1

Specimen: ISO 3167 A, see 2.2.2

Property	Symbol	Unit
Tensile creep modulus		
1h	$E_{tc}1$	MPa
1000h	$E_{tc}10^3$	MPa

All strains shall be below 0,5 %. For the effects of ageing see ISO 899-1, annex A, and clause 1.3.3. of this document.

### 2.2.2.3 Charpy Impact Test

ISO 179-1 and -2

ISO 179 is split up into two parts, covering non-instrumented (Part 1) and instrumented (Part 2) tests. These test methods are regarded as equivalent.

Specimen: 80 \* 10 \* 4 mm<sup>3</sup> cut from the middle of the multipurpose test specimen ISO 3167 A, see 2.2.2

Property		Symbol	Unit
Unnotched Charpy impact strength	23°C	$a_{cU}+23$	kJ/m <sup>2</sup>
	-30°C	$a_{cU}-30$	kJ/m <sup>2</sup>
Notched Charpy impact strength	23°C	$a_{cA}+23$	kJ/m <sup>2</sup>
	-30°C	$a_{cA}-30$	kJ/m <sup>2</sup>

**Symbols** are as follows.

<i>a</i>	<i>Impact strength</i>
<i>c</i>	<i>Charpy</i>
<i>1</i>	<i>Specimen type 80 * 10 * 4</i>
<i>e</i>	<i>Edgewise impact, see below</i>
<i>U</i>	<i>Unnotched</i>
<i>A</i>	<i>V notch, r = 0,25 mm, 8 mm remaining width at notch base</i>
<i>+23</i>	<i>Temperature in °C</i>
<i>-30</i>	<i>Temperature in °C</i>

The direction of blow shall be edgewise.

For details of impact **pendulums** see ISO 13802.

Using conventional impact pendulum machines and respecting their individual application ranges of 10%-80% of their potential energy, that with the highest potential energy possible shall be used, see ISO 179-1.

Machine **notches** in accordance with ISO 2818. Use a single cutter tool and select values of the feed speed and of the chip thickness, the window of ranges for which is given in the standard.

### 2.2.2.4 Tensile Impact Test

ISO 8256

Specimen: 80 \* 10 \* 4 mm<sup>3</sup>, Double-V notch r = 1 mm, 6 mm remaining width at notch base, see also 2.2.2

Property	Symbol	Unit
Tensile impact strength	$a_t1$	kJ/m <sup>2</sup>

**Symbols** are as follows.

$a$	Impact strength
$t$	tensile
1	Specimen type 80 x 10 x 4
+23	Temperature in °C

For details of conventional **impact pendulums** see ISO 13802.

Using conventional impact pendulum machines and respecting their individual application ranges, that with the highest potential energy possible shall be used, see ISO 8256.

Machine **notches** in accordance with ISO 2818. Use a single cutter tool and select values of the feed speed and of the chip thickness, the window of ranges for which is given in the standard.

### 2.2.2.5 Puncture Impact Test

ISO 6603-2

Specimen: 60 \* 60 \* 2 mm<sup>3</sup>

Property		Symbol	Unit
Maximum force	23°C	$F_{M23}$	N
	-30°C	$F_{M-30}$	N
Puncture energy	23°C	$W_p23$	J
	-30°C	$W_p30$	J
Transition temperature		$T_{ab}$	°C

For **specimens** prepared by injection molding use mold type D2 for 2 mm thickness, see ISO 294-3 for thermoplastics and ISO 10724-2 for thermosets.

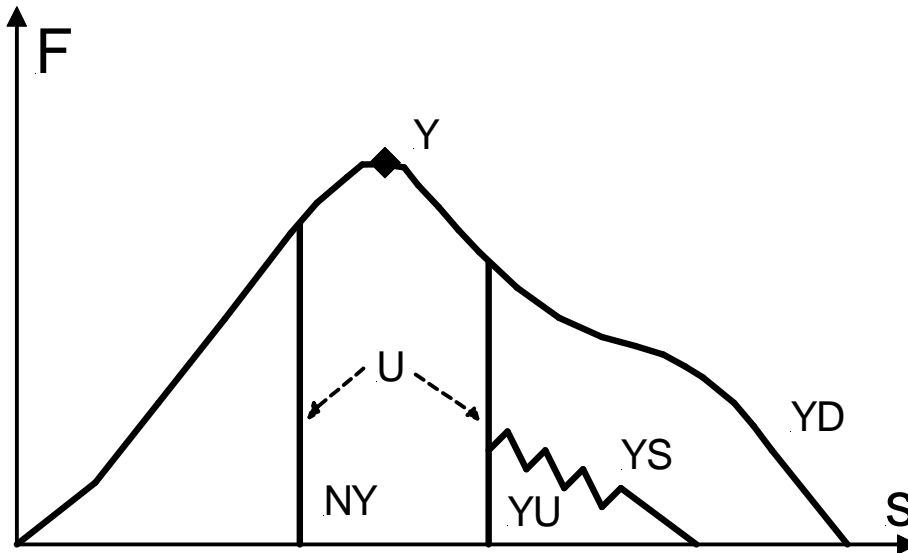
Use a **striker velocity** of 4,4 m/s ± 0.2 m/s (falling height 1 m), which shall not decrease by more than 20% during impact. In case of a falling mass system, its minimum potential energy therefore shall be 3 times the puncture energy.

Use a striker with a **diameter** of 20 mm, lubricated at its top by oil or grease in the viscosity range of  $10^{-2} \text{ Pa}\cdot\text{s} \leq \eta \leq 10^1 \text{ Pa}\cdot\text{s}$ , equipped by a force detector near its top resulting in a minimum natural frequency of the device of 6 kHz.

**Clamp** the test specimen by a force that is sufficiently high to prevent the test specimen from any out-of-plane movement of its outer regions. The diameter of the unclamped central area of the test specimen shall be 40 mm.

The **puncture energy** is taken at 50% decrease in force after the maximum.

Record data only for material with sufficiently high toughness at 23°C is. For materials that show failure type NY, see Figure 2, record \* (inapplicable)



- YD** Yielding (zero slope at maximum force) followed by **Deep drawing**
- YS** Yielding (zero slope at maximum force) followed by (partially) **Stable crack growth**
- YU** Yielding (zero slope at maximum force) followed by **Unstable crack growth**
- NY** **No Yielding**

Figure 2: Curves of Force F versus displacement s for puncture testing and failure

For the ductile-brittle transition temperature a series of puncture tests is conducted at various test temperatures. It's value is taken as the temperature where the maximum change in puncture energy occurs when plotted as a function of test temperature.

### 2.2.3 Thermal Properties

#### 2.2.3.1 Differential Scanning Calorimetry

ISO 11357-1, -2 and -3

Specimen: Material

Property	Symbol	Unit
Melting temperature	$T_m$	°C
Glass transition temperature	$T_g$	°C

For **melting temperature** use 10 °C/min. Record melting peak temperature.

For **glass transition temperature** use 10 °C/min. Record midpoint temperature.

#### 2.2.3.2 Temperature of Deflection under Load

ISO 75-1 and -2

Specimen: 80 \* 10 \* 4 mm<sup>3</sup>, see also 2.2.2

Property	Symbol	Unit
Temperature of deflection under load		
A	$T_f1.8$	°C
B	$T_f0.45$	°C
C	$T_f8.0$	°C

The **designations and abbreviations** that have been used for the property are somewhat confusing: On the one hand the long-term type of the „Temperature of Deflection Under Load, DTUL“ will not find common usage, on the other hand the commonly used abbreviation „HDT“ has no standardized wording. The designation therefore is: „Flexural softening temperature,  $T_f$ “, similar to the „Vicat softening temperature,  $T_v$ “.

The Numbers of symbols indicate flexural stress (i.e. maximum surface stress) in MPa:

Use 1,8 MPa and one other value.

The 80 \* 10 \* 4 mm<sup>3</sup> bars are loaded **flatwise** with a support span of 64 mm, as in flexural testing (ISO 178). Beyond the procedures described in the relevant standard for the material no conditioning at elevated temperatures is allowed, see clause 1.3.3.

### 2.2.3.3 Vicat Softening Temperature

ISO 306

Specimen: ≥10 \* 10 \* 4 mm<sup>3</sup>

Property	Symbol	Unit
Vicat softening temperature	$T_v50/50$	°C

The numbers of the symbol indicate the heat rate in °C/h and the load in N.

For **injection molded test specimens** carry out the test at the central region of the multipurpose test specimen where possible.

Use a **heating rate** of 50 °C/h and a load of 50 N.

Beyond the procedures described in the relevant standard for the material **no conditioning** at elevated temperatures is allowed, see clause 1.3.3.

This property is less suitable for thermosets and semi crystalline materials.

### 2.2.3.4 Linear Thermal Expansion

ISO 11359-1 and -2

Specimen: For injection molded test specimens carry out the test at the central region of the multipurpose test specimen where possible.

Property	Symbol	Unit
Coefficient of linear thermal expansion		
parallel (p)	$a_p, \alpha_p-40$	$10^{-6}/K$
normal (n)	$a_n, \alpha_n-40$	$10^{-6}/K$

Where specimens are prepared by **injection molding**, record property values both parallel (p) and normal (n) to the flow direction into the mold. For **compression molded** specimens record \* (not applicable) for the normal direction.

Record the **secant slope** of the specimen relative length change over the temperature range 23 °C to 55 °C or -40 °C to 100 °C (VDA datasheet).

$$a = \frac{L_1 - L_0}{L_0(T_1 - T_0)}$$

### 2.2.3.5 Burning Behavior

IEC 60695-11-10 and -11-20

Specimen: 50 W flame: 125 \* 13 \* thickness mm<sup>3</sup>

500 W flame: ≥150 \* ≥150 \* thickness mm<sup>3</sup>

Property	Symbol	Unit
Burning behavior		
1,5 mm thickness	$B50/1.5$	Class
-. - mm thickness	$B50/-.-$	Class
Burning behavior 5V		
-. - mm thickness	$B500/-.-$	Class

**Symbols** are as follows.

- $B$  Burning behavior
- $50$  Small flame (50 W)
- $500$  500 W Flame
- $1.5$  Thickness in mm
- $-. -$  Thickness in mm to be recorded

Record one of the following **classifications**:

- 50 W flame: V-0, V-1, V-2, HB or N, where N indicates, that the material does not satisfy the criteria of any of the other classes.
- 500 W flame: 5VA, 5VB or N, where N indicates, that the material does not satisfy the criteria of any of the other classes.

### 2.2.3.6 Flammability

ISO 4589-1 and -2

Specimen: 80 \* 10 \* 4 mm<sup>3</sup>

Property	Symbol	Unit
Flammability by Oxygen index	<i>OI23</i>	%

Test at ambient **temperature**, Use **procedure** A: top surface ignition.

### 2.2.3.7 Burning Rate

ISO 3795 (Federal Motor Vehicle Safety Standard §572.302)

Specimen: 356 \* 102 \* 1 mm<sup>3</sup>

Property	Symbol	Unit
Burning rate (Thickness 1 mm)	<i>FMVSS</i>	mm/min

## 2.2.4 Electrical Properties

The tests are generally carried out at the standard laboratory conditions 23 °C / 50 % r.h.. For testing the properties of moisture sensitive materials in the dry state (as molded) see clause 1.4.2. For testing low-temperature-conditioned specimens at room temperature see clause 1.4.3.

### 2.2.4.1 Dielectric Properties

IEC 60250

Specimen: 60 \* 60 \* 2 mm<sup>3</sup>

Property	Symbol	Unit
Relative permittivity		
100 Hz	$e_{r100}$	
1 MHz	$e_{r1M}$	
Dissipation factor		
100 Hz	$\tan\delta_{100}$	10 <sup>-4</sup>
1 MHz	$\tan\delta_{1M}$	10 <sup>-4</sup>

For **specimens** prepared by injection molding use mold type D2 for 2 mm thickness, see ISO 294-3 for thermoplastics and ISO 10724-2 for thermosets.

Compensate for **electrode edge effects**.

### 2.2.4.2 Resistivity

IEC 60093

Specimen: 60 \* 60 \* 2 mm<sup>3</sup>

Property	Symbol	Unit
Volume resistivity	$r_e$	$\Omega\text{m}$
Surface resistivity	$s_e$	$\Omega$

For **specimens** prepared by injection molding use mold and type D2 for 2 mm thickness, see ISO 294-3 for thermoplastics and ISO 10724-2 for thermosets.

To gain reproducible values it is necessary to be aware of **polarization effects** by shortening the electrodes and measuring discharge current until it is constant, before starting the test.

For Volume resistivity values larger than  $10^{13} \Omega\text{m}$  record  $>10^{13}$ .

For Surface resistivity values larger than  $10^{15} \Omega$  record  $>10^{15}$ .

For the volume-resistivity record 1-minute value after electrification.

Use contacting line **electrodes** 1 mm to 2 mm width, 50 mm long and 5 mm apart, a grounded contacting electrode at the back side of the plate and the test voltage of 500V.

#### 2.2.4.3 Electric Strength

IEC 60243

Specimen:  $\geq 60 * \geq 60 * 1 \text{ mm}^3$

Property	Symbol	Unit
Electric strength	$E_{B1}$	kV/mm

For **specimens** prepared by injection molding use mold type D1 for 1 mm thickness, see ISO 294-3 for thermoplastics and ISO 10724-2 for thermosets.

For testing electric strength use 1 mm **thickness** and the small tolerance of  $\pm 0,1 \text{ mm}$ .

If the specimen type 60 mm x 60 mm x 1 mm shows **discharge** along the surface, use larger compression molded test specimens with 1 mm thickness.

Use 20 mm diameter spherical **electrodes**. Immerse in transformer oil in accordance with IEC 60296. Use the short-time test with a voltage application rate of 2 kV/s.

#### 2.2.4.4 Comparative Tracking Index

IEC 60112

Specimen:  $\geq 15 * \geq 15 * 4 \text{ mm}^3$

Property	Symbol	Unit
Comparative tracking index	$CTI$	

For injection molded **specimens** use test specimens from the shoulder of the multipurpose test specimen.

Use **solution A**.

## 2.2.5 Other Properties

### 2.2.5.1 Water and Humidity Absorption

ISO 62 and ISO 15512

Specimen: Thickness  $\geq 1$  mm

Property	Symbol	Unit
Water absorption	$W_W$	%
Humidity absorption	$W_H$	%

For **specimens** prepared by injection molding use mold type D1 for 1 mm thickness and type D2 for 2 mm thickness, respectively, see ISO 294-3 for thermoplastics and ISO 10724-2 for thermosets.

For **water absorption** record saturation value in water at 23 °C.

For **humidity absorption** record saturation value at 23 °C/ 50% r.h..

### 2.2.5.2 Density

ISO 1183

Specimen: For injection molded test specimens carry out the test at the central region of the multipurpose test specimen where possible.

Property	Symbol	Unit
Density	$r$	kg/m <sup>3</sup>

The four methods specified in ISO 1183 are regarded as equivalent.

## 2.2.6 Material Specific Properties

These material specific properties are not included in ISO 10350-1.

### 2.2.6.1 Viscosity Number

ISO: see Table 6

Specimen: Material

Property	Symbol	Unit
Viscosity number	VN	cm <sup>3</sup> /g

Material	Standard	Solvent (Temp. in °C, if different from 25 °C) <sup>1)</sup>	Concentration in g/l	
PA6, 66, 66, 69, 610, 612 and 6/6T	ISO 307	Sulphuric acid	5	
PA11, 12, 11/12 and all PA reinforced by chalk		m-Cresol		
PVC	ISO 1628-2	Cyclohexanone	5	
PE and PP	40 < VN < 200	Decahydronaphthaline (135)	5	
	200 < VN < 1000		1	
	1000 < VN < 5000		0,2	
PC	ISO 1628-4	Dichloromethane	5	
PET	ISO 1628-5,	Phenol /		
PBT and ET/BT	ISO 7792-1	1.2-dichlorobenzene		
PMMA	ISO 1628-6	Chloroform	2,6	
PS	ISO 1622-2	<sup>2)</sup>		
ABS	ISO 2580-2			
PS-I (SB)	ISO 2897-2			
SAN	ISO 4894-2			
ASA, AEDPS, ACS	ISO 6402-2			
POM	ISO 9988-2			
MABS	ISO 10366-2			
EVAC	ISO 4613-2		See ISO 1628-3	
PB	ISO 8986-2			
TPR	ISO 14910-2			
PK	Item 686A			
LCP, PES, PES, PPS, PPSU, PSU and TEEE	unknown			

<sup>1)</sup> For the purpose of comparable data only a unique set of test parameters have been selected for each type of polymer. For some polymer types the testing or the material standard give several sets of test conditions, i.e. solvents/temperatures. In case where suitable equations are given, the data may be measured using test conditions differing from Table 6 and converted to those indicated in Table 6.

<sup>2)</sup> This material standard does not provide VN in the standard property table. Record \* (not relevant) for these materials and property.

Table 6: Conditions for testing viscosity number, VN

### 2.2.6.2 Indicative Density

ISO 1872-1

Specimen: Material

Property	Symbol	Unit
Indicative density (for PE only)	$\rho_l$	kg/m <sup>3</sup>

### 2.2.6.3 Luminous Transmittance

ISO 13468-1, -2

Specimen: 60 \* 60 \* 2 mm<sup>3</sup>

Property	Symbol	Unit
Luminous transmittance	$t_t$	%

Calculation for illuminant D65 with CIE standard observer, alternatively C2°.

The total transmission shall be recorded. That is the non-diffuse and possibly diffuse parts of transmission from colorless transparent material.

### 2.2.7 Processing Conditions for Test Specimens

For injection or compression molding, the **procedures** described in ISO 293, ISO 294-1 and -3, ISO 295 or ISO 10724-1 and -2 shall be used. The molding method and the conditions are specified in the relevant International Standard for the material. If molding conditions have not yet been standardized, they shall represent the centre of the recommended processing ranges. In each case and for each of the processing methods they shall be the same for every specimen.

If only **compression molding** conditions are indicated, all test specimens shall be compression molded. If both compression and injection molding conditions are indicated, only the plates larger than 60 mm x 60 mm shall be compression molded.

Material standards, Part 2: ISO ...-2

#### 2.2.7.1 Injection Molding (I) of Thermoplastics (P)

ISO 294-1 and -3 and Table 7, Table 8 and Table 9

Property	Symbol	Unit
Melt temperature	$T_{MIP}$	°C
Mold temperature	$T_{CP}$	°C
Injection velocity	$v_{IP}$	mm/s
Pressure at hold	$p_H$	MPa

The values for the **injection velocity**  $v_i$  to be recorded shall be taken for processing multipurpose-test specimens and bars, using the ISO molds type A or B, see ISO 294-1. For the other specimen types, i.e. small plates (ISO molds D1 or D2, see ISO 294-3), it is recommended that the relevant injection velocity  $v_i$  be chosen such that the injection time  $t_i$  is comparable to that used for the ISO mold type A.

The values for the **pressure at hold**  $p_H$  to be recorded are suitable for processing 4 mm thick test specimens, i.e. multipurpose-test specimens and bars, using the ISO molds type A or B, see ISO 294-1. For the other specimen types, i.e. small plates (ISO molds D1 or D2, see ISO 294-3), markedly lower values may be sufficient to prevent the test specimen from sink marks.

Material	Standard	Group <sup>2)</sup>	T <sub>M</sub> <sup>3)</sup>	T <sub>C</sub> <sup>4)</sup>	v <sub>I</sub> <sup>5)</sup>	p <sub>H</sub> <sup>6) 7)</sup>	w <sub>w</sub> <sup>7) 8)</sup>
PE	ISO 1872-2	1 < MVR	210	40	100*	70	≤ 0,2
PP	ISO 1873-2	MVR < 2 <sup>C</sup>	255				
		2 <sup>C</sup> ≤ MVR ≤ 10 <sup>C</sup>	230				
		10 <sup>C</sup> < MVR	200				
PS	ISO 1622-2		220	45			
PS-I	ISO 2897-2	General purpose	220				
		Flame retarded	210	60	200**	100	
ABS	ISO 2580-2	All grades	250				
		Flame retarded	220				
MABS	ISO 10366-2		245				
ASA, AES and ACS	ISO 6402-2		250				
SAN	ISO 4894-2		240				
PMMA	ISO 8257-2	MVR ≤ 1	270	T <sub>V</sub> 50/50 - 40 °C <sup>9)</sup>	250**		≤ 0,1
		1 < MVR ≤ 2	260				
		2 < MVR ≤ 4	250				
		4 < MVR ≤ 8	240				
		8 < MVR ≤ 16	230				
		16 < MVR	220				
PC	ISO 7391-2	MVR ≤ 5	310	90			
		5 < MVR ≤ 10	300	80			
		10 < MVR ≤ 15	290				
		15 < MVR	280				
		Filled / reinforced	300	110			
PBT		Unfilled	260	80		70	
		Imp. mod. / flame r.	250				
		Filled	260				
		Filled, imp.m.a.fl.r.	250				
PET	ISO 7792-2	Unfilled	Amorph.	285	20	200**	≤ 0,02
			Crystall.	275			
		Filled, crystall.	Unnucl.	285	135		
			Nucleat.		110		
		Flame ret	Unnucl.	275	135		
			Nucleat		110		
PCT		Unfilled	Amorph.	300	20		
			Crystall.		120		
		Filled, semicrystall.					
PEN		Unfilled, amorph.			20		
TEEE	7)	Shore D	70	240	45		≤ 0,1
			55	230			
			40	190			

Table 7: Processing conditions for injection molding thermoplastic materials<sup>1)</sup>.  
(For polyamides see Table 8, for polyphenylene ether see Table 9.)

Material	Standard	Group <sup>2)</sup>		T <sub>M</sub> <sup>3)</sup>	T <sub>C</sub> <sup>4)</sup>	v <sub>I</sub> <sup>5)</sup>	p <sub>H</sub> <sup>6) 7)</sup>	w <sub>w</sub> <sup>7) 8)</sup>
POM Homopol.	ISO 9988-2	Unmodified	MFR ≤ 7	215	90	140**	100	≤ 0,15
			MFR > 7			300**		
		Impact modified	MFR ≤ 7			140**		
			MFR > 7			300**		
POM Copol.	ISO 9988-2	Unmodified		205	90	200**	100	≤ 0,15
		Impact modified			80			
PPS	7)			330	145	400***		
LCP	7)			295	100	300**		
EVOH	ISO 14663-2	F = 0	15 < EC ≤ 30	220	5	150	70	
			30 < EC ≤ 45	200	50			
			45 < EC ≤ 60	180				
		F ≤ 30	15 < EC ≤ 30	230	60			
		F ≤ 30	15 < EC ≤ 30	250				
EVAC	ISO 4631-2							
TPC	ISO 14910-2							
PK-EP	ISO 15526-2	205 < T <sub>m</sub> ≤ 215		235	80	200**	70	
		215 < T <sub>m</sub> ≤ 225		245				
		225 < T <sub>m</sub> ≤ 235		255				
		235 < T <sub>m</sub> ≤ 245		265				
		245 < T <sub>m</sub> ≤ 255		275				
PK-E	ISO 15526-2	255 < T <sub>m</sub>		275				
LCP								
PES								
PPSU								
PSU								

1) Except for the maximum water content w<sub>w</sub> only those parameters have been included that are indicated in ISO 10350-1 and ISO 11403-1. Some material standards give numbers for additional data, e.g. cooling time or cycle time, which however cannot be used commonly for all types of molds. For these data therefore see the general regulations given in ISO 294-1.

2) MVR: Melt volume-flow rate in ccm/10 min, tested at a load, of 2,16 kg. For the test temperatures see table 6. The sign <sup>C</sup> indicates, that the values are converted from MFR data.

T<sub>m</sub>: Melting temperature.

F: Filling

EC: Ethylene content

3) T<sub>M</sub>: Melt temperature of injection molding (I) in °C.

4) T<sub>C</sub>: Mold cavity temperature in °C.

5) v<sub>I</sub>: Injection velocity in mm/s. For the use of data see 2.2.7.1.

Tolerances are: \* ± 20 mm/s; \*\* ± 100 mm/s and \*\*\* ± 200 mm/s.

6) p<sub>H</sub>: Hold pressure in front of the screw, in MPa, tolerance: ± 10 MPa. For testing molding shrinkage, S<sub>M</sub>, see clause 2.2.1.2.

7) Values recommended by CAMPUS.

8) w<sub>w</sub>: Water content in % m/m.

9) T<sub>V50/50</sub>: Vicat softening temperature, see clause 2.2.3.3.

Polymer	VN <sup>2)</sup> -Group	w <sub>G</sub> <sup>3)</sup>	w <sub>P</sub> <sup>4)</sup>	T <sub>Ml</sub> <sup>5)</sup>	T <sub>C</sub> <sup>6)</sup>	v <sub>I</sub> <sup>7)</sup>	p <sub>H</sub> <sup>8) 9)</sup>	w <sub>w</sub> <sup>9) 10)</sup>
PA6	VN ≤ 160	0	0	250	80	200	70	
	160 < VN ≤ 200			260				
	200 < VN ≤ 240			270				
	240 ≤ VN	w <sub>G</sub> ≤ 50		290				
PA66	VN ≤ 200	0		300	100			
	VN ≤ 160	10 ≤ w <sub>G</sub> ≤ 50		315	120			
		50 ≤ w <sub>G</sub> ≤ 70						
PA46	VN ≤ 260	w <sub>G</sub> ≤ 50						
PA69, PA610	VN ≤ 200	0		240				
PA612	VN ≤ 150	w <sub>G</sub> ≤ 10		250				
	150 < VN ≤ 200		270					
	200 < VN ≤ 250		250					
	VN ≤ 140	10 ≤ w <sub>G</sub> ≤ 30	260					
		30 ≤ w <sub>G</sub> ≤ 50	270					
	140 < VN ≤ 180	10 ≤ w <sub>G</sub> ≤ 30	210	80				
		30 ≤ w <sub>G</sub> ≤ 50	230					
	PA11	150 < VN ≤ 200	0	250				
200 < VN ≤ 240		230						
VN ≤ 130		30 ≤ w <sub>G</sub> ≤ 50	250					
130 < VN ≤ 240		10 ≤ w <sub>G</sub> ≤ 20	200	70				
		20 ≤ w <sub>G</sub> ≤ 50						
PA12		VN ≤ 130	w <sub>G</sub> ≤ 10	≤ 5	200			
	120 < VN ≤ 150	210						
	150 < VN ≤ 200	220						
	200 < VN ≤ 240	240						
	VN ≤ 150	0	> 5	200				
	150 < VN ≤ 200			210	70			
	200 < VN ≤ 250			220				
	VN ≤ 130	10 ≤ w <sub>G</sub> ≤ 30		230	240	80		
		30 ≤ w <sub>G</sub> ≤ 50						
		130 < VN ≤ 180			10 ≤ w <sub>G</sub> ≤ 30		250	
30 ≤ w <sub>G</sub> ≤ 50								
PAMXD6	VN ≤ 130	0	0	260	130			
	VN ≤ 130	20 ≤ w <sub>G</sub> ≤ 50		270				
	130 < VN ≤ 160			280				
PANDT/INDT	VN ≤ 160	0		300	80			≤ 0,1
	VN ≤ 120	20 ≤ w <sub>G</sub> ≤ 50						

Table 8: Processing conditions for injection molding polyamides (ISO 1874-2)<sup>1)</sup>

<sup>1)</sup> Except for the maximum water content w<sub>w</sub> only those parameters have been included that are indicated in ISO 10350-1 and ISO 11403-1. Some material standards give numbers for

additional data, e.g. cooling time or cycle time, which however cannot be used commonly for all types of molds. For these data therefore see the general regulations given in ISO 294-1.

- 2) VN: Viscosity number, see clause 2.2.6.1.
- 3)  $w_G$ : Glass content in %(m/m).
- 4)  $w_P$ : Plasticizer content in % (m/m).
- 5)  $T_M$ : Melt temperature of injection molding (I) in °C.
- 6)  $T_C$ : Mold cavity temperature in °C.
- 7)  $v_i$ : Injection velocity in mm/s,  $\pm 100$  mm/s. For the use of data see clause 2.2.7.
- 8)  $p_H$ : Hold pressure in front of the screw, in MPa, tolerance:  $\pm 10$  MPa. For testing molding shrinkage,  $S_M$ , see clause 2.2.1.2.
- 9) Values recommended by CAMPUS.
- 10)  $w_W$ : Water content in % m/m.

Polymer	$T_{f1,8}^{2)}$ -Group	$w_F^{3)}$	$T_M^{4)}$	$T_C^{5)}$	$v_i^{6)}$	$p_H^{7) 8)}$	$w_W^{8) 9)}$
PPE	$210 < T_{f1,8}$	0	340	120	200 $\pm$ 100	70 $\pm$ 10	< 0,05
PPE+PS	$T_{f1,8} \leq 90$	$\leq 50$	260	60			
	$90 < T_{f1,8} \leq 110$		240	80			
	$110 < T_{f1,8} \leq 130$		280				
	$130 < T_{f1,8} \leq 150$		290				
	$150 < T_{f1,8} \leq 160$		310	120			
	$160 < T_{f1,8} \leq 170$		320				
	$170 < T_{f1,8} \leq 200$		340				
	$200 < T_{f1,8}$	0					
PPE+PA	$160 < T_{f1,8} \leq 180$	$\leq 50$	290	190			
	$180 < T_{f1,8}$		300	100			
PPE+ +other		$\leq 30$	280	80			
		$30 < w_F \leq 50$	300	100			
	$180 < T_{f1,8} \leq 190$	0	290	90			
		$\leq 50$	300	100			
	$190 < T_{f1,8} \leq 200$	0	310	120			
	$200 < T_{f1,8}$	$\leq 50$	320	120			
PPE+PS+ +other	$190 < T_{f1,8} \leq 200$						

Table 9: Processing conditions for injection molding polyphenylene ether (ISO 15103-2)<sup>1)</sup>

- 1) Except for the maximum water content  $w_W$  only those parameters have been included that are indicated in ISO 10350-1 and ISO 11403-1. Some material standards give numbers for additional data, e.g. cooling time or cycle time, which however cannot be used commonly for all types of molds. For these data therefore see the general regulations given in ISO 294-1.
- 2)  $T_{f1,8}$ : Flexural softening temperature at the flexural stress of 1,8 MPa.
- 3)  $w_F$ : Filler content in %(m/m).
- 4)  $T_M$ : Melt temperature of injection molding (I) in °C.
- 5)  $T_C$ : Mold cavity temperature in °C.

- 6)  $v_i$ : Injection velocity in mm/s. For the use of data see clause 2.2.7.
- 7)  $p_H$ : Hold pressure in front of the screw, in MPa, tolerance:  $\pm 10$  MPa. For testing molding shrinkage,  $S_M$ , see clause 2.2.1.2.
- 8) Values recommended by CAMPUS.

### 2.2.7.2 Injection Molding (I) of Thermosets (S)

ISO 10724-1, -2

Property	Symbol	Unit
Injection temperature	$T_{M/S}$	°C
Mold temperature	$T_{C/S}$	°C
Injection velocity	$v_i/S$	mm/s
Cure time	$t_c/I$	s

The values for the **injection velocity**  $v_i$  to be recorded shall be taken for processing multipurpose-test specimens and bars, using the ISO molds type A or B, see ISO 10724-1. For the other specimen types, i.e. small plates (ISO molds D1 or D2, see ISO 10724-1), it is recommended that the relevant injection velocity  $v_i$  be chosen such that the injection time  $t_i$  is comparable to that used for the ISO mold type A.

### 2.2.7.3 Compression Molding (C) of Thermoplastics (P)

ISO 293 and table 13

Property	Symbol	Unit
Molding temperature	$T_{M/CP}$	°C
Mold time	$t_M$	min
Cooling rate	$R_C$	K/min
Demolding temperature	$T_D$	°C

Material	Standard	Group	$T_{MC}^{1)}$	$R_C^{2)}$	$T_D^{3)}$
PE	ISO 1872-2	LD	180	15	$\leq 40$
		HD			
	ISO 11542-2	UHM	210		
PVC-U	ISO 1163-2		$T_{V50/50} + 100$ °C		
		VC/VAC	$T_{V50/50} + 90$ °C		
		Acryl-modified	$T_{V50/50} + 105$ °C		
PVC-P	ISO 2898-2	Shore < 35	135 to 160	$\approx 40$	
		$35 \leq \text{Shore} \leq 50$	145 to 170		
		$50 < \text{Shore}$	170 to 180		
EVAC	ISO 4613-2	$\leq 10$ % VAC	155	$\leq 40$	
		$> 10$ % VAC	125		
PB	ISO 8986-2		200	30	$30 \pm 5$
TPR	ISO 14910-2				

PK	ISO 15526-2				
LCP					
PES					
PPS					
PPSU					
PSU					
TEEE					

Table 10: Processing conditions for compression molding thermoplastic materials

- 1)  $T_{MC}$ : Molding temperature of compression molding (C) in °C.
- 2)  $R_C$ : Cooling rate in °C / min.
- 3)  $T_D$ : Demolding temperature in °C

### 2.2.7.4 Compression Molding (C) of Thermosets (S)

ISO 295

Property	Symbol	Unit
Mold temperature	$T_{MC}$	°C
Cure time	$t_C$	min

### 2.2.8 Other stability properties

The following properties are not described in ISO 10350 but instead in VDA 232-201.

The weather stability properties are determined after exposure according to ISO 4892-2A for 750 h, the light stability properties after exposure according to ISO 4892-2B for 250 h.

Property	Symbol	Unit	Standard
Weather stability delta l	WS $\Delta$ l	-	ISO 11664-4
Weather stability delta a	WS $\Delta$ a	-	ISO 11664-4
Weather stability delta b	WS $\Delta$ b	-	ISO 11664-4
Weather stability delta E	WS $\Delta$ E	-	ISO 11664-4
Weather stability grey scale	WS Grey	-	ISO 105-A02
Light stability delta l	LS $\Delta$ l	-	ISO 11664-4
Light stability delta a	LS $\Delta$ a	-	ISO 11664-4
Light stability delta b	LS $\Delta$ b	-	ISO 11664-4
Light stability delta E	LS $\Delta$ E	-	ISO 11664-4
Light stability grey scale	LS Grey	-	ISO 105-A02
Emission of organic compounds	EOC	$\mu$ g C/g	VDA 277
Thermal desorption analysis of organic emissions	TDS <sub>oc</sub>	$\mu$ g/g	VDA 278
Odor test*	Odor	-	VDA 270 B 3

Footnotes:

(\*) Evaluation after storage of 3 plates 60 x 60 x 2 (mm)<sup>3</sup> for 2 h  $\pm$  10 min at 80 °C.

## 2.3 Film Grades

### 2.3.1 Mechanical Properties

The tests are generally carried out at the standard laboratory conditions 23 °C / 50 % r.h.. For testing the properties of moisture sensitive materials in the dry state (as molded) see clause 1.4.2. For testing low-temperature-conditioned specimens at room temperature see clause 1.4.3.

#### 2.3.1.1 Tensile Test

ISO 527-1 and -3

Specimen: strip, 15 mm wide

Property		Symbol	Unit
Yield stress	parallel	$S_{Yp}$	MPa
	normal	$S_{Yn}$	MPa
Yield strain	parallel	$e_{Yp}$	%
	normal	$e_{Yn}$	%
Maximum stress	parallel	$S_{Mp}$	MPa
	normal	$S_{Mn}$	MPa
Maximum nominal strain	parallel	$e_{tBp}$	MPa
	normal	$e_{tBn}$	MPa

Use a **clamping distance** of 100 mm.

Record nominal strains only, relative to clamping distance.

#### 2.3.1.2 Tear Resistance

ISO 6383-2

Specimen:

**Elmendorf:** rectangular  $(63,5 \pm 0,5) * (75 \pm 0,5)$  mm<sup>2</sup>, cut perpendicular to longer edge, length of cut  $(20 \pm 0,5)$  mm

**Trouser:** rectangular,  $50 * 150$  mm<sup>2</sup>, cut perpendicular to shorter edge, length of cut  $(75 \pm 1)$  mm, thickness  $d \leq 1$  mm

Property		Symbol	Unit
Elmendorf tear resistance	parallel	$F_{tp}$	N
	normal	$F_{tn}$	N
Trouser tear resistance	parallel	$r_{tp}$	N/mm
	normal	$r_{tn}$	N/mm

For the Elmendorf tear resistance the **work spent in tearing** the specimen shall be between 20% and 80% of the pendulum energy.

For trouser tear resistance use a test speed of  $v=200$  mm/min.

### 2.3.1.3 Dart Drop Test

ISO 7765-1

Specimen: 230 \* 230 mm<sup>2</sup>

Property	Symbol	Unit
Dart drop A	<i>DartA</i>	g
Dart drop B	<i>DartB</i>	g

### 2.3.1.4 Friction

ISO 8295

Specimen: Strip (80 \* 200) mm<sup>2</sup>

Property	Symbol	Unit
Dynamic coefficient of friction	$\mu_D$	

Use a **test speed** of  $v = (100 \pm 10)$  mm/min, a **mass** of  $m = (200 \pm 2)$  g and a **loaded area** of 40 cm<sup>2</sup>

## 2.3.2 Optical Properties

### 2.3.2.1 Gloss

ISO 2813

Specimen: ISO

Property		Symbol	Unit
Gloss	20°	<i>Gloss20</i>	
	45°	<i>Gloss45</i>	
	60°	<i>Gloss60</i>	

### 2.3.2.2 Haze

ISO 14782

Specimen: sufficient size, e.g. 50 \* 50mm<sup>2</sup>

Property	Symbol	Unit
Haze	<i>Haze</i>	%

## 2.3.3 Barrier Properties

### 2.3.3.1 Water Vapor Transmission Rate

ISO 15106-1 and -2

Specimen: ISO

Property	Symbol	Unit
Water vapor transmission rate at 23°C; 85% r.h.	<i>WVTR2385</i>	g/(m <sup>2</sup> *d)

### 2.3.3.2 Transmission Rate

ISO 15105-1 and -2

Specimen: ISO

Property		Symbol	Unit
Oxygen transmission rate	23°C; 0% r.h.	<i>OTR23/0</i>	cm <sup>3</sup> /(m <sup>2</sup> *d*bar)
	23°C; 85% r.h.	<i>OTR23/85</i>	cm <sup>3</sup> /(m <sup>2</sup> *d*bar)
Carbon Dioxide transmission rate	23°C; 0% r.h.	<i>CDTR23/0</i>	cm <sup>3</sup> /(m <sup>2</sup> *d*bar)
	23°C; 85% r.h.	<i>CDTR23/85</i>	cm <sup>3</sup> /(m <sup>2</sup> *d*bar)

### 2.3.4 Processing Conditions for Test Specimens

Property	Symbol	Unit
Type of extrusion	<i>ExtTy</i>	blown cast
Minimum achievable thickness	<i>MinThick</i>	mm
Thickness	<i>SThick</i>	mm

For the type of extrusion indicate Blown or Cast

## 2.4 Thermoplastic Elastomers (TPE)

### 2.4.1 Mechanical Properties

The tests are generally carried out at the standard laboratory conditions 23 °C / 50 % r.h.. For testing the properties of moisture sensitive materials in the dry state (as molded) see clause 1.4.2. For testing low-temperature-conditioned specimens at room temperature see clause 1.4.3.

#### 2.4.1.1 Tensile Test

ISO 527-1 and -2

Specimen: ISO 527-1/1BA

Property	Symbol	Unit
Stress at 10% strain	$S_{10}$	MPa
Stress at 100% strain	$S_{100}$	MPa
Stress at 300% strain	$S_{300}$	MPa
Nominal strain at break	$e_{tB}$	%
Stress at break	$S_B$	MPa

The **test speed** is 200 mm/min.

If break occurs **above 300 % nominal strain**, record it as >300.

#### 2.4.1.2 Compression Set under Constant Strain

ISO 815

Specimen: Type B: Plate with 13 mm diameter and thickness 6.3 mm

Property		Symbol	Unit
Compression set under constant strain	23°C	$CS_{23}$	%
	70°C	$CS_{70}$	%
	100°C	$CS_{100}$	%

Apply a constant strain of 25% for at least 22-24 h

Specimens may be stacked if initial **thickness is smaller than 6.3 mm**.

**Time of measurement** after relief of compression 30 min.

ISO 815 refers to IRHD in order to define the strain to be applied.

IRHD	strain (%)
10 - 95	25
80 - 89	15
90 - 95	10
>95	not covered -> indicate: <sup>1*</sup>

Determination of IRHD acc. ISO 48 "Rubber, vulcanized or thermoplastic - Determination of hardness".

#### 2.4.1.3 Tear Test

ISO 34-1

Specimen: angle test specimen with nick

Property	Symbol	Unit
Tear strength	<i>TearS</i>	kN/m

The test speed is 500 mm/min

For the test take Method B, procedure b of ISO 34-1. Loading shall be in parallel direction, the cut (nick) is in the normal direction

#### 2.4.1.4 Abrasion Resistance

ISO 4649

Specimen: ...

Property	Symbol	Unit
Abrasion resistance	<i>AbrRes</i>	mm <sup>3</sup>

#### 2.4.1.5 Shore Hardness

ISO 868

Specimen:  $\geq 6 * 25 * 25$  mm<sup>3</sup>

Property	Symbol	Unit
Shore A hardness (3s)	<i>ShrA/3</i>	
Shore D hardness (15s)	<i>ShrD/15</i>	