

# **Contents of CAMPUS<sup>â</sup>**

## **3 Multi-Point Data**

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### **3 Multi-Point Data**

The multipoint data included in CAMPUS are based on the International Standards for comparable multipoint data ISO 11403, Part 1 and Part 2, and on the ISO test Standards indicated in table 14.

Instead of recording data for the relevant material, reference may be given to a similar grade that shows comparable behavior.

Properties data may be interpolated but not extrapolated out of the relevant tested ranges of variables and parameters.

Select temperatures from the series of integral multiples of 10 °C replacing 20 °C by 23°C if relevant.

For the injection or compression molding of test specimens see „Processing conditions for test specimen“ and tables 10, 11 and 12.

For machining specimens from compression molded plates see ISO 2818.

For the conditioning of the test specimens see clause 1.3.

### 3.1 Summary of Test Conditions

Property Variable Parameter(s)	Symbol	ISO 11403: Part, clause	ISO testing standard	Specimen	Unit
Dyn. shear storage modulus Temperature	$G'(T)$	1, 6.2	6721-1, 2 and 7	d > 1	MPa °C
Dyn. shear loss modulus Temperature	$G''(T)$				MPa °C
Shear loss factor ( $\tan \delta$ ) Temperature	$\tan d(T)$				- °C
Dyn. tensile storage modulus Temperature	$E'(T)$	1, 6.2	6721-1, 4	d > 1	MPa °C
Dyn. tensile loss modulus Temperature	$E''(T)$				MPa °C
Tensile loss factor ( $\tan \delta$ ) Temperature	$\tan d(T)$				- °C
Tensile modulus Temperature	$E_t(T)$	1, 6.3	527-1, -2 and -3	ISO 3167	MPa °C
Stress Strain Temperature	$\sigma(\varepsilon, T)$				MPa % °C
Secant modulus Strain Temperature	$E_{tS}(\varepsilon, T)$	-	-		MPa % °C
Creep stress Strain Time, Temperature	$\sigma_c(\varepsilon, t, T)$	1, 6.4	899-1		MPa % h, °C
Creep secant modulus Strain Time, Temperature	$E_{tcS}(\varepsilon, t, T)$	-	-		MPa % h, °C
Specific enthalpy difference Temperature	$\Delta H(T)/m$	2, 6.2	11357-1 and 4		Material
Viscosity Shear rate Temperature	$\eta(\dot{g}, T)$		11443	Pa s s <sup>-1</sup> °C	
Shear stress Shear rate Temperature	$\tau(\dot{g}, T)$	2, 6.4		Pa s <sup>-1</sup> °C	
Specific volume Temperature Pressure	$v(T, p)$	-	17744	m <sup>3</sup> / kg °C MPa	

Table 14: Test conditions for multipoint data

### 3.2 Dynamic Shear Test

ISO 6721-1, -2

Specimen: Use a specimen of 1 mm thickness prepared by compression molding if feasible. Alternatively use a test specimen machined from an injection molded plate 60 mm x 60 mm x 1 mm according to ISO 294-3 for thermoplastics and ISO 10724-2 for thermosets.

Property	Symbol	ISO 11403: Part, clause	Unit
Dyn. shear storage modulus Temperature	$G'(T)$	1, 6.2	MPa °C
Dyn. shear loss modulus Temperature	$G''(T)$		MPa °C
Shear loss factor ( $\tan \delta$ ) Temperature	$\tan d(T)$		- °C

Shear modulus is the real part  $G'$  of the dynamic (complex) shear modulus  $G^* = G' + G''$ , measured at a frequency of  $1 \text{ Hz} \pm 0,5 \text{ Hz}$ . Begin the measurement at the lowest temperature and proceed to higher values.

Record data between  $-40 \text{ °C}$  and the maximum working temperature.

### 3.3 Dynamic Tensile Test

ISO 6721-1, -4

Specimen: Use a specimen of 1 mm thickness prepared by compression molding if feasible. Alternatively use a test specimen machined from an injection molded plate 60 mm x 60 mm x 1 mm according to ISO 294-3 for thermoplastics and ISO 10724-2 for thermosets.

Property	Symbol	ISO 11403: Part, clause	Unit
Dyn. tensile storage modulus Temperature	$E'(T)$	1, 6.2	MPa °C
Dyn. tensile loss modulus Temperature	$E''(T)$		MPa °C
Tensile loss factor ( $\tan \delta$ ) Temperature	$\tan d(T)$		- °C

Tensile modulus is the real part  $E'$  of the dynamic (complex) shear modulus  $E^* = E' + E''$ , measured at a frequency of  $1 \text{ Hz} \pm 0,5 \text{ Hz}$ . Begin the measurement at the lowest temperature and proceed to higher values.

Record data between  $-40 \text{ °C}$  and the maximum working temperature.

### 3.4 Tensile Test

ISO 527-1 and -2  
Specimen: ISO 3167.

Property	Symbol	ISO 11403: Part, clause	Unit
Tensile modulus Temperature	$E_t(T)$	1, 6.3	MPa °C
Stress Strain Temperature	$s(e, T)$		MPa % °C

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.

Record data between -40 °C and the maximum working temperature. Data can be recorded for 10 temperatures maximum

For testing single-point (room-temperature) data the test speed depends on the mode of failure of the material, see table 8. In order to avoid changing the test speed at different temperatures for a given material, multipoint data are measured using the common test speed of 5 mm min<sup>-1</sup>.

The test is carried out up to an ultimate point that may be the yield point Y or, if no yielding is observed, the breaking point B or 50% strain maximum. If relevant, the ultimate point of the diagrams are designated by B (Break) or Y (Yield). Resulting from the difference in test speed, the stress and strain at yield or the stress at 50% strain, may differ from the corresponding single-point data.

The stresses at 10 equidistant intervals of strain up to the relevant ultimate point are recorded.

### 3.5 Secant Modulus

Specimen: 3167 A, see 2.2.2

Property	Symbol	ISO 11403: Part, clause	Unit
Secant modulus Strain Temperature	$E_{tS}(e, T)$	-	MPa % °C

The secant modulus  $E_{tS}$  and the creep secant modulus  $E_{tcS}$  are not given in the standards. They are the ratio between the relevant stress and strain, calculated by the CAMPUS program, and do not require additional data input.

### 3.6 Creep Test

ISO 899-1

Specimen: ISO 3167.

Property	Symbol	ISO 11403: Part, clause	Unit
Creep stress Strain Time, Temperature	$s_c(e, t, T)$	1, 6.4	MPa % h, °C

For a given temperature, strains are recorded for the times of 1 h,  $10^1$  h,  $10^2$  h,  $10^3$  h and  $10^4$  h, for 5 stress levels, which are equidistantly distributed between zero and a maximum stress that the polymer could experience for prolonged periods of time at the relevant temperature. CAMPUS provides the optional inclusion of up to five additional, equidistant higher stress levels. These may be suitable for describing the behavior at short loading times, where the test specimen can carry higher stresses.

Data can be recorded for 6 temperatures maximum that cover the range between -40 °C and the maximum working temperature.

### 3.7 Specific Enthalpy Difference - Temperature

ISO 11357-1 and -4

Specimen: Material

Property	Symbol	ISO 11403: Part, clause	Unit
Specific enthalpy difference Temperature	$\Delta H(T)/m$	2, 6.2	$\text{kJ} / \text{kg}$ $^{\circ}\text{C}$

The specific enthalpy difference is referred to room temperature [ $\Delta H(23^{\circ}\text{C}) = 0$ ]: It is the integral of the specific heat  $c_p$  (at constant pressure), starting at room temperature to higher and lower temperatures.

The specific heat is measured in a cooling run, using the temperature rate of  $-10 \text{ K min}^{-1}$ , starting at the maximum recommended processing temperature and down to  $-40^{\circ}\text{C}$ .

The resulting temperature at the onset of crystallization  $T_c$ , respectively the glass transition temperature  $T_g$  may be indicated in the diagram. The difference between the melting temperature  $T_m$  (see table 2.1) and the crystallization temperature  $T_c$  gives an impression of the hysteresis in the melting range.

### 3.8 Shear Stress (Viscosity) –Shear Rate

ISO 11443

Specimen: Material

Property	Symbol	ISO 11403: Part, clause	Unit
Shear stress (viscosity) Shear rate Temperature	$t(\dot{\gamma}, T)$	2, 6.4	$\text{Pa s}$ $\text{s}^{-1}$ $^{\circ}\text{C}$

Based on a capillary or slit-die rheometer, the basic properties are the shear stress  $\tau$ , corrected according to the Bagley method, and the shear rate  $\dot{\gamma}$ , corrected according to Weissenberg- Rabinowitsch. For each temperature the shear stress  $\tau$  (the shear viscosity, i.e. the ratio  $\eta = \tau / \dot{\gamma}$ ) is recorded between the shear rates  $3 \text{ s}^{-1}$  and  $30.000 \text{ s}^{-1}$  at nine values equidistant on a logarithmic scale:  $\Delta \lg \dot{\gamma} = 0,5$ .

Data are recorded for 3 temperatures that cover the range of the recommended processing temperatures.

Corresponding to the secant moduli (see 3.3), the viscosity is the secant slope of the shear-stress versus shear-rate diagram, the latter however being much easier to understand and to interpret compared to the viscosity diagram.

### 3.9 Specific Volume - Temperature

ISO/CD 17744:2001

Specimen: Material

Property	Symbol	ISO 11403: Part, clause	Unit
<i>Specific volume</i> <i>Temperature</i> <i>Pressure</i>	$v(T, p)$	-	$m^3 / kg$ $^{\circ}C$ $MPa$

The specific volume is measured at constant pressures of (20; 40; 80; 120; 160 and 200) MPa, starting at the maximum recommended processing temperature and cooling with  $2,5 \text{ K min}^{-1}$  down to room temperature. The isobar for 0,1 MPa ( $\approx 1 \text{ bar}$ ) is extrapolated.

For the data below the relevant freezing temperatures, crystallization or glass transition temperatures, record if they are measured, using a direct piston-displacement method, i.e. under uniaxial -strain condition, or indirectly with the test specimen immersed in a hydraulic fluid, e.g. mercurium.

Below the relevant freezing temperatures, data from different isobars should not be used for the calculation of isothermal properties, e.g. the compressibility of the solid state, as each isobar in this region reflects the properties of a different frozen-in state of the material.

25 generic grades of thermoplastics have been tested, commissioned by CAMPUS. These pvT data are included in CAMPUS and can be linked to commercial grades where relevant. pvT data mainly depend on the chemical composition of the plastic only and are nearly independent of features between different commercial grades, including average molecular mass, except extreme cases like PE-UHM. The contribution of inorganic fillers and reinforcement can be taken into account by assuming that their volume does not change with temperature nor pressure.