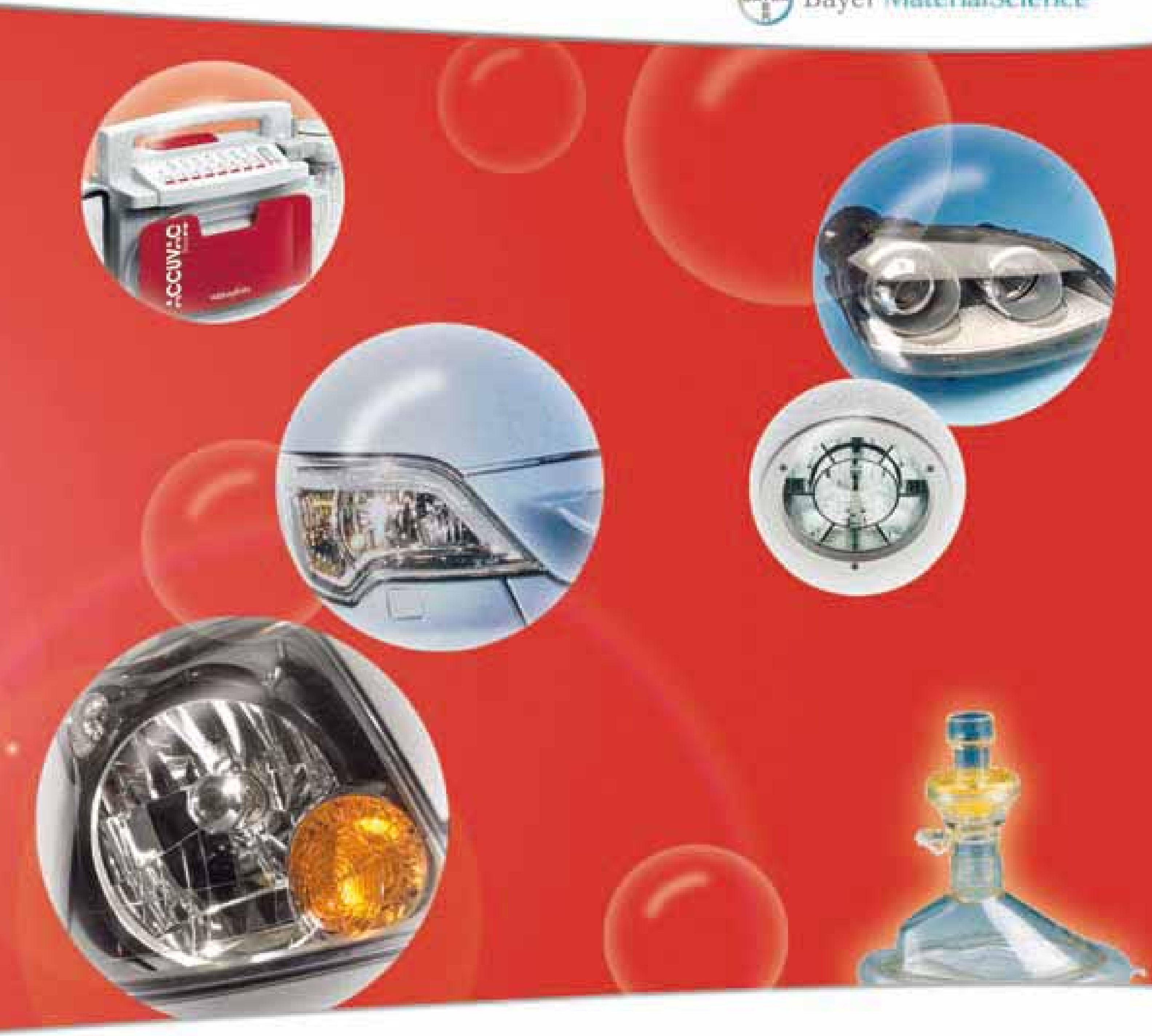
Bayer MaterialScience



Product Range, Reference Data, Processing

Apec® is the brand name for copolycarbonates that constitute a further development of Makrolon® polycarbonate. With its unique combination of high heat resistance, toughness, transparency, light stability and flowability, Apec® is unlike any other engineering thermoplastic. Particular mention should be made of its high heat resistance, which can be as high as 220 °C depending on the grade. This makes Apec® ideal for molded parts that are subject to such pronounced thermal stressing that general-purpose polycarbonate is no longer adequate.

CHARACTERIZATION

The Apec® grades are linear, amorphous copolycarbonates (PC-HT), made of BPA, the building block for Makrolon®, and BPTMC, a special polymer constitutional unit. Depending on the ratio in which the two bisphenol components are mixed, products are obtained whose heat resistance increases in proportion to the BPTMC content.
Apec® belongs to the polycarbonate family and is a further development of the standard (BPA) polycarbonate, Makrolon®, with a higher heat resistance.

Apec® is noted for its particularly favorable combination of the following properties:

- high heat resistance
- high toughness
- high transparency
- only slight inherent color
- good flowability
- high dimensional stability

Together with a low-temperature impact strength that is sufficient for many applications, this allows Apec® to be used over a broad range of temperatures from approximately –30 °C to approximately +200 °C.

Apec® product range

Grade	Vicat softening temperature (°C)	MVR[1] (cm^3/10 min)	UV-stabilized	Easy release
Sales Products				
General-purpose grades				
1703	171	16	X	
1745	170	17		X
1800	185	10		
1803	184	10	X	
Easy-flowing grades				
1695	158	45		X
1795	173	24		X
1895	183	18		X
1897	182	18	X	X
2095	203	8		X
2097	202	8	X	X
Developmental Products				
Easy-flowing grades				
DP1-9389/5	218	5		X
Flame-retardant grades				
DP1-9354	185	11		
DP1-9354/1	185	10		

Delivery form

Cylindrical pellets (Ø 2 to 4 mm, length 2 to 4 mm), packed in 25-kg PE bags, Big-Bags, large cartons with a PE inliner or delivered in silo trucks. Apec® is available in a large number of transparent and opaque colors.

All Apec® grades are homogenized.

The production plants for Apec® are certified to DIN ISO. Details can be found in our Technical Information Sheet “Plastics Business Group QM Certificates worldwide; ISO 9000ff., ISO/TS 16949”.

Designation of Sales Products

The designation of Apec® sales products is based on a 4-digit, self-explanatory nomenclature. The first two digits denote the heat resistance.

16 _ _ Vicat approx. 160 °C
17 _ _ Vicat approx. 172 °C
18 _ _ Vicat approx. 185 °C
20 _ _ Vicat approx. 205 °C
22 _ _ Vicat approx. 220 °C

Digits 3 and 4 describe the grade.

_ _ **00** Basic grade
_ _ **03** Basic grade, UV-stabilized
_ _ **05** Basic grade, easy release
_ _ **45**[1)] Medical grade, easy release
_ _ **95** Easy-flowing, easy release
_ _ **97** Easy-flowing, UV-stabilized, easy release

Designation of Developmental Products

Apec® Developmental Products are identified by a 4-digit number behind the status “DP 1”. The first two digits (93..) stand for Apec®. The third digit denotes heat resistance, …

_ _ **3**_ Vicat approx. 160 °C
_ _ **4**_ Vicat approx. 172 °C
_ _ **5**_ Vicat approx. 185 °C
_ _ **7**_ Vicat approx. 205 °C
_ _ **8**_ Vicat approx. 220 °C

…while the fourth indicates the particular grade.

_ _ _ **1** standard grades
_ _ _ **3** UV-stabilized grades
_ _ _ **4** flame-retardant grades
_ _ _ **9** easy-flowing grades

A further distinction can be made by adding an oblique stroke and a figure to the four-digit code number.

_ _ _ _ **/5** easy release
_ _ _ _ **/7** easy-flowing, easy release, UV-stabilized

Color designations

These are based on a six-digit code. The first two digits indicate the main color while the four remaining digits are used to distinguish between the different shades.

	Opaque color shades	Transparent color shades	Translucent color shades
White	01	–	02 (milky)
Yellow	10	15	12
Orange	20	25	22
Red	30	35	32
Violet	40	45	42
Blue	50	55	52
Green	60	65	62
Gray	70	75	72
Brown	80	85	82
Black	90	–	–
Natural	00	00	–
Colorless	–	55	–

1) Suitable for hot-steam sterilization and for pharmaceutical applications as per the United States Pharmacopeia (USP) XXII Class VI.

Apec®: Typical Values

General-purpose grades

Properties	Test conditions	Units	Standards	1703	1745	1800	1803
Rheological properties							
• Melt volume-flow rate (MVR)	330 °C; 2.16 kg	cm³/(10 min)	ISO 1133	16	17	10	10
Melt mass-flow rate (MFR)	330 °C; 2.16 kg	g/(10 min)	ISO 1133	16	17	10	10
• Molding shrinkage, parallel		%	ISO 2577	0.8	0.8	0.85	0.85
• Molding shrinkage, tranverse		%	ISO 2577	0.8	0.8	0.85	0.85
Mechanical properties (23 °C/50 % r.h.)							
• Tensile modulus	1 mm/min	MPa	ISO 527-1, -2	2400	2400	2400	2400
• Yield stress	50 mm/min	MPa	ISO 527-1, -2	70	70	72	72
• Yield strain	50 mm/min	%	ISO 527-1, -2	6.4	6.4	6.8	6.8
• Nominal tensile strain at break	50 mm/min	%	ISO 527-1, -2	>50	>50	>50	>50
• Charpy impact strength	23 °C	kJ/m²	ISO 179-1 eU	NB	NB	NB	NB
• Charpy impact strength	–30 °C	kJ/m²	ISO 179-1 eU	NB	NB	NB	NB
Charpy notched impact strength	23 °C; 3.0 mm	kJ/m²	ISO 179-1 eA	14	14	11	11
Charpy notched impact strength	–30 °C; 3.0 mm	kJ/m²	ISO 179-1 eA	12	12	11	11
• Puncture maximum force	23 °C; 2.0 mm	N	ISO 6603-2	5500	5500	5500	5500
• Puncture maximum force	–30 °C; 2.0 mm	N	ISO 6603-2	6400	6400	6400	6400
• Puncture energy	23 °C; 2.0 mm	J	ISO 6603-2	60	60	60	60
• Puncture energy	–30 °C; 2.0 mm	J	ISO 6603-2	65	65	65	65
Flexural modulus	2 mm/min	MPa	ISO 178	2400	2400	2400	2400
Flexural strength	5 mm/min	MPa	ISO 178	105	105	105	105
Ball indentation hardness	–	N/mm²	ISO2039-1	120	120	120	120
Thermal properties							
• Deflection temperature under load, Af	1.80 MPa	°C	ISO 75-1,-2	147	146	159	158
• Deflection temperature under load, Bf	0.45 MPa	°C	ISO 75-1,-2	161	160	174	173
Vicat softening temperature	50 N, 120 K/h	°C	ISO 306	171	170	185	184
Resistance to heat (ball pressure test)	–	°C	IEC 60335-1	161	160	174	173
Relative temperature index (tensile strength)	1.5 mm; 3.0 mm	°C	UL 746B	140	140 1)	150	150
Relative temperature index (tensile impact strength)	1.5 mm; 3.0 mm	°C	UL 746B	130	130 1)	130	130
Relative temperature index (electric strength)	1.5 mm; 3.0 mm	°C	UL 746B	140	140 1)	150	150
• Coefficient of linear thermal expansion, parallel	23 to 55 °C	10-4/K	ASTM E 831	0.7	0.7	0.7	0.7
• Coefficient of linear thermal expansion, transverse	23 to 55 °C	10-4/K	ASTM E 831	0.7	0.7	0.7	0.7
Burning behavior UL 94	1.5 mm	Class	UL 94	HB	HB	HB	HB
Burning behavior UL 94	3.0 mm	Class	UL 94	HB	HB	HB	HB
Burning behavior UL 94	3.0 mm	Class	UL 94	–	–	–	–
• Oxygen index	Method A	%	ISO 4589	25	25	25	25
Glow wire temperature	2.0 mm	°C	IEC 695-2-12	850	850	850	850
Electrical properties (23 °C/50 % r.h.)							
• Relative permittivity	100 Hz	–	IEC 250	3	3	3	3
• Relative permittivity	1 MHz	–	IEC 250	3	3	3	3
• Dissipation factor	100 hZ	10-4	IEC 250	7	7	7	7
• Dissipation factor	1 MHz	10-4	IEC 250	80	80	80	80
• Volume resistivity	–	Ohm*m	IEC 93	1.00E+14	1.00E+14	1.00E+14	1.00E+14
• Surface resistivity	–	Ohm	IEC 93	1.00E+16	1.00E+16	1.00E+16	1.00E+16
• Electric strength	–	kV/mm	IEC 243-1	35	35	35	35
• Comparative tracking index CTI	Solution A	Rating	IEC 112	275	275	600	600
Comparative tracking index CTI M	Solution B	Rating	IEC 112	<100M	<100M	<100M	<100M
Electrolytic corrosion	–	Rating	IEC 426	A1	A1	A1	A1
Other properties (23 °C)							
• Water absorption (saturation value)	in water at 23 °C	%	ISO 62	0.3	0.3	0.3	0.3
• Humidity absorption (equilibrium value)	23° C; 50 % r.h.	%	ISO 62	0.12	0.12	0.12	0.12
• Density	–	kg/m³	ISO 1183	1170	1170	1150	1150
Material-specific properties							
Refractive index		–	ISO 489-A	1.578	1.578	1.572	1.572
• Optical transmittance	2 mm	%	DIN 5036-1	90	90	90	90
Processing conditions for test specimens							
• Injection molding – melt temperature	–	°C	ISO 294	330	330	330	330
• Injection molding – mold temperature	–	°C	ISO 294	100	100	100	100
• Injection molding – flow front velocity	–	mm/s	ISO 294	200	200	200	200

• These property characteristics are taken from the CAMPUS plastics data bank and are based on the international catalog of basic data for plastics according to ISO 10350.

1) Own measurement
Trial product

Easy-flowing grades							Flame-retardant grades	
1695	1795	1895	1897	2095	2097	DP 1-9389/5*	DP 1-9354*	DP 1-9354/1*
45	24	18	18	8	8	5	11	10
46	25	19	19	8	8	5	11	10
0.75	0.8	0.85	0.85	0.9	0.9	0.95	0.85	0.85
0.75	0.8	0.85	0.85	0.9	0.9	0.95	0.85	0.85
2400	2400	2400	2400	2400	2400	2400	2400	2400
68	72	74	74	76	76	78	72	72
6.2	6.4	6.8	6.8	6.9	6.9	6.9	6.8	6.8
>50	>50	>50	>50	>50	>50	50	50	50
NB	NB	NB	NB	NB	NB	NB	NB	NB
NB	NB	NB	NB	NB	NB	250	NB	NB
16	13	10	10	8	8	6	11	11
13	12	10	10	8	8	6	11	11
5200	5200	5200	5200	5200	5200	5000	–	–
6000	6000	6000	6000	6000	6000	5200	–	–
55	55	55	55	55	55	50	–	–
60	60	60	60	60	60	40	–	–
2400	2400	2400	2400	2400	2400	2400	2400	2400
105	105	105	105	110	110	110	105	105
120	120	120	120	125	125	130	120	120
138	149	158	157	173	172	187	159	159
150	163	173	172	192	191	206	174	174
158	173	183	182	203	202	218	185	185
150	162	172	171	189	188	204	174	174
140	140	150	150	150	150	150	140	140[1)]
130	130	130	130	130	130	130	130	130[1)]
140	140	150	150	150	150	150	140	140[1)]
0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
HB	HB	HB	HB	HB	HB	HB	VO	VO
HB	HB	HB	HB	HB	HB	HB	VO	VO
–	–	–	–	–	–	–	5VA	–
25	25	25	25	25	25	25	35	35
850	850	850	850	850	850	850	960	960
3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3
7	7	7	7	7	7	7	7	7
80	80	80	80	80	80	80	80	80
1.00E+14	1.00E+14	1.00E+14	1.00E+14	1.00E+14	1.00E+14	1.00E+14	1.00E+14	1.00E+14
1.00E+16	1.00E+16	1.00E+16	1.00E+16	1.00E+16	1.00E+16	1.00E+16	4.00E+15	4.00E+15
35	35	35	35	35	35	35	30	30
275	275	600	600	600	600	600	225	275
<100M	<100M	<100M	<100M	<100M	<100M	<100M	<100M	<100M
A1	A1	A1	A1	A1	A1	A1	A1	A1
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
1180	1170	1150	1150	1140	1140	1120	1150	1150
1.578	1.576	1.573	1.573	1.566	1.566	1.560	–	1.572
90	90	90	90	90	90	90	–	87
330	330	330	330	330	330	330	330	330
100	100	100	100	100	100	100	100	100
200	200	200	200	200	200	200	200	200

Product data

Reference data for the Apec® range are listed in the table on pages 4/5.

Heat resistance/Aging behavior

The outstanding property of Apec® is its graded, high-level heat resistance in conjunction with excellent transparency, only slight inherent color, good flowability and high impact strength.
There is currently no other thermoplastic which combines these properties at such a high level.
At present, products produced on an industrial scale are available with a Vicat softening temperature of up to 218 °C (e. g. DP 1-9389/5*).

With short-term thermal loading and parts subject to only a low level of mechanical stress, the service temperatures possible for the Apec® grades are approximately 15 °C below the Vicat softening temperature.

The long-term service temperature of Apec® parts depends on the demands placed on the part.
As with all thermoplastics, long-term high-temperature stressing can cause changes in the property level (e.g. mechanical properties and color).
The extent of the changes also depends on the duration of the stressing.
With excessive thermal stressing, part failure can result in extreme cases as a result of brittle fracture or incipient melting.
The temperature indices to UL746B constitute guidelines for the temperature stressing and service life of parts in Apec® (see reference data table).
These are the temperatures at which the tested material property displays at least 50 % of its starting level for a defined exposure time.

Optical properties

The light transmission of all Apec® grades[1] corresponds to the standard level for PC, at 90 % for a wall thickness of 1 mm. The refractive index is affected by the ratio of the two monomer components and falls as the heat resistance increases.

Toughness

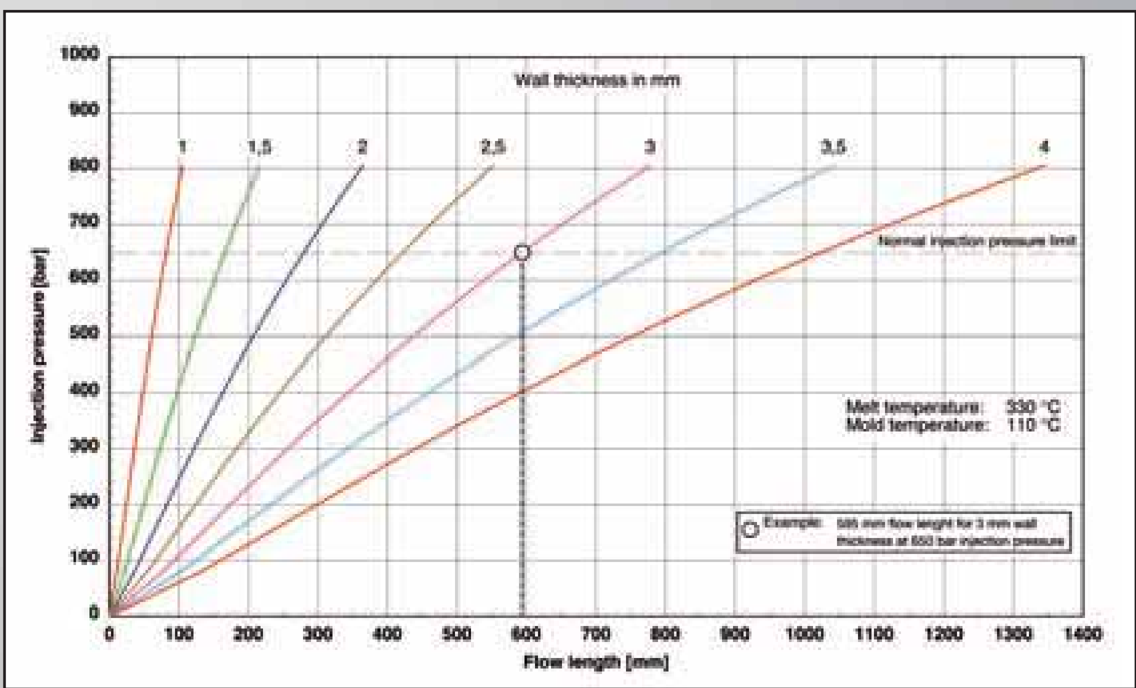
With thermoplastics, high heat resistance is often achieved at the expense of toughness. Although their notched impact strength is lower, the impact strength of Apec® moldings is equal to that of standard polycarbonate parts, both at room temperature and at –30 °C. The material's high energy absorption capacity is also apparent under biaxial stress in the penetration test.

Melt viscosity; flow properties

Like most resins, the increased heat resistance of Apec® also means higher viscosity. Compared with other amorphous thermoplastics with comparable heat resistance such as polyarylates, however, Apec® exhibits a markedly lower melt viscosity and hence better flow properties. (See the following injection pressure/flow length diagrams.)

Flow properties
Calculated values

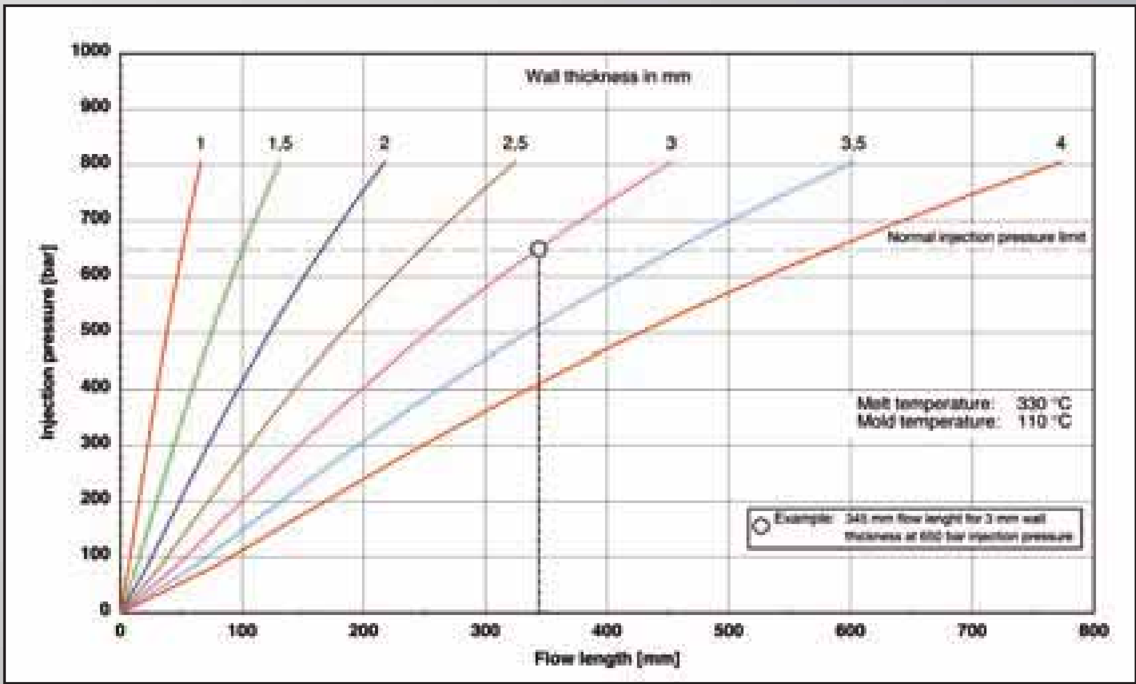
Apec® 1695



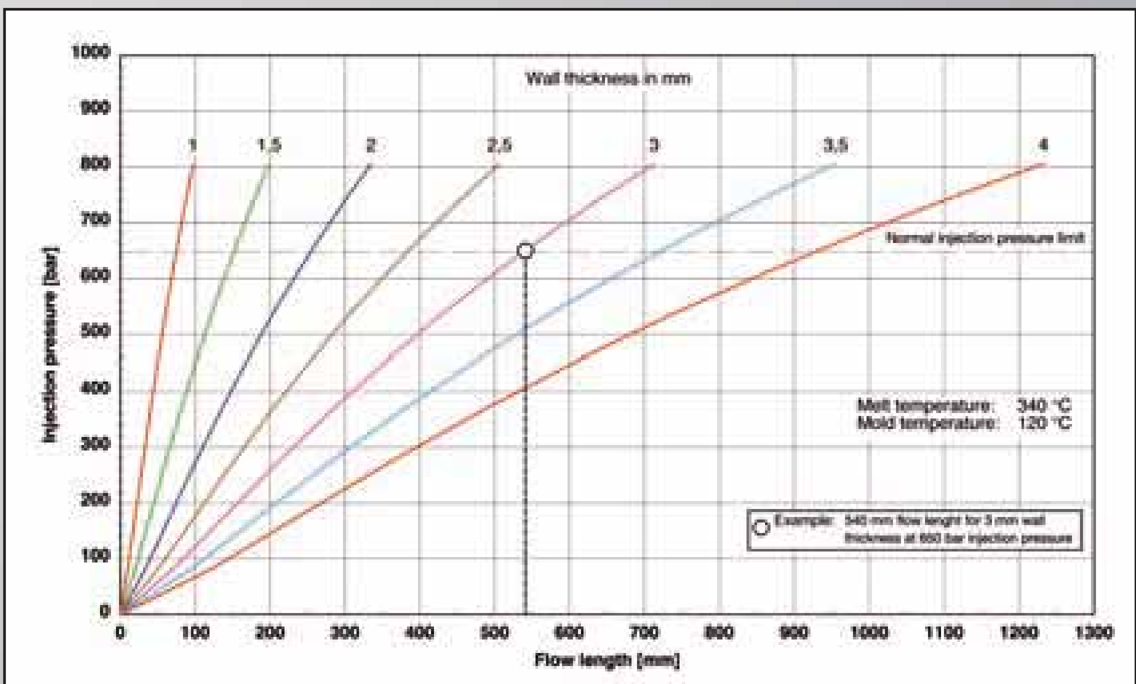
1) Applies to the non-colored (natural) state; does not apply to flame-retardant grades.

Flow properties
Calculated values

Apec® 1703

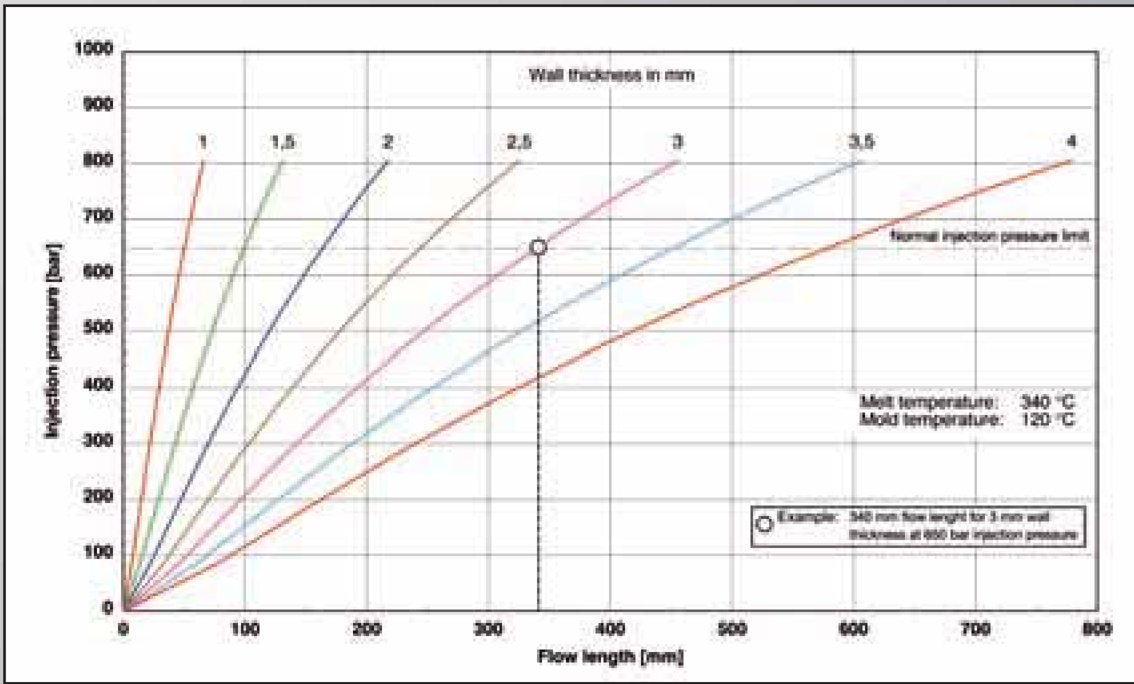


Apec® 1795

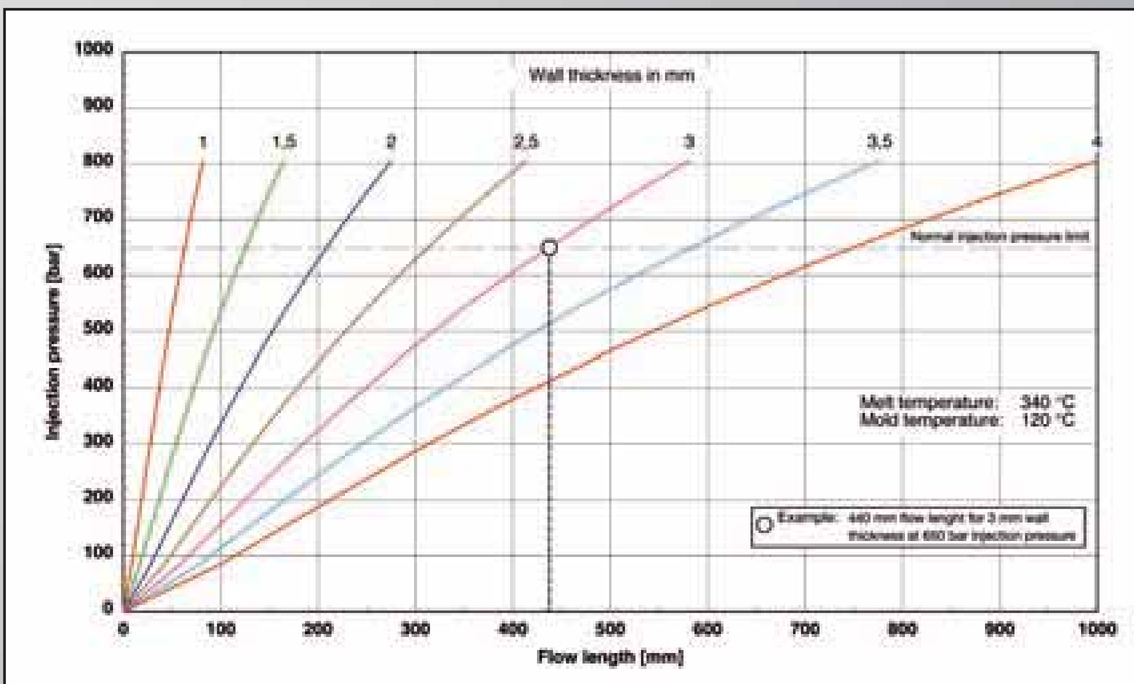


Flow properties
Calculated values

Apec® 1803

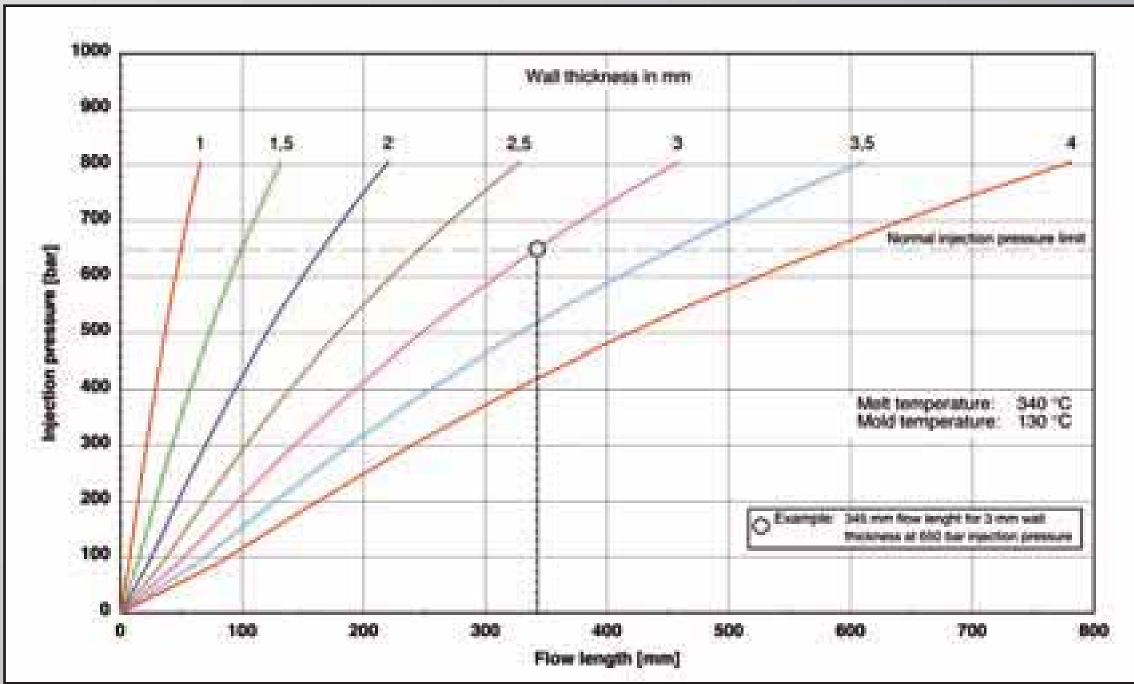


Apec® 1895

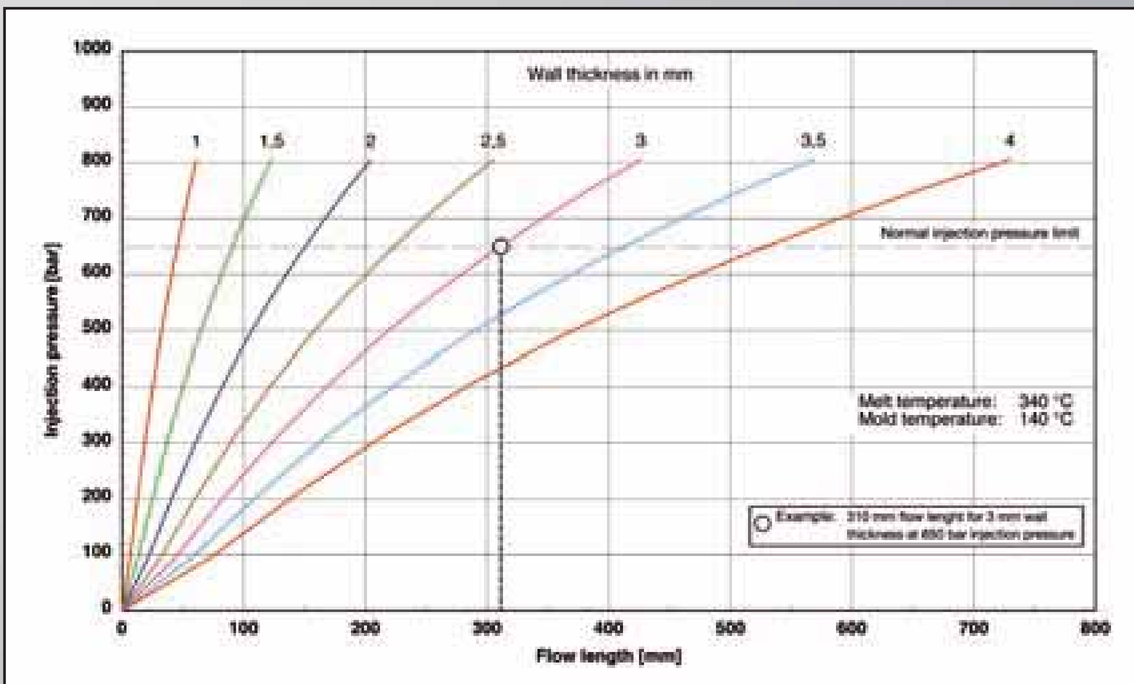


Flow properties
Calculated values

Apec® 2095



Apec® DP1-9389/5 (Versuchsprodukt)



Electrical properties

The electrical properties of Apec® and polycarbonate parts are also broadly similar. This applies particularly to surface resistivity, volume resistivity and the dielectric constant.

Flame retardance

Apec® without flame retardant additives is classified HB in accordance with UL 94. If small amounts of flame retardant (<1 %) are added, opaque shades achieve a V-0 rating at 1.5 mm thickness.

UV resistance

The behavior of Apec® when exposed to UV radiation also indicates that it belongs to the polycarbonate family. Both materials become yellow after prolonged exposure, but this discoloration is considerably less than with PAR (polyarylate) and PSU (polysulphone). UV-stabilized Apec® grades show a markedly reduced tendency to yellowing of transparent colors. For applications requiring an exceptionally high level of UV stability, an additional UV protective coating is recommended.

Chemical resistance, stress crack resistance

The behavior of Apec® in contact with chemicals is similar to that of standard polycarbonate.
Apec® parts show good resistance to saturated aliphatic hydrocarbons, alcohols, dilute mineral acids, and both neutral and acid salt solutions.
Apec® is not resistant to aromatic hydrocarbons, ammonia, amines and aqueous alkaline solutions.

The chemical resistance and stress crack resistance are also largely dependent on the stress states of the parts, the temperature of the objects and the concentration of the chemicals. A practical test should therefore always be conducted in cases of doubt. If this is not possible, the bent strip test (DIN 53 449/3) at least provides a rough guide.
In order to avoid stress cracking, care must always be taken to ensure that the residual outer fiber strain does not exceed 0.3 %.

Resistance to hydrolysis

Hot water leads to gradual chemical degradation, coupled with a reduction in the impact strength and elongation at break. Permanent service in water at temperatures of above 60 °C is therefore only possible to a limited extent.

Solubility

As their heat resistance or TMC bisphenol content increases, the solubility of Apec® grades in non-halogenated solvents, such as toluene, acetic acid ethyl ester, methyl ethyl ketone and tetrahydrofurane also increases (see TI “Apec® for Solubility Applications”).

APPLICATIONS

Thanks to its unique combination of properties (excellent transparency, heat resistance and toughness), Apec® yields moldings with a broad spectrum of applications.

Electronics/electrical engineering; Domestic appliances:

- Domestic appliances/measurement transformer components
- Lamp covers (for tumble dryers, cooker hoods, bus bar supports, insulators)
- Fuse housings
- Front panels for electric cookers
- Covers for food appliances
- Socket housings
- Illuminated rotary switches
- Chip trays

Automotive:

- Automotive brake and indicator bulb caps
- Automotive headlamp reflectors/bezels
- Flat fuses
- Interior light covers
- High-mount brake lights
- Motorcycle bulb housings
- Housings for license-plate lights
- Headlamp lenses

Lighting:

- Signal lamp systems
- Lights/recessed lights
- Covers for industrial lamps
- Dentists' operating lamps
- Housings for halogen lights
- Housings for spotlights
- Fittings for halogen systems
- Lenses for ships' lights

Medical technology:

- Contact lens holders
- Hot steam sterilization safety valves for respiratory aids
- Medical vessels
- Syringe tops
- Medical packaging film

PROCESSING

Material preparation/drying

To achieve optimum molded part properties, it is essential for Apec® granules to be dried prior to processing. Insufficiently dried granules will lead to a molecular weight reduction during processing, which can affect the properties of the finished part in the following ways:

- "silver streaks" and bubbles on the surface
- embrittlement (deterioration in mechanical properties, e.g. impact strength, tensile strain at break, flexural strength)
- impairment of flammability properties
- increased susceptibility to stress cracking

Apec® will absorb up to 0.12 % water from the air (23 °C/ 50 % relative humidity) and up to 0.3 % when in direct contact with water. In order to avoid the property deteriorations referred to above it is vital for the water content to be reduced to 0.02 % prior to processing. Fresh-air dryers and dry-air dryers are best. We recommend the following drying conditions as a function of the moisture content of the granules and the efficiency of the dryer:

Recommended drying conditions

	Drying temperature (granule temperature)	Drying time
Circulating air dryer (50 % fresh air)	130 °C	4 to 12h
	130 °C	2 to 4h
Dry-air dryer	130 °C	2 to 3h

Summer temperatures, especially when coupled with a high relative humidity, create the need for longer drying times in circulating air and fresh-air dryers, which can exceed the number of hours specified in the table.
In extreme cases, it may not even be possible for the requisite 0.02 % to be achieved with dryers of this type. The use of dry-air dryers is recommended in these cases in order to ensure independence from external climatic conditions.
To prevent the granules from becoming moist once again, particularly when they are subject to prolonged residence times in the injection molding machine, a heated hopper should be used.

Insufficiently dried material can be recognized by a greater or lesser degree of bubble formation in the strand of melt (as a function of the moisture content) after it has been pumped out of the die.

The TVI test (Tomasetti's Volatile Indicator) provides reliable information on the degree of drying, which will be adequate for most cases, for only a low outlay in terms of the apparatus and time involved. To perform the test, it is necessary to have a hotplate which can be heated to a surface temperature of approximately 330 °C (material temperature). Two microscope slides are heated at this temperature for two minutes. Three or four granules of the polymer are then placed on one of the glass slides using tweezers. The second glass slide is positioned on top of the first one and pressed down on it as hard as possible using an appropriate object. This causes the molten grains to be squeezed into thin, round films (with a diameter of approximately 10 mm). sAfter a further minute on the hotplate, with the pressure removed, the specimen is allowed to cool in the air. If bubbles are visible in the films then the granules are not yet sufficiently dry. This method is suitable for transparent and opaque colors (see also ATI 8024 d,e "Determining the dryness of Makrolon® by the TVI test").

Processing temperatures / processing advice

Injection molding is the chief process employed for the production of parts in Apec®. The advice set out below thus relates exclusively to this form of processing.
Present-day injection molding machines are suitable for the injection molding of Apec®. Open nozzles of the free-flow type with a relatively large cross-section have proved successful. If there is a slight leakage of melt, this can generally be prevented by retracting the screw somewhat (removing the pressure from the melt).

Recommended mold and melt temperatures

Grade	Melt temperature in °C	Mold temperature in °C
16xx	320 – 340	100 – 120
17xx	320 – 340	110 – 130
18xx	330 – 340	120 – 140
20xx	330 – 340	130 – 150
DP1-9354*, DP1-9354/1	330 – 340	120 – 140
DP1-9389*	330 – 340	130 – 160

In order to obtain parts with the lowest possible level of inherent stress (and particularly in the case of parts that have to be suitable for superheated steam sterilization) we recommend that the mold temperature be set as high as possible. The injection velocity, holding pressure level and holding pressure time are a function not only of the thermoplastic being processed but also, and more especially, of the geometry of the part and the layout of the gating system. Apec® can be injected at high speeds as a matter of principle, and graded injection has also proved successful. The holding pressure should not be set higher than is absolutely necessary or allowed to act for longer than strictly required.

It is important to bear the following in mind in the event of interruptions to production:

- if a nitrided steel injection molding machine is being used, the cylinder temperature should be reduced to approximately 180 °C and the machine kept consistently heated to this temperature

- if a wear and corrosion-proof screw is being used (centrifuged cylinder with a chromium steel screw), this can be allowed to cool to room temperature.

As a rule, no problems will be encountered when parts made of Apec® are demolded (recommended demolding drafts ≥1 %).

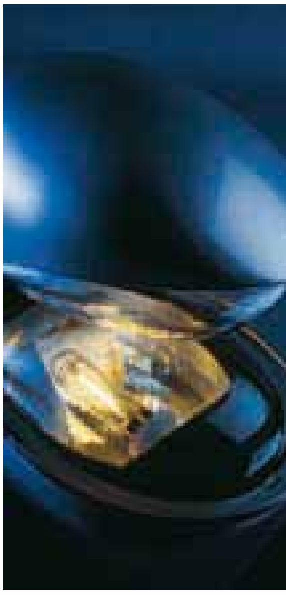
When demolding cores, experience has shown a high mold temperature to have a positive influence.

If demolding problems are still encountered, it may be possible to switch to a grade that contains release agent. We do not recommend the use of mold lubricants, however, since these can damage the injection molded part.

Further advice on processing can be obtained from our general information brochure “Processing data for the injection molder” (Order no. MS 005756). Apec® can similarly be processed by the following methods:

- sheet extrusion
- film extrusion
- profile extrusion
- extrusion blow molding
- injection blow molding
- film casting

Too little experience has been acquired with these processes to date for us to be able to give advice specific to Apec® at this point.



RECYCLING / MATERIAL DISPOSAL

Rejects and processing waste can be reground and processed into new moldings while observing the same drying and processing advice as for virgin product.
It is essential to check the property level and color of molding compounds containing recyclate in order to ensure their suitability for the intended application. The permitted content of recyclate must be established in each individual case.

When using regrind, it must be borne in mind that the different grain geometry of regrind compared with extrusion granules affects the feed and plasticating behavior. For this same reason, physical mixtures of regrind and granules tend to separate when moved during transport, conveying and metering.

When re-using Apec®, it is important to ensure that no foreign materials or dirt are introduced.
Apec® displays good compatibility with additive-free non-blended BPA-PC, which means that the two can essentially be recycled together.
It should be borne in mind that, with homogeneous mixtures of the two molding compounds, the properties obtained will be a function of the mixing ratio.

Apec® can be disposed of in an environmentally-friendly manner, either on a landfill or through correctly performed incineration. The identification for the different Apec® grades is as follows:

Standard grades: > PC-HT <
FR grades: > PC-HT <
Easy flowing grades: > PC-HT FR <

More detailed information on this may be obtained from our ATI 0309 d,e

General safety advice

Under the recommended processing conditions small quantities of decomposition product may be given off during processing. To preclude any risk to the health and well-being of the machine operatives, tolerance limits for the work environment must be ensured by the provision of efficient exhaust ventilation and fresh-air at the workplace in accordance with the Safety Data Sheet.
In order to prevent the partial decomposition of the polymer and the generation of volatile decomposition products, the prescribed processing temperatures should not be substantially exceeded.
Since excessively high temperatures are generally the result of operator error or defects in the heating system, special care and controls are essential in these areas.

DESIGNING WITH APEC®

Apec® is an amorphous thermoplastic with a high heat deflection temperature which belongs to the family of polycarbonates. Apec® displays good flowability in comparison with other amorphous thermoplastics with a high heat deflection temperature. This gives the design engineer a high level of freedom in design and means that the processor can benefit from a broad processing range.

Shrinkage, tolerances

Apec® displays identical shrinkage properties both parallel to and across the direction of flow. This is essential for the production of molded parts with a high dimensional stability. With optimum processing conditions, it is possible to achieve tolerances of ± 0.1 % for a nominal dimension of 100 mm.

Molding shrinkage[2)]

Apec® grades	With flow / across flow
16xx	0.75/0.75
17xx	0.80/0.80
18xx	0.85/0.85
20xx	0.90/0.90
DP1-9354*	0.85/0.85
DP1-9354/1*	0.85/0.85
DP1-9389*	0.95/0.95

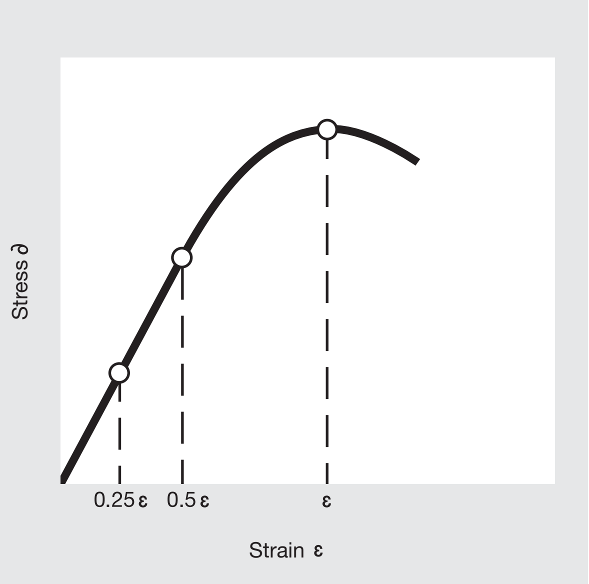
2) The shrinkage values were measured on a rectangular test plate 150 x 90 x 3 mm with a film gate at the 90 mm side.
Melt temperature: 330 to 340 °C (as a function of grade)
Mold temperature: 120 to 150 °C (as a function of grade)
Injection time: 1 s
Max. cavity pressure: 600 bar (pressure sensor close to film gate)
NB: The shrinkage values given are reference values and thus only suitable for mold layout to a limited extent. Please contact our design department if you require assistance.

*) Developmental Product

Mechanical properties, permitted stresses and strains

If Apec® is subject to prolonged mechanical stressing it can suffer stress cracking in the same way as other amorphous thermoplastics.
This process will be accelerated under the action of media that trigger stress cracking. It is not possible for all the factors that influence stress cracking to be recorded or taken into account at the design stage.
If mechanical stressing is specified, then the design should be such that irreversible elongation does not exceed 0.3 %.
Under short-time loading, considerably higher strain values are possible. Up to 50 % of the tensile strain at yield is permissible for once-only short-time loading, and up to 25 % of the tensile strain at yield for repeated short-time loading. If there is any uncertainty regarding the mathematical determination of the stress, the appropriate safety factors should be applied.

Permitted stresses and strains



Apec®	Short time once only MPa/%	Short time repeated MPa/%	Long-term MPa/%
All grades	56/3.4	35/1.7	7/0.3

The chemical resistance and stress cracking behavior of Apec® are largely conditioned by the temperature of the object, the nature and composition of the chemicals involved and the internal and external stresses acting on the molded parts.
Both compressive stresses and tensile stresses occur as a function of the geometry of the molded part. If excessive tensile stresses prevail, this can lead to local deformation zones in the surface and in the regions close to the surface (microcracks, crazes) and hence to weak points.
In order to produce parts with a high serviceability, it is in the manufacturer's interest to avoid weak points of this type by ensuring that the stresses are properly under control.

As with standard polycarbonate, there is also a quick method for estimating the frozen-in tensile stresses in molded parts made of Apec®:
The molded part to be tested, which has cooled to room temperature (22 ± 3 °C) is fully immersed in a test medium (n-propanol). After 15 minutes' immersion, it is taken out of the medium and visually examined for any cracks that may have developed, together with their dimensions. If cracks are present, this indicates an unfavorable design or mold layout, or processing errors. The response threshold is approximately 14 MPa, i.e. tensile stresses that exceed this value are released in the form of stress cracks. This response threshold is to be regarded as relatively high, which means that only a rough estimate of the stress conditions is possible with this test medium[3].

Recommendation

A molded part in Apec® must at least pass the test in n-propanol – even if no mechanical stressing is to be expected when it is in service. Sometimes, it is difficult to recognize stress cracks on colored plastics. In such cases, it is recommended that sample parts be made of transparent material and checked.

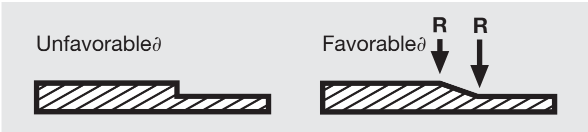
Safety advice

The test should be conducted under a ventilation hood or in well ventilated surroundings. Protective eyewear and gloves should be worn!
We will be pleased to send you our safety data sheet on request.

[3] In previous editions of ATI 2001d,e, use of the test media TnP 1:10 and TnP 1:3 (toluene/n-propanol in a volumetric ratio of 1:10 or 1:3) was also recommended for estimating internal stresses. These test media have considerably lower response thresholds for molded parts in Apec® (TnP 1:10 approx. 9 MPa; TnP 1:3 approx. 5 MPa) and thus make it possible to detect considerably lower stress.
On occupational safety grounds, it is essential to observe the appropriate regulations governing the handling of these media.

Radii, transitions in cross-section

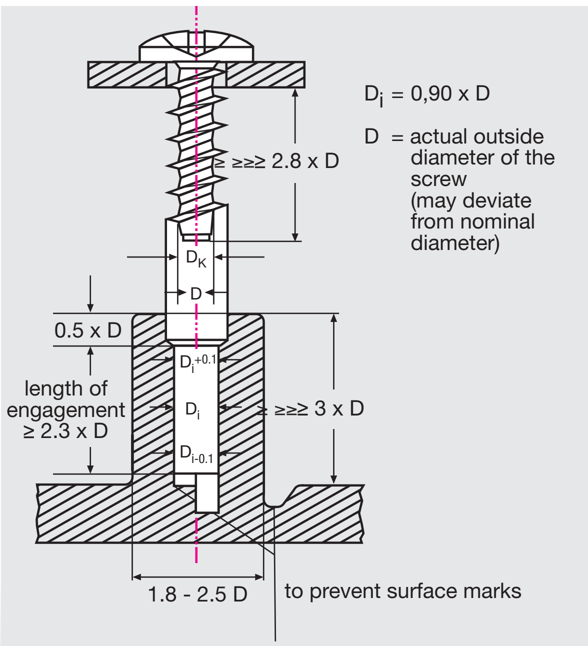
Sharp edges and corners lead to excessive stresses (notch effect) in corner and edge regions under loading. In the case of molded parts in Apec® which are subject to mechanical stressing, all edges and corners should be designed with a radius of at least 0.5 mm. In the same way, it is essential to avoid abrupt changes in cross-section (sudden changes in stiffness). Changes in cross-section should be gradual, wherever possible.



Design of transitions in cross-section

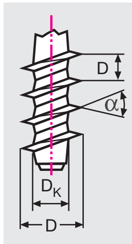
Screw connections and snap-fit joints

Screw bosses and snap-fitting hooks are elements of a plastics component that are subject to mechanical load.
Screw bosses for self-tapping screws or screws that are inserted by stamping expand when the screw is inserted, giving rise to long-term stressing. The degree of expansion and hence the level of stress in the screw boss is determined by the type of screw used and its geometry.
In the case of screws that are stamped into the boss, the degree of expansion is greater than for self-tapping screws. Small thread angles reduce the level of stress in the screw boss. Any grease should be removed from the screws prior to insertion. Brass screws are not recommended for this application, since it is more difficult to remove grease from these than from nickel-plated screws, for instance.
Determining the level of stress by mathematical means is difficult and always involves a high level of uncertainty (screw tolerances). In practical tests, favorable results have been obtained by observing the design guidelines given below.



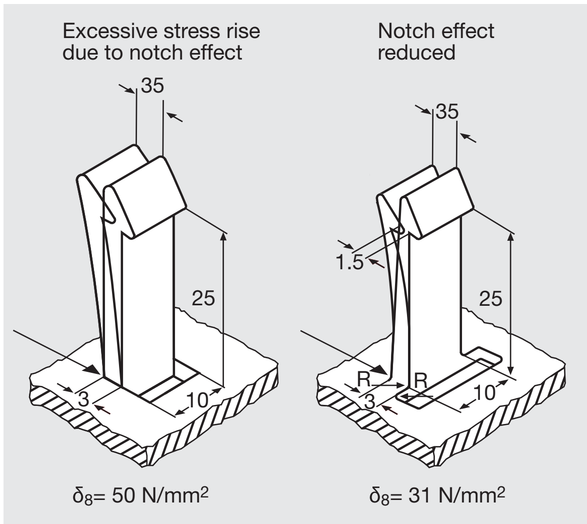
Dimensioning of screw bosses for Apec®

Core diameter D_K (mm)	<0.65 x D
Pitch P (mm)	0.35 x D to 0.55 x D
Thread angle α	<40°



Screw coupling with Apec®
(recommended screw geometry)

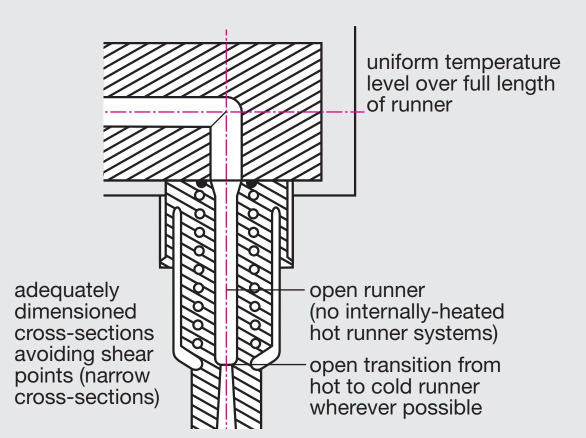
Snap-fit joints are a simple and inexpensive type of connection. A snap-fit joint is subject to short-time mechanical load during the assembly operation. Once it has been assembled, the joint is then generally only subject to a low level of mechanical stressing.
In most cases, stresses and strains can be determined mathematically.
Our ATI 1119d,e on snap-fit joints contains calculation formulae and sample applications for a wide range of different snap-fit joints.
High stresses can be avoided through skilful dimensioning, as shown in the diagram below.



Designing of snap-fit joints for Apec®

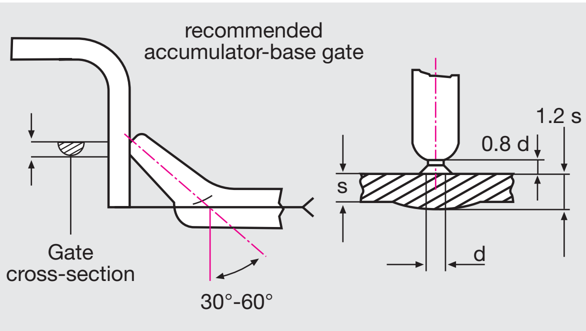
Gate layout

All the standard gating techniques can be employed for Apec®. Apart from the customary cold runner molds, molds with hot runner systems can also be used. If a hot runner system is employed, however, this should satisfy the requirements set out in the diagram below:



Requirements for the hot runner system

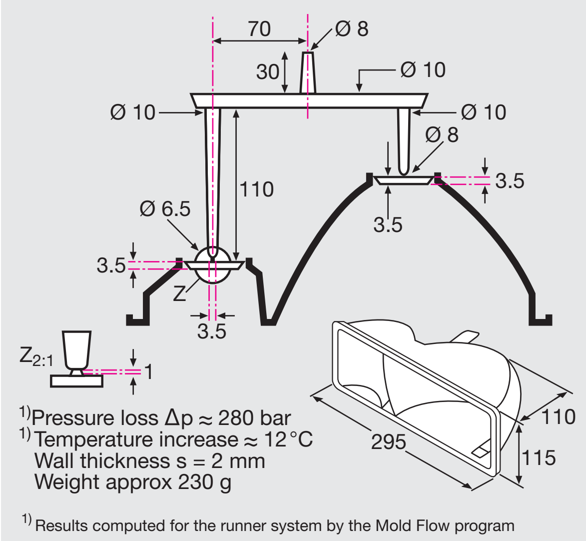
Molded parts made of Apec® should be produced with a low level of stress. In the case of pinpoint gates, the point of injection is the area where the highest stress level prevails within the mold.
These frozen-in stresses are caused by the very high flow velocity close to the gate.
The level of stress can be reduced not only by employing large gate cross-sections but also by partially increasing the wall thickness in the region of the mold. If tunnel gates are used, a version with an accumulator base is recommended.
This variant permits a clear reduction in melt stressing (see below).



Gate dimensioning - Minimum gate diameter (d = 60 %) of wall thickness (s)

The cross-sections of the feed channels must be dimensioned as a function of the grade of Apec® employed, the weight of the molded part and the length of the gate. It is not possible to give general recommendations on account of the many different influencing factors that are involved.
By using rheological computer programs, however, it is possible to reliably dimension gate systems with a low outlay.

The following illustration shows an actual example.



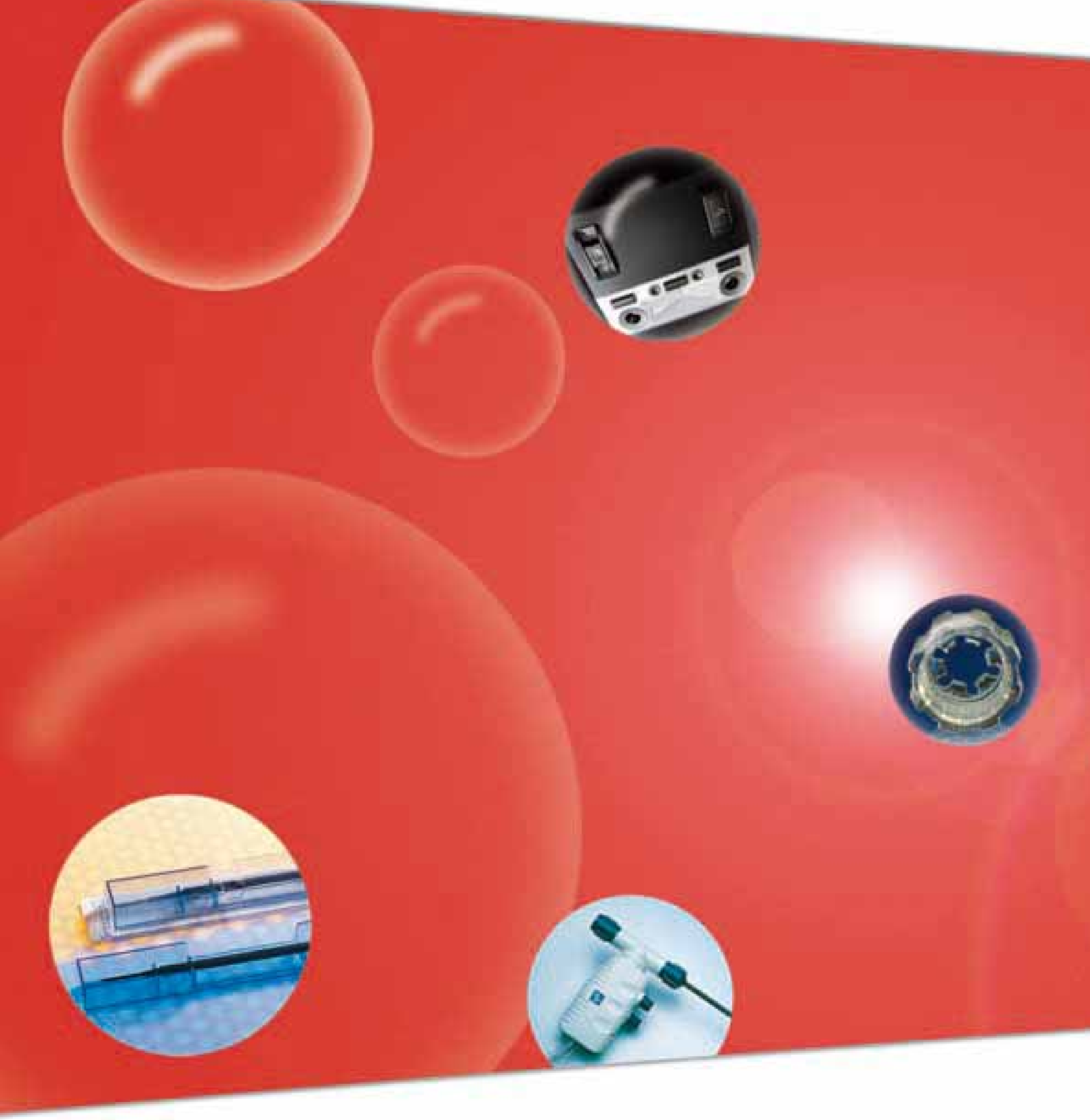
Automotive light reflector – recommended gate cross sections for Apec® 1800

REFERENCES

Title:
Apec® for solubility applications;
Apec® 1745 in medical technology;
Optical data of Makrolon® and
Apec® / Transparency and color;
The injection molding of high-quality molded parts –
Preparing the material: Drying;
Processing Data and Advice –
Processing Data for the Injection Molder
(Order No. MS 005756)

* This is a Developmental Product. Further information, including amended or supplementary data on hazards associated with its use, may be compiled in the future. For this reason no assurances are given as to type conformity, processability, long-term performance characteristics or other production or application parameters. Therefore, the purchaser/user uses the product entirely at his own risk without having been given any warranty or guarantee and agrees that the supplier shall not be liable for any damages, of whatever nature, arising out of such use.

Unless specified to the contrary, the values given have been established on standardized test specimens at room temperature. The figures should be regarded as guide values only and not as binding minimum values. Please note that, under certain conditions, the properties can be affected to a considerable extent by the design of the mold/die, the processing conditions and the coloring.



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