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Thermoplastics for plain bearings — Classification and designation

Matières thermoplastiques pour paliers lisses — Classification et désignation

Reference number
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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 6691 was prepared jointly by Technical Committee ISO/TC 123, *Plain bearings* and ISO/TC 61, *Plastics.*

Annexes A, B and C of this International Standard are for information only.

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Thermoplastics for plain bearings — Classification and designation

1 Scope

This International Standard specifies a system for designating the most common thermoplastics for plain bearings.

The thermoplastic materials are differentiated from each other by a classification system based on appropriate levels of designatory properties, additives and information about their application for plain bearings. The designation system does not include all properties; materials having the same designation cannot therefore be interchanged in all cases.

This International Standard does not specify performance data which may be required for particular applications.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 307 : 1984, *Plastics — Polyamides — Determination of viscosity number.*

ISO/R 527 : 1966, *Plastics — Determination of tensile properties.*

ISO 1043-1 : 1987, *Plastics — Symbols — Part 1: Basic polymers and their special characteristics.*

ISO 1133 : 1981, *Plastics — Determination of the melt flow rate of thermoplastics.*

ISO 1183 : 1987, *Plastics — Methods for determining the density and relative density of non-cellular plastics.*

ISO 1628-5 : 1986, *Plastics — Determination of viscosity number and limiting viscosity number — Part 5: Poly(alkylene terephthalates).*

ISO 1872-1 : 1986, *Plastics — Polyethylene (PE) and ethylene copolymer thermoplastics — Part 1: Designation.*

ISO 1872-2 : 1989, *Plastics — Polyethylene (PE) and ethylene copolymer thermoplastics — Part 2: Preparation of test specimens and determination of properties.*

ISO 1874-1 : 1985, *Plastics — Polyamide (PA) homopolymers for moulding and extrusion — Part 1: Designation.*

ISO 1874-2 : 1987, *Plastics — Polyamide (PA) homopolymers for moulding and extrusion — Part 2: Preparation of test specimens and determination of properties.*

ISO 7792-1 : 1985, *Plastics — Polyalkylene terephthalates — Part 1: Designation.*

3 Designation system

The classification and designation are based on a block system consisting of a Description Block and an Identity Block. The Identity Block comprises an International Standard Number Block and an Individual Item Block. For unambiguous coding of all thermoplastics, the Individual Item Block is subdivided into five data blocks.

Designation						
Description Block	Identity Block					
	International Standard Number Block	Individual Item Block				
		Data Block 1	Data Block 2	Data Block 3	Data Block 4	Data Block 5

The Individual Item Block starts with a dash. The Data Blocks are separated by commas.

Data Blocks 1 to 5 include the following information:

Data Block 1: Symbol of material and, if applicable, symbol of the plasticizer separated by a dash (see 3.1).

Data Block 2: Intended application or method of processing (see 3.2).
Positions 2 to 4: Important properties and/or additives (see 3.2).

Data Block 3: Designatory properties (see 3.3).

Data Block 4: Type and content of filler or reinforcing materials (see 3.4).

Data Block 5: Information about tribological properties for plain bearings (see 3.5).

The meaning of the letters and digits is different for each data block (see 3.1 to 3.5).

Data block 2 comprises up to 4 positions. If at least one of Positions 2 to 4 is taken, and no information is given in Position 1, then the letter X shall figure in Position 1. The letters in Positions 2 to 4 shall be arranged in alphabetical order.

If a data block is not used, this shall be indicated by two commas (,,).

Designation examples are given in clause 4.

3.1 Data Block 1

The chemical nature of the plastic is designated by its symbol in accordance with ISO 1043-1 and — separated by a hyphen — plasticized materials are indicated by a P (see table 1).

Table 1 — Symbols for the chemical structure of the materials

Thermoplastics Group/name	Thermoplastics Symbol	Name and chemical structure
Polyamide	PA 6	Polyamide 6; homopolymer based on ε-caprolactam
	PA 6G 1)	Polyamide 6, cast; homopolymer based on ε-caprolactam
	PA 66	Polyamide 66; homopolycondensate based on hexamethylenediamine and adipic acid
	PA 610	Polyamide 610; homopolycondensate based on hexamethylenediamine and sebacic acid
	PA 612	Polyamide 612; homopolycondensate based on hexamethylenediamine and dodecanedioic acid 2)
	PA 11	Polyamide 11; homopolymer based on 11-aminoundecanoic acid
	PA 12	Polyamide 12; homopolymer based on ω-laurinlactam or ω-aminododecanoic acid
	PA 12G 1)	Polyamide 12, cast; homopolymer based on ω-laurinlactam or ω-aminododecanoic acid
Polyoxymethylene	POM	Polyacetal (homopolymer) Polyacetal (copolymer)
Polyalkylene-terephthalate	PET	Poly(ethylene terephthalate)
	PBT	Poly(butylene terephthalate)
Polyethylene	PE-UHMW	Polyethylene with ultra high molecular weight
	PE-HD	Polyethylene
Polyfluorocarbon	PTFE	Polytetrafluoroethylene
Polyimide	PI	Polyimides from polyaddition reactions are available as thermosetting plastics. Polyimides from polycondensation reactions are available as thermoplastics and thermosetting plastics, as well as copolymers of the imide group. Some thermoplastic polyimides are "apparent thermosetting plastics" because their thermoplastic range lies above the decomposition temperature. Because of their intermediate position, polyimides and imide copolymers are only treated marginally in this International Standard.
Plasticizer	P	—

1) Symbol not standardized in ISO 1043-1 : 1987.

2) Dodecanedioic acid is a synonym for decanedicarboxylic acid 1,10.

3.2 Data Block 2

Position 1 gives the code for the intended use (see table 2).

Table 2 — Data Block 2 — Position 1

Code	Use
E	Extrusion
G	General use
M	Injection moulding
Q	Compression moulding
R	Rotational moulding
X	No indication

Up to three important properties and/or additives can be indicated in Positions 2 to 4 (see table 3).

Table 3 — Data Block 2 — Positions 2 to 4

Code	Property or additive
A	Processing stabilized
F	Special burning characteristics
H	Heat ageing stabilized
L	Light and weather stabilized
R	Release agent
S	Slip agent, lubricated

3.3 Data Block 3

The levels of designatory properties are coded by letters and figures.

The properties appropriate for the designation are different for every thermoplastic material.

Due to manufacturing tolerances, single property values can lie on, or to either side of, the cell limit. It is up to the manufacturer to state which cell will designate the material.

3.3.1 Polyamides

The viscosity number of polyamides designated in accordance with ISO 1874-1 by two digits (see table 4) and, separated by a dash, the modulus of elasticity by three digits (see table 5).

In the last position, rapid-setting products can be indicated with the letter N.

The viscosity number shall be determined in accordance with ISO 307 using the solvents given in table 4. The modulus of elasticity shall be determined in the dry state in accordance with ISO 527 under the conditions specified in ISO 1874-2.

Table 4 — Viscosity number for polyamides

Material	Code	Viscosity number, ml/g			
		Solvent			
		Sulfuric acid 96 % (*m*/*m*)		*m*-cresol	
		above	up to	above	up to
	09	—	90		
	10	90	110		
PA 6	**12**	110	130		
PA 6G	**14**	130	160		
PA 66	**18**	160	200	—	
PA 610	**22**	200	240		
PA 612	**27**	240	290		
	32	290	340		
	34	340	—		
	11			—	110
	12			110	130
PA 11	**14**			130	150
PA 12	**16**	—		150	170
PA 12G	**18**			170	200
	22			200	240
	24			240	—

Table 5 — Modulus of elasticity

Code	Modulus of elasticity N/mm²	
	above	up to
001	50	150
002	150	250
003	250	350
004	350	450
005	450	600
007	600	800
010	800	1 500
020	1 500	2 500
030	2 500	3 500
040	3 500	4 500
050	4 500	5 500
060	5 500	6 500
070	6 500	7 500
080	7 500	8 500
090	8 500	9 500
100	9 500	10 500
110	10 500	11 500
120	11 500	13 000
140	13 000	15 000
160	15 000	17 000
190	17 000	20 000
220	20 000	23 000
250	23 000	—

3.3.2 Polyethylenes

The density of polyethylenes is designated in accordance with ISO 1872-1 by two digits (see table 6) and, separated by a dash, the melt flow rate (MFR) by one letter and three digits (see table 7).

The density of the base material shall be determined in accordance with ISO 1183 under the conditions specified in ISO 1872-2.

The melt flow rate shall be determined in accordance with ISO 1133 at 190 °C with a load of 2,16 kg (symbol D). For materials with a melt flow rate < 0,1, a test under a load of 5 kg (symbol T) is recommended. If the melt flow rate is still < 0,1, the test should then be carried out under a load of 21,6 kg (symbol G).

The symbols D, T and G shall be given in front of the code for melt flow rate.

Table 6 — Density

Code	Density[1)] g/cm³	
	above	up to
15	—	0,917
20	0,917	0,922
25	0,922	0,927
30	0,927	0,932
35	0,932	0,937
40	0,937	0,942
45	0,942	0,947
50	0,947	0,952
55	0,952	0,957
60	0,957	0,962
65	0,962	—

1) Density ranges for uncoloured and unfilled polyethylene materials.

Table 7 — Melt flow rate

Code	Melt flow rate (MFR) g/10 min	
	above	up to
000	—	0,1
001	0,1	0,2
003	0,2	0,4
006	0,4	0,8
012	0,8	1,5
022	1,5	3
045	3	6
090	6	12
200	12	25
400	25	50
700	50	100

3.3.3 Polyalkyleneterephthalates

The designatory property of polyalkyleneterephthalates according to ISO 7792-1 is the viscosity number, determined in accordance with ISO 1628-5, and designated by two digits (see table 8).

Table 8 — Viscosity number for polyalkyleneterephthalate

Material	Code	Viscosity number, ml/g	
		above	up to
PET	06	—	60
	07	60	70
	08	70	80
	09	80	90
	10	90	100
	11	100	120
	13	120	140
	15	140	—
PBT	08	—	90
	10	90	110
	12	110	130
	14	130	150
	16	150	170
	18	170	—

3.3.4 Others

The coding for the properties of polyxymethylene, polytetrafluoroethylene and polyimide will be included in future editions of this International Standard.

3.4 Data Block 4

The fillers and reinforcing materials, as well as additives specific for the application in plain bearings, are coded:

Position 1: Types of fillers and reinforcing materials coded by a letter (see table 9).

Position 2: Physical forms of fillers and reinforcing materials coded by a letter (see table 10).

Positions 3 and 4: Mass content of fillers and reinforcing materials coded by two digits (see table 11).

Positions 5 and 6: Fillers in position 1 coded by two letters (see table 12).

Table 9 — Types of fillers and reinforcing materials (Position 1)

Code	Type
B	Boron
C	Carbon
G	Glass
K	Chalk
M	Minerals[1], metal[1]
S	Synthetic organic material
T	Talcum
X	No indication
Y	Others[1]

1) More detailed information on the fillers shall be given in Positions 5 and 6 (see table 12).

Table 10 — Physical form of fillers and reinforcing materials (Position 2)

Code	Morphology
D	Powder
F	Fibre
H	Whisker
S	Spheres
X	No indication

Table 11 — Mass content (Positions 3 and 4)

Code	Weight percentage	
	above	up to
0X	No indication	
01	0,1 (inclusive)	1,5
02	1,5	3
05	3	7,5
10	7,5	12,5
15	12,5	17,5
20	17,5	22,5
25	22,5	27,5
30	27,5	32,5
35	32,5	37,5
40	37,5	42,5
45	42,5	47,5
50	47,5	55
60	55	65
70	65	75
80	75	85
90	85	—

Table 12 — Fillers (Positions 5 and 6)

Code	Type
CU	Bronze
GR	Graphite
MO	MoS_2 (Molybdenumdisulfide)
OL	Mineral oil
PE	Polyethylene
SI	Silicone
TF	PTFE (Polytetrafluoroethylene)
WS	Tungsten-sulfide or -disulfide, tungsten-selenide

3.5 Data Block 5

Tribological properties (corresponding International Standards are in preparation).

4 Designation examples

A summary of the designation system is given in table 13.

Table 13 — Summary of the designation system

Description Block	Thermoplastics				
International Standard Number Block	ISO 6691				
Individual Item Block	**Data Block**	**Position**	**Contents**	**Reference** Subclause	**Reference** Table
	1	—	Symbol of material and, if applicable, symbol of the plasticizer separated by a dash	3.1	1
	2	1	Intended application or method of processing	3.2	2
		2 to 4	Important properties and/or additives	3.2	3
	3	—	Designatory properties	3.3	4 to 8
	4	1	Types of fillers and reinforcing materials	3.4	9
		2	Physical forms of fillers and reinforcing materials	3.4	10
		3 and 4	Mass content of fillers and reinforcing materials	3.4	11
		5 and 6	Additional information	3.4	12
	5[1)]	—	Tribological properties for plain bearings	3.5	—

1) See 3.5.

EXAMPLE 1

A polyamide 6 (PA 6), for injection moulding (M) with mould release agent (R), having a viscosity number of 140 ml/g (14), a modulus of elasticity of 2 600 N/mm^2 (030) and rapid setting (N) would be designated:

Thermoplastics ISO 6691 -PA 6, MR, 14-030N

Description	Thermoplastics
International Standard	ISO 6691
Data Block 1: symbol	-PA 6,
Data Block 2: Position 1: for injection moulding	M
Position 2: for mould release agent	R
Data Block 3: Position 1: viscosity number	14
Position 2: modulus of elasticity	030
Position 3: rapid setting	N

Designation: ISO 6691-PA 6,MR,14-030N

EXAMPLE 2

A polyamide 66 (PA 66), without indications as to use and additives in Data Block 2, having a viscosity number of 280 ml/g (27), a modulus of elasticity of 4 000 N/mm^2 (040), rapid setting (N) and 20 % glass fibre (GF20) would be designated:

Thermoplastics ISO 6691 -PA 66 ,, 27-040N, GF20

Description	Thermoplastics
International Standard	ISO 6691
Data Block 1: symbol	-PA 66
Data Block 2: no indication, therefore two commas only	,,
Data Block 3: Position 1: viscosity number	27
Position 2: modulus of elasticity	040
Position 3: rapid setting	N
Data Block 4: Position 1: for glass	G
Position 2: fibres	F
Positions 3 and 4: for mass content	20

Designation: ISO 6691-PA 66,,27-040N,GF20

5 Ordering information

Purchaser and supplier shall agree if and which tests are to be carried out.

If mechanical and/or tribological properties are to be tested, it shall be agreed whether such tests be carried out on

a) unmodified parts of the delivered goods;

b) test bars, manufactured from the same batch;

c) test bars taken from a finished part to be supplied, and whether the test shall be carried out parallel or perpendicular to the flow direction and/or machining direction.

Annex A
(informative)

Characteristics and properties of the most common thermoplastics (unfilled)

A.1 Properties and applications of unfilled thermoplastics

Table A.1 gives an outline of the properties and applications of unfilled thermoplastics most commonly used for plain bearings.

Table A.1

Group of thermoplastics (symbol)	General description	Chemical properties	Examples of application
Polyamide (PA)	Impact-resistant material, extraordinarily shock- and wear-resistant, good damping properties. High sliding resistance in dry running. Relatively high moisture absorption.	Resistant to fuels, oils, and greases and to most common solvents. Sensitive to mineral acid even in dilute solution, but not attacked even by strong alkalis. The use of PA 6 and PA 66 in hot water requires formulations that are stabilized against hydrolysis. PA 11 and PA 12 are widely resistant to hydrolysis.	Bearings subjected to shock and vibration. Guide blocks in steel mill couplings. Bushes for brake rods in wagon construction. Bearings for agricultural machinery. Spring eye bushes.
Polyoxymethylene (POM)	Hard material; therefore higher resistance to pressure than polyamide, but more sensitive to shock. Less wear resistant but smaller coefficient of friction than polyamide. Very low moisture absorption.	Resistant to numerous chemicals, above all to organic liquids. Only a few solvents can dissolve POM. Even at high temperatures POM-copolymer withstands strong alkaline solutions such as 50 % NaOH. Chemicals having an oxidizing effect and strong acids (pH < 4) attack POM.	Plain bearings having more severe requirements concerning dimensional stability and coefficient of friction. Good for dry running or deficient lubrication. Plain bearings for fine mechanics, electromechanics and household appliances.
Polyethylene-terephthalate (PET) Polybutylene-terephthalate (PBT)	Hardness similar to that of POM; however, decreases considerably above 70 °C. Up to 70 °C, wear and coefficient of friction very low. Low moisture absorption.	Good weather resistance and high resistance to numerous solvents, oils, greases, and salt solutions. Sufficiently resistant to many acids and alkalis in aqueous solution. Attacked by concentrated inorganic acids and alkalis. Halogenated hydrocarbons such as methylene chloride and chloroform lead to high swelling. Sensitive to hydrolysis at higher temperatures.	Application for plain bearings similar to POM. Mostly for plain bearings at temperatures below 70 °C. Good for dry running and deficient lubrication. Plain bearings for fine mechanics and submerged installations, guide bushes for rods. Plain bearings for oscillating movements.
Polyethylene with ultra high molecular weight (PE-UHMW) High-density polyethylene (PE-HD)	PE-UHMW has high shock resistance. PE-HD has low resistance to permanent pressure. However, it is resistant to shock. About twice the thermal expansion of PA and POM. Excellent wear resistance against abrasive stresses. Good sliding and bedding characteristics. No moisture absorption. Resistant to low temperatures.	At room temperature, PE is inert to water, alkaline solutions, salt solutions, and inorganic acids (except strongly oxidizing acids). At room temperature, polar liquids such as alcohols, organic acids, esters, ketones, and the like only result in slight swelling. Aliphatic and aromatic hydrocarbons and their halogen derivates are absorbed more strongly, resulting in a decrease in strength. After the diffusion of these media, polyethylene can regain its original properties. Non-volatile liquids such as greases, oils, waxes, etc. are less active.	Plain bearings for installation in waters carrying sand. Road and agricultural machinery construction. Bearings for low temperatures. Plain bearings in chemical installations.

Table A.1 *(concluded)*

Group of thermoplastics (symbol)	General description	Chemical properties	Examples of application
Polytetra-fluoroethylene (PTFE)	Resistant to shock, has good bedding characteristics and can be used for dry running. Under high load and slow sliding velocity, low coefficient of friction. Antiadhesive; can be used at high and low temperatures. No moisture absorption. Unfilled PTFE is less resistant to wear; it is mostly used for confined bearings.	At temperatures below 260 °C, is not attacked by chemicals, except by dissolved or molten alkali or alkaline earth metals. Elemental fluorine or chlorine fluoride attack above room temperature.	Plain bearings in chemical installations, high-frequency engineering, application at high temperatures or lowest coefficient of friction. Bridge bearings and similar bearings with lowest sliding velocities (crawling velocity). For plain bearings used in the foodstuff sector unfilled PTFE is physiologically harmless.
Polyimide (PI)	High-temperature material, with high hardness. Low wear. Relatively high coefficient of friction in dry running at sliding surface temperatures below 70 °C. High load-carrying capacity. Low moisture absorption. Also suitable for use at very low temperatures.	Resistant to most of the aliphatic and aromatic hydrocarbons, to diluted or weak acids and to oils and fuels. Depending on concentration and temperature, alkaline solutions are attacking. When used in hot water or steam, hydrolysis has to be taken into account.	Plain bearings in tunnel furnaces.

A.2 Characteristic properties in plain bearing applications

Typical requirements for thermoplastics used for plain bearings in tribological systems are their behaviour under compressive stress, influence of temperature and moisture, as well as their heat conductivity and sliding characteristics including wear resistance.

The tribological system depends not only on the properties of the plain bearing thermoplastic, but also on the type and surface of the mating partner, the type of application, the design, the environmental influences, the general working conditions, and, if necessary, the lubricant. (See also annex B.)

Table A.2 and figure A.1 show approximate values of these parameters.

The actual values can deviate within the groups of thermoplastics according to the type of plastic used and the manufacturer's grades. Depending on the application, other properties are to be considered.

A.3 General properties

In addition to the characteristics referred to in A.1 and A.2, other properties are important for plain bearing applications.

Table A.3 gives some values for guidance for such properties. The actual values may differ widely depending on the thermoplastic used and on the type of processing (within each group).

The wear of the thermoplastic plain bearing depends to a large extent on the accuracy of the geometrical shape.

Table A.2

Characteristic properties for unfilled thermoplastics in plain bearings			PA 6	PA 6G	PA 66	PA 610 PA 612	PA 11	PA 12	PA 12G	POM	PET	PBT	PE-UHMW	PE-HD	PTFE[1]	PI[2]
Sliding behaviour[3), 4)]			See figure A.1													
Wear resistance[4)]			See figure A.1													
Recommended mating	Mating from metal[5)]	Steel hardness (HRC min.)	50	50	50	50	50	50	50	50	50	50	50[5)]	50[5)]	50[5)]	50[5)]
		Roughness, R_z (µm)	2 to 4	2 to 4	2 to 4	2 to 4	2 to 4	2 to 4	2 to 4	1 to 3	0,5 to 2	0,5 to 2	0,5 to 2	0,5 to 2	0,2 to 1	2 to 4
	Mating from thermoplastic	Thermoplastic and thermoplastic modified (mod.)[6)]	POM POM mod.	POM POM mod.	POM POM mod.	POM POM mod.	POM POM mod.	POM POM mod.	POM	PA PA mod.	POM	POM	PA	PA	PA POM PET PBT	—
		Roughness[7)] (µm) R_z	10	10	10	10	10	10	10	10	10	10	10	5	5	—
		R_a	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,6	0,8	0,8	—
Equilibrium moisture content [% (V/V)]	At standard atmosphere[8)]		2,5 to 3,5	2,2 to 3	2,2 to 3,1	1,2 to 1,6	0,8 to 1,2	0,7 to 1,1	0,4 to 0,9	0,2 to 0,3	0,3	0,2	0	0	0	1 to 1,3
	In water at 20 °C[9)]		9 to 10	7 to 9	8 to 9	3 to 3,6	1,6 to 2	1,3 to 1,7	1,3 to 1,5	0,6 to 0,7	0,6	0,5	0	0	0	—
Temperature limits (°C)	Melting temperature (ISO 1218 and ISO 3146)		215 to 220	210 to 220	250 to 260	210 to 220	180 to 185	175 to 180	186 to 192	165 to 184	255 to 260	220 to 225	130 to 178	125 to 130	327	10)
	Vicat softening temperature (ISO 306, method A)		180	—	200	170	—	165	190 (method B)	163 to 173[11)]	188	178	70	65	110	—
	Short-time working temperature		140	150	160	140	140	140	140	120 to 140	180	165	110	110	300	300 to 480
	Constant working temperature[12)]		80 to 100	80 to 100	80 to 100	80 to 100	70 to 100	70 to 100	80 to 110	80 to 100	70 to 100	60 to 100	70 to 100	70 to 100	250	260
Pressure limits[13)] (N/mm^2) (see figure A.1)	Ball pressure hardness 30 s (ISO 2039)[14)]		55	55	65	70	60	70	100	125	155	130	40	45	30	—
	Continuous (static)		12	13	14	13	10	11	12	18	19	18	8	6	5	20

1) The figures apply to unfilled PTFE. Unfilled PTFE is only used for plain bearings where the design keeps it from creeping (confined sliding elements). Filled PTFE compounds are generally used: they are more resistant to compression and wear.

2) Polyimides are mostly used with fillers: because of this and of the wide range of the polyimide class, it is impossible to designate these materials here in detail.

3) See B.2.4 (lubrication).

4) The proportions shown on figure A.1 apply to unfilled thermoplastics. They may change considerably when fillers are added to the specified thermoplastics.

5) See B.2.3 (mating partner).

6) Examples of common modifying, filler materials: PE, PTFE, MoS_2, graphite, chalk.

7) See B.2.3 d) (counterface roughness).

8) A method for determining the equilibrium moisture content in standard atmosphere 23/50 is given in ISO 291.

9) Determination of water absorption in accordance with ISO 62.

10) Most do not melt below decomposition temperature.

11) The upper temperature applies to homopolymer.

12) See B.2.7 (temperature).

13) At equilibrium moisture content in standard atmosphere 23/50 (23 °C air temperature, 50 % relative humidity). See also B.2.5 (compression stress).

14) Since the new test methods now specify only the 30 s value instead of the former 10 s and 60 s values, it is suggested that the 1 h value be also tested if information on creep behaviour is important.

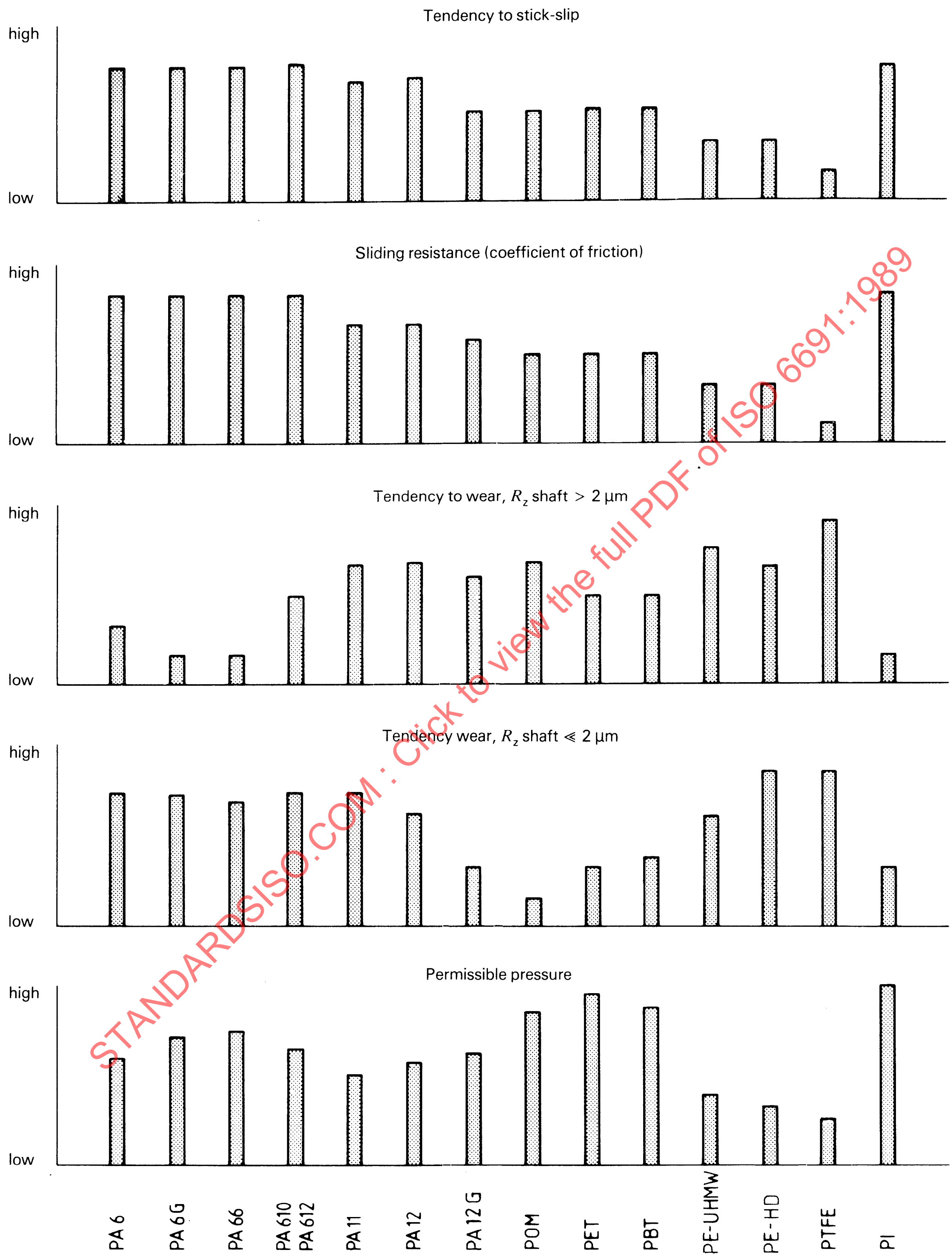

Figure A.1 — Typical behaviour of some unfilled plastics when used in plain bearings sliding at low velocity against steel, without lubrication (relative comparison)

Table A.3

General properties for unfilled thermoplastics		Material													
		PA 6	PA 6G	PA 66	PA 610 PA 612	PA 11	PA 12	PA 12G	POM	PET	PBT	PE-UHMW	PE-HD	PTFE	PI
Density (g/cm^3)	dry	1,13	1,13	1,14	1,08 1,06	1,04	1,02	1,03	1,41	1,37	1,29	0,94	0,95	2,15	1,43
Tensile strength (yield point) (N/mm^2)	dry	50 to 80	50 to 85	80 to 90	60 to 70	48	50	55	65 to 72	70	60	20 to 38	20 to 25	7 to 15	85
	moist	40 to 50	40 to 60	55 to 60	50 to 55	38	40	45	—	—	—	—	—	—	—
Elongation at break (%)	dry	130	10	40	70	150	250	150	25 to 70	50	200	450	600	300	—
	moist	220	70	150	150	330	280	200	—	—	—	—	—	—	—
Limiting bending stress (N/mm^2)	dry	120	140	125 to 130	100	70	70	90	100 to 105	130	105	27	30	16 to 20	—
	moist	50	60	60	50	—	—	—	—	—	—	—	—	—	—
Modulus of elasticity (tensile) (N/mm^2)	dry	2 600	2 700	2 800	2 400	1 600	1 900	2 400	2 800 to 3 200	3 000	2 800	790	950	700	3 400
	moist	1 400	1 500	1 600	1 500	1 000	1 600	2 100	—	—	—	—	—	—	—
Notch impact strength (kJ/m^2)	dry	3 to 6	1,5 to 3	3 to 5	10	13	10 to 17	5 to 15	6 to 9	6	3 to 6	No break	No break	16	—
	moist	No break	30	20 to 80	15	No break	25	15	—	—	—	—	—	—	—
Impact strength (kJ/m^2)	dry	No break													
	moist														
Coefficient of linear thermal expansion (10^{-6} K^{-1})	dry	85	75	85	—	150	110	100	120	80	60	—	190	100 to 160	31
Coefficient of thermal conductivity [W/(m·K)]	dry	0,23	0,23	0,23	0,23	0,29	0,29	0,29	0,31	0,26	0,27	0,41	0,42	0,23	0,3
Electrical disruptive strength (kV/mm)	dry	50	50	50	50	—	33	35	70	89	109	90	80	50	—
	moist	20	20	41	47	28	32	30	—	—	—	—	—	—	—

Annex B
(informative)

Fundamental application parameters

This annex lists some of the fundamental parameters that influence the selection of thermoplastics used for plain bearings.

However, it is by no means sufficiently comprehensive for the final selection, calculation and design of thermoplastic plain bearings. Definitive information should be obtained from the suppliers of plain bearings or raw materials.

B.1 Selection and application of thermoplastics used for plain bearings

The thermoplastics referred to in this International Standard fulfil, to various degrees, the requirements for plain bearing application, such as

a) a low coefficient of friction;

b) high resistance to wear;

c) adequate load-bearing ability;

d) adequate temperature stability;

e) emergency running ability.

In addition, the following properties, which depend on the type of thermoplastic used, are to be mentioned, even though wide range of characteristics may be given:

f) dry-running ability;

g) whether it is maintenance-free (in many cases one lubrication during assembly will suffice);

h) environmental medium (such as water, lyes, acids, etc.) may function as lubricant or coolant, if chemical resistance of the plain bearing thermoplastic is given;

i) whether it is smooth running;

j) ability to absorb vibrations and impacts;

k) resistance to corrosion;

l) resistance to chemicals;

m) whether it is of low toxicity;

n) insulation;

o) whether it is of low mass.

The thermoplastic plain bearing with the mating partner, the lubricant and the environmental influences forms a tribological system the field of application and service conditions of which are mainly determined by the temperature (ambient temperature + temperature rise due to friction). Figure B.1 shows the dependence of the mechanical values of thermoplastics on temperature using the example of the modulus of elasticity.

B.2 Influences of system and environment

B.2.1 Plain bearing type

Depending on the type of thermoplastic, unlubricated radial bearings give a value of pu between two and four times better than thrust bearings.

B.2.2 Kind of motion

In instruments, thermoplastic plain bearings are mainly used to support rotating shafts. In machines and vehicles, they mostly absorb oscillating and reciprocating motions.

The different stresses between rotating, oscillating and reciprocating movement and between continuous and intermittent operation have an essential influence on the permissible value of pu and on wear.

B.2.3 Mating partner

B.2.3.1 Material

Hardened steel is the most suitable material as mating partner for thermoplastics. Glass is also suitable. Mating partners made of non-ferrous metals can be used as well but the following points have to be taken into account:

a) the coefficient of friction is higher if the surface hardness is < 50 HRC;

b) sliding wear may increase;

c) the permissible value of pu and the wear resistance are lower even though the heat conductivity is better than in steel.

PE shows reasonable properties when running with a mating partner made from copper alloys. PTFE shows reasonable properties when running with a mating partner made from copper alloys; however, it should not be used when running with a mating partner made of aluminium alloys unless the surface is hard anodized.

If a thermoplastic runs with a plastic partner instead of a metallic one, lower and constant friction can be achieved.

Table A.2 gives suitable matings.