KRAIBURG TPE

THERMOLAST®
Product Properties and Processing

CUSTOM-ENGINEERED ***TPE*** *AND MORE*

Introduction

This brochure provides a broad overview of THERMOLAST® including properties and processing techniques. Recommendations are offered for equipment and tooling which will help ensure successful manufacturing of products made from THERMOLAST®.

THERMOLAST® is a trade name for three high-performance TPE product groups: THERMOLAST® K, THERMOLAST® V and THERMOLAST® A. Most THERMOLAST® compounds are based on hydrogenated styrene block copolymers (HSBC).

THERMOLAST® K
THERMOLAST® K compounds are the largest product family in the KRAIBURG TPE portfolio. Available with a wide range of modifications, they provide outstanding properties in a wide variety of application fields. Many years of experience and extensive development work on product and application-specific projects have brought about a unique range of THERMOLAST® K compound series.
These compounds fulfil key requirements in a broad spectrum of industries and application sectors and provide cost-effective and reliable solutions for perfect end products.
The most commonly used conversion processes for THERMOLAST® K compounds are injection moulding and extrusion. A special compound series is also available for hot melt processing.

THERMOLAST® M
The product line THERMOLAST® M provides a safe and high-quality basis for the products of the customers from the medical and pharmaceutical industry. The purpose of the project THERMOLAST® M was the development of a product which meets the high standards for safety, quality and reliability and which allows a processing up to the liability risk of indirect blood contact. The contents of the THERMOLAST® M Service Package are exceptional on the market.

THERMOLAST® V
THERMOLAST® V compounds provide superb physical properties in high temperature applications. They also exhibit excellent hysteresis behaviour, outstanding compressive stress relaxation and extremely low long-term compression set at high temperatures. THERMOLAST® V is preferred for use in automotive (under-the-hood) applications or for gaskets of any kind exposed to high temperatures. THERMOLAST® V compounds are normally processed by injection moulding or extrusion.

THERMOLAST® A
One of the THERMOLAST® A compound series provides enhanced oil resistance even at very low hardness ratings. The other series offers excellent UV resistance and outstanding adhesion to PC and PC/ABS. Both THERMOLAST® A compound series offer exceptional scratch resistance and superior wet grip properties. With this combination of properties, THERMOLAST® A is perfect for use in automotive applications, manual tools, power tools, etc. THERMOLAST® A is well suited for processing by injection moulding.

A quick overview of our compound series and their most important properties is provided on www.kraiburg-tpe.com.

Along with our standard compound series, we also offer tailor-made THERMOLAST® compounds engineered specifically to your individual needs.

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Introduction

Polymer Family Tree

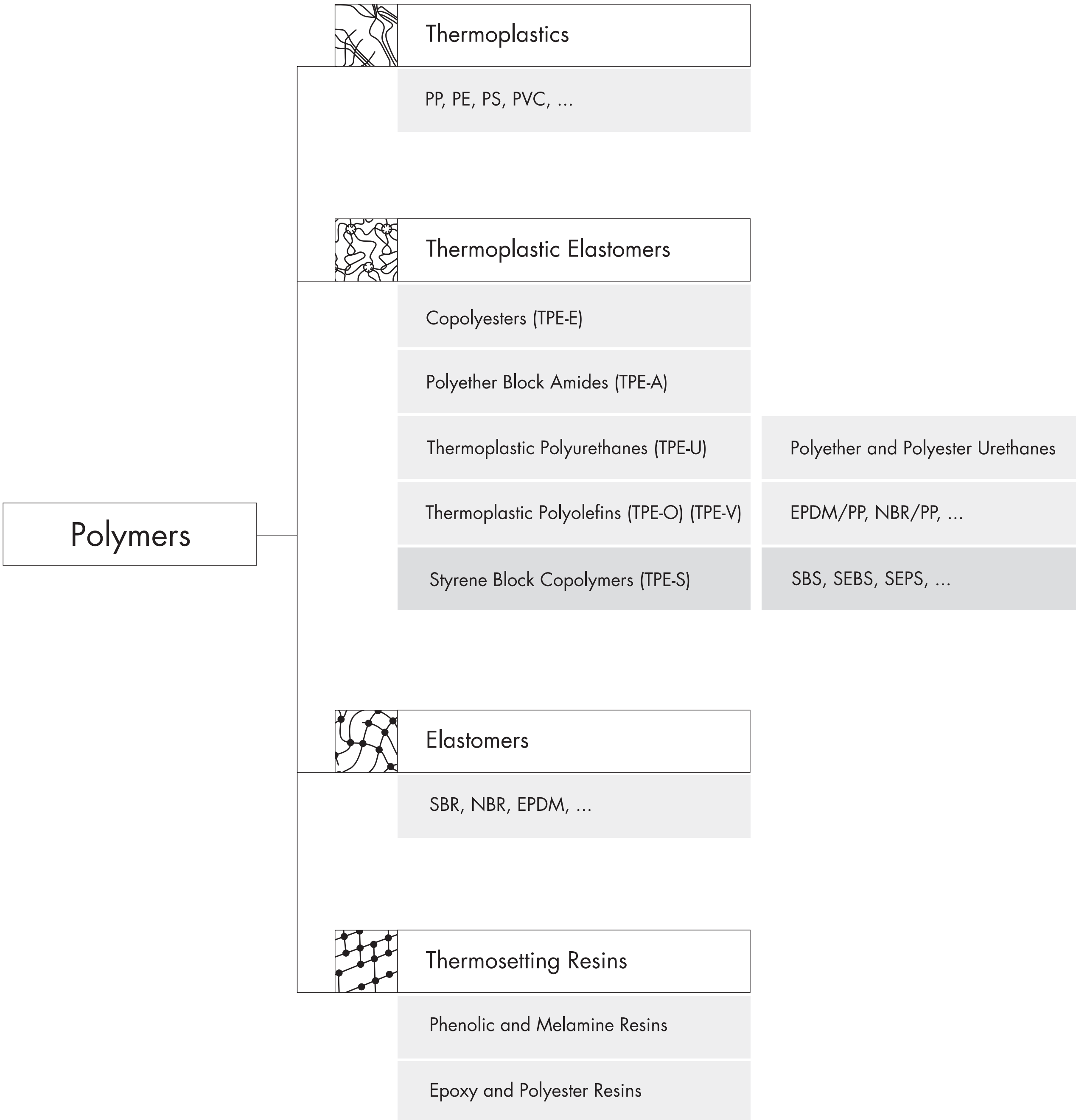
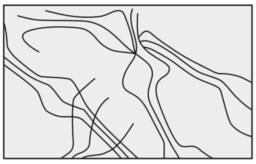
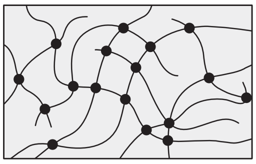


Figure 1:
Positioning of TPEs within the plastics family.



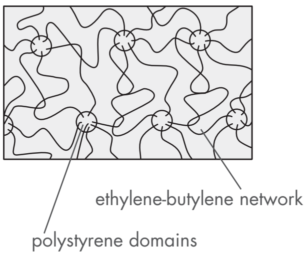
Thermoplastics

- become free-flowing and shapeable under application of heat and shear force
- resolidify when cooled
- purely physical process without chemical transformation or crosslinking
- thermoforming process is reversible, i.e. can be repeated



Elastomers

- initially deformable, can be crosslinked under application of heat crosslinking is a chemical process involving bonding of neighbouring molecular chains
- after crosslinking have elastic properties (high resistance to heat and mechanical stress)
- crosslinking is irreversible, i.e. material cannot be reshaped by repeated heating



Thermoplastic Elastomers

Based on hydrogenated styrene block copolymers (for example SEBS)

ethylene-butylene network
polystyrene domains

- under application of heat and shear force, become free-flowing and shapeable
- molecules are made up of thermoplastic polystyrene end blocks and elastic ethylene-butylene mid-blocks
- on cooling, physical crosslinks (polystyrene domains) are formed which connect the elastic ethylene-butylene blocks, creating a fixed three-dimensional network
- as a result, the elastic properties of TPEs are comparable with those of chemically crosslinked elastomers
- thermoforming process is reversible, allowing problem-free recycling of production scrap without impairing mechanical property levels (see page 14 Point 2. 'Recycling')

Introduction

Compounds

1. Compound Composition

THERMOLAST® compounds are formulated from a combination of raw materials including, for example:

- Polymer: hydrogenated styrene block copolymer
- Thermoplastic carrier: polyolefin
- Plasticizer: paraffinic white oil
- Inorganic fillers
- Other additives

2. Significant Benefits in Processing

THERMOLAST® compounds are supplied as pellets and can be processed directly as delivered without requiring additives of any kind. THERMOLAST® offers the following advantages in processing as compared to conventional elastomers:

- No vulcanization required
- New machine investments normally not required
- Can be processed by conventional plastics processing methods
- Simple to process
- Short cycle times
- Excellent heat resistance, i.e. large processing window
- Low energy consumption
- Production scrap can be re-used by direct recycling
- Processing parameters can be modified to enhance product quality and reduce dimensional tolerances
- Easy to colour
- Outstanding adhesion to virtually all thermoplastics in coextrusion and multicomponent injection moulding processes

3. Series Compounds - Significant Features

- Excellent adhesion on virtually all common thermoplastics
- Highly transparent, available in all colours
- Hardness grades available from 0 Shore A to 60 Shore D
- Elastic
- High flexibility at low temperatures
- Superb thermal resistance
- Excellent electric insulation
- Resistant to hydrolysis
- Resistant to acids and bases

4. THERMOLAST® Compound series

THERMOLAST® compounds fulfil key requirements in a broad range of industries and applications fields.

Application fields	Key requirement of different industries	Further important properties
Consumer, Care	· BfR, FDA, 2002/72/EC	· Smooth surface · Adhesion to PP
Medical	· USP Class VI · ISO 10993-5 und ISO 10993-10 (no skin and mucous membrane irritation)	· Sterilizable (Gamma, EtO, autoclave) · Extremely flexible · Excellent mechanical properties
Toys	· EN 71/3	· Super soft Compounds
Automotive	· excellent UV resistance (e.g. Florida test, Kalahari test, VW PV 3930, 3929)	· Improved oil resistance · Emission optimized (automotive interior) · Low density
Electronics / Industries	· flame retardant and UL 94 HB, V0 listed · Conforming to RoHS	· Adhesion to conventional technical thermo-plastics (in conformance with Taisei patents*)
Construction	· excellent UV resistance (e.g. RAL GZ716/1, CSTB/DER/BV-PEM REV01 · WRAS and W270 KTW approval	· No interaction with other materials

* for coinjected parts, without infringement of Taisei patents US 5149589 and JP 2888305

Introduction

Compounds

Further characteristics, irrespective of industry an application field:

- Adhesion to all common engineering thermoplastics (in conformance with Taisei patents*)
- Optimized compression set
- Easy to colour
- Transparent
- Very soft but with excellent mechanical properties
- High elasticity
- Excellent resilience
- Etc.

IMPORTANT NOTE: The information provided here shows only some of the industries and application fields in which THERMOLAST® compounds are used and an overview of their important properties.
More detailed information is available at www.kraiburg-tpe.com.

5. Custom Engineered TPE

Many products, particularly those intended for new application fields, cannot be realized with materials from standard product ranges. Whether used in existing or new applications, sometimes a „perfect" compound is needed to meet specific requirements.
We invite you to benefit from our many years' experience in tailor-made resin development. Contact us and together we'll find the ideal solution for your product.

Here are some of the properties that can be modified to meet your requirements:
Hardness

- Density
- Tactile feel
- Flow characteristics
- Damping characteristics
- Colour
- Resilience
- UV-resistance
- Elasticity
- Abrasion resistance
- Etc.

We will be happy to assist you in selecting the compounds which best fit your specific needs. We look forward to your enquiry.

Product Properties

Physical Values

THERMOLAST® compounds can be designed to specific user requirements and are therefore available with an extensive range of physical values. Detailed data is provided on our data sheets.

1. Hardness

Compounds are available in hardness ratings ranging from 0 Shore A to 60 Shore D. Shore A hardness testing is suitable for compounds with hardness ratings only within the range 10 to 80 Shore A. If the compound to be tested is softer than 10 Shore A, our IRHD SS test procedure should be used to get accurate results. Further details are provided in our data sheets for super-soft compounds.

2. Tensile Strength and Elongation at Break

The degree of molecular orientation depends on the geometry of the part moulded and the processing conditions employed. Tensile strength and elongation at break are greater in the direction perpendicular to orientation. (please also refer to page 25, 6. Types of Gates)

3. Service Temperatures

The permissible service temperature range for THERMOLAST® compounds is generally from -50 to 120 °C (-58 to 248 °F) and for THERMOLAST® V from -50 to 140 °C (-58 to 284 °F). Variations are possible in specific applications depending on the particular types and durations of stress encountered as well as other factors.

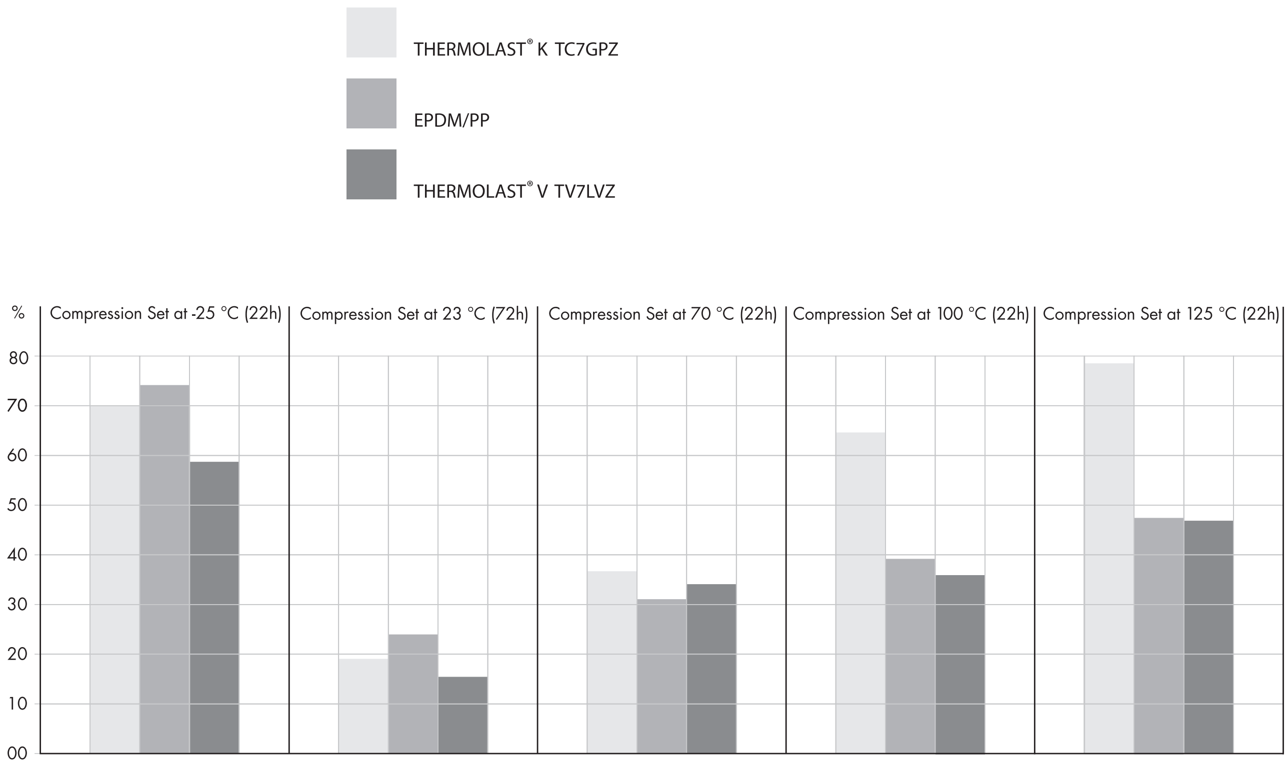
Detailed information on hot air ageing and/or cryogenic behaviour of THERMOLAST® can be provided upon request.

Product Properties

Physical Values

4. Compression Set

THERMOLAST® is available in a wide range of compounds with optimized compression set for use in both 1-component and 2-component injection moulding processes. The bar graphs below compare compression set of a standard THERMOLAST® K compound, a typical EDPM/PP and a THERMOLAST® V compound - each with a Shore A hardness of 70 - at various temperatures.



Please consult our data sheets for detailed information and mechanical property values or contact us for more particulars concerning compounds with optimized compression set.

1. Chemical Resistance

THERMOLAST® compounds exhibit excellent resistance to water and a wide variety of aqueous solutions including strong inorganic acids and alkali solutions. However, long-term contact with oils, fuels, aromatics and various organic acids can cause a certain amount of degradation. Whether or not resistance to these substances is sufficient for a given application must be evaluated on a case-by-case basis.
As absorption behaviour is highly dependent on the prevailing service conditions (e.g. temperature), material tests are normally recommended under the actual conditions found in the subsequent application. As mentioned earlier, a number of THERMOLAST® A compounds are available with enhanced oil resistance – please contact us for further information.

2. Behaviour in contact with Acrylic Paint

Contact exposure testing shows that THERMOLAST® compounds generally have excellent resistance to acrylic paints.
A 14-day immersion of a THERMOLAST® test plaque fixed between 2 acrylic-painted wooden boards at 50 °C yielded the following test results: No interfacial sticking between the plaque and the boards, no matte spots, no softening, no discolouration and no wetness on the painted boards. Natural-coloured compounds may turn slightly yellow in colour but are not otherwise attacked or altered by acrylic paint.
More details can be provided on request.

Product Properties

Environmental Resistance

3. Weathering and Ozone Resistance

THERMOLAST® compounds are resistant to the effects of UV and ozone as found in normal applications. Several compound series are available with additional weathering resistance for long-term outdoor use as provided by specially developed stabilization and colouring systems. Products made from these compounds fulfil demanding specifications in the automotive industry (e.g. Kalahari test, Florida test, VW PV 3930, 3929) and construction industry (RAL GZ 716/1 and CSTB certification for qualityassured plastic window systems).
We will be happy to send you data sheets providing more detailed information.

For a quick overview of the compound series which are particularly well suited for outdoor applications, visit www.kraiburg-tpe.com.

Important Additional Information

1. Packaging and Storage

THERMOLAST® compounds can be supplied in 20 or 25 kg (44 or 55 lb) sacks, bulk octabins or in bigbags. The material should be kept in a dark, dry area if it will be stored for a long time prior to use.
PLEASE NOTE: When exposed to high temperatures, super-soft compounds may agglomerate which can result in blockage of conveying systems. Therefore high temperatures must be avoided in transport and storage. We will be glad to provide more information in this regard on request.

2. Recycling

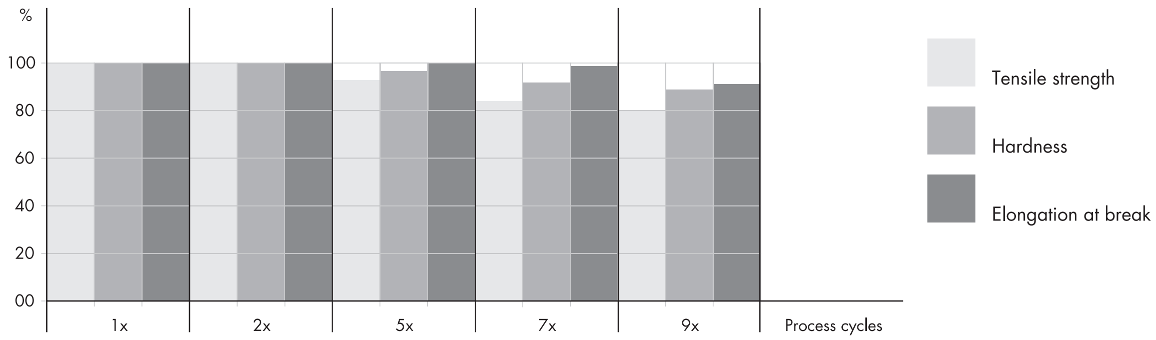
THERMOLAST® scrap can be recycled without difficulty, as is the case with scrap from other thermoplastics. We recommend a maximum recycle blend-in rate of 15% relative to virgin material.

The bar graphs below illustrate the change in mechanical values as a function of process cycles for injection-moulded product consisting of 100% recycle. Overall the material was injection moulded 9 times and ground between each cycle, i.e. ground a total of 8 times.

Tensile strength
Hardness
Elongation at break

Mechanical properties after X process cycles, given as % of original value.

Mechanical properties after X process cycles, given as % of original value.



3. Environmental Compatibility

THERMOLAST® is environmentally friendly. Any scrap which cannot be recycled as described in the previous section can be disposed of in landfills in accordance with local regulations. When incinerated, THERMOLAST® burns in a manner similar to polyolefins.
Any scrap which cannot be recycled as described in the previous section can be disposed of in landfills in accordance with local regulations.

4. Colouring

Almost all compounds from our standard compound series are transparent or translucent and natural-coloured or black in colour. Upon request we can supply THERMOLAST® compounds in virtually any colour required. However, inprocess colouring, e.g. in injection moulding or extrusion, is very simple and normally far more economical. Due to their natural light colour THERMOLAST® compounds can be coloured in process, even in light or luminous colours, providing finished products with outstanding visual appearance and offering significant benefits over EPDM/PP.
Colouring can be done with universal colour batches. Best results are achieved using polyolefin batches. Depending on the desired colour to be attained, the batch should be added at a level of around 2 – 5%. Colouring normally does not result in significant changes in material properties except for hardness which can increase by up to approx. 2 Shore A depending on the amount of colourant added.
Liquid colourants can also be used with THERMOLAST®; however in some cases they cause problems in homogenization and therefore master batches are to be preferred. Compounds which must conform with industry-specific requirements or specifications (e.g. UL 94, BfR, FDA, excellent UV resistance, etc.) should be coloured with suitable colouring agents to maintain conformance.

Product Properties

Important Additional Information

5. Predrying

As THERMOLAST® is not hygroscopic, predrying prior to processing is normally not required. Should condensation occur due to large temperature fluctuations between transport, storage and/or production, we recommend drying the material for 2 hours at 80 °C (175 °F).
Adhesion-modified compounds should be pre-dried prior to processing in accordance with the processing instructions (www.kraiburg-tpe.com).

6. Weldability

Most THERMOLAST® compounds are easy to weld (e.g. by hot plate welding). Very high seam strengths can be attained due to the material's thermoplastic characteristics.
Further information can be provided by your KRAIBURG TPE representative.

7. Contact Behaviour with Other Thermoplastics

In applications in which THERMOLAST® directly contacts other thermoplastics - except for plasticized PVC - no interaction (i.e. stress cracks, plasticizer migration) occurs between the adjacent materials.

8. Adhesive Bonding and Surface Decoration

Adhesive Bonding:
Most THERMOLAST® compounds can be joined by adhesives with good bonding results. The adhesive selected for use must fulfil diverse requirements in terms of environmental protection, surface appearance and bonding strength.

The bonding strength of an adhesive depends primarily on the surface contact achieved between the components joined. The following rules should be followed to ensure optimum adhesion:

- Ensure that the surfaces joined are dry and free of foreign material of any type.
- Apply high pressure to the bond immediately after joining to improve flow of the adhesive and its contact with the surfaces joined.
- Higher bonding strength can be achieved by increasing contact pressure, contact pressure application time and/or temperature.

The adhesive used must be compatible with the material or materials joined, i.e. it must provide the required strength without attacking (solvating or dissolving) the material or being attacked by the material (e.g. due to plasticizer migration). Your KRAIBURG TPE representative will be pleased to recommend suitable adhesives for specific compounds to be joined.

Surface Decoration:
Special THERMOLAST® compounds are available which are suited for printing, painting, or lacquer coating when appropriate application procedures are used. We will be happy to provide further information as required.
In the event an adhesive or decoration system does not adhere sufficiently, adhesion can normally be improved by suitable pretreatment (e.g. primer coating or corona treatment).

THERMOLAST® in Injection Moulding

Machines and Processing

1. Processing Machinery

THERMOLAST® compounds can be processed on standard injection moulding machines for thermoplastics incorporating 3 screw zones.
Screws should have a compression ratio of at least 2:1 and an L/D ratio of at least 20:1. Barrier screws may be required in certain cases, e.g. to achieve an increased plasticizing rate.
Processing is possible with open nozzles. The use of shut-off nozzles and a backflow check valve at the tip of the screw can be advantageous.

2. Cleaning of Machines

Before processing THERMOLAST®, purge out the injection moulding system with polypropylene. If another material is to be used afterwards, run system until empty and purge again with polypropylene.

3. Processing Parameters

The following sections 4. - 8. provide information and general recommendations for processing THERMOLAST®. Please keep in mind that your experience with your machines and the particular material processed should always be taken into consideration as well. As THERMOLAST® compounds are frequently custom-developed to individual customer requirements, differences in processing can result.

Our applications engineers will be happy to provide any advice you may require and to come to your plant upon request to observe processing of sample materials.

4. Barrel and Melt Temperatures

The optimum barrel and melt temperatures for plasticizing differ considerably depending on the specific compound processed. These temperatures are of particular importance in 2-component injection (coinjection) moulding and must be selected in accordance with the compounds processed. Please refer to the Processing Guide provided at www.kraiburg-tpe.com.

As a general rule the barrel temperature should increase progressively by 10 to 20 °C (15 to 35 °F) per zone starting from the feed hopper. The nozzle temperature should be equal to or 10 °C (15 °F) below the temperature of the last heating zone

5. Mould Temperature

The optimum tool temperature is also highly dependent on the specific compound processed, particularly in the case of coinjection moulding. Recommended mould temperatures can be found at www.kraiburg-tpe.com.

As a general rule, we recommend using a tooling temperature of 40 - 60 °C when moulding thin-walled components.

We will be happy to assist you in selecting the correct mould temperature for your application, particularly if you are processing a custom-engineered compound. We look forward to your enquiry.

6. Injection Pressure and Injection Rate

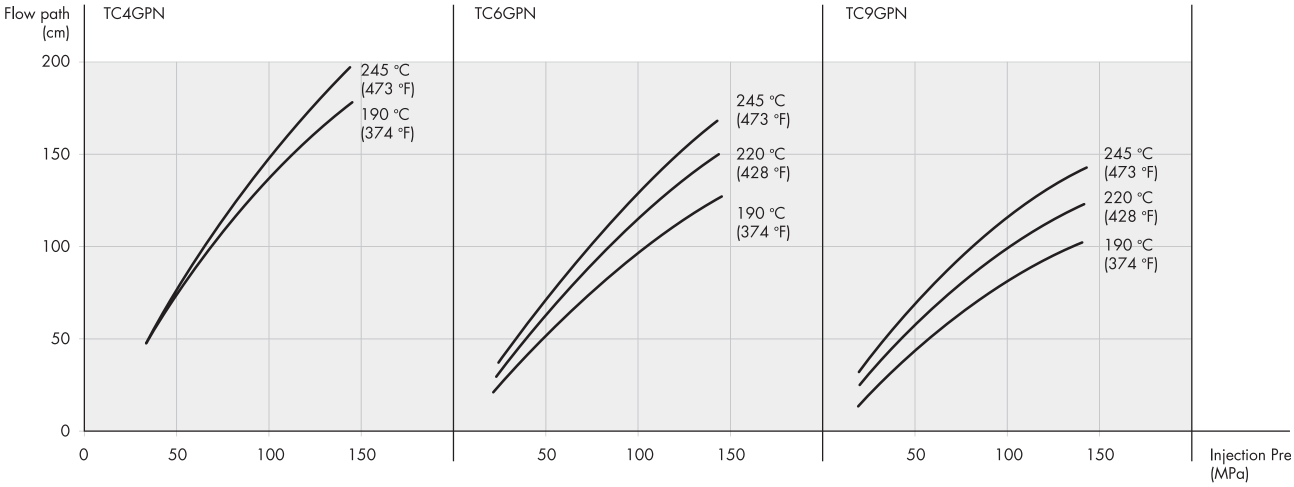
The injection pressure and injection rate must be selected in accordance with the melt viscosity and shear sensitivity of the material processed and therefore will vary for different THERMOLAST® compounds. When processing high viscosity compounds, take care to ensure sufficient melt shear rates: The cavity should be filled at high injection pressure and high flow rate (in the range of approx. 100 - 200 g/s).

THERMOLAST® in Injection Moulding

Machines and Processing

This is required to achieve long melt flow paths, particularly when moulding very thin-walled parts. Starting with these recommendations, users can conduct optimization trials to find the filling point providing high part quality.

The flow path diagrams shown below illustrate the effects of temperature and injection pressure on flow behaviour for 3 high-viscosity THERMOLAST® compounds.



Injection process conditions:
- Injection time 10 seconds
- Spiral flow path in 6 mm (0.236 in.) D semicircular channel
- Mould temperature 45 °C (113 °F)

We will be happy to provide more detailed information on the optimum injection rate for your specific compound. You can also obtain this information for many compounds from the Processing Guide in the appendix to this brochure or at www.kraiburg-tpe.com.

7. Back Pressure and Screw Speed

Usually we recommend a back pressure of approximately 20 – 50 bar (285 – 710 psi). The screw speed should be between 25 and 75 rpm.

Effects of higher back pressure:
- improves distribution e.g. of colour batches and other additives
- increases melt homogeneity
- plasticizing time is increased for a given screw speed
- reducing the screw speed also has a positive effect on homogeneity
- may cause deformation around the sprue

Effects of lower back pressure:
- creates insufficient shear energy and inhomogeneous melt
- as a result, higher-melting components in the compound may not plasticate.

8. Hold Pressure and Hold Time

The mould should be filled initially without applying hold pressure. Low hold pressure can then be applied to prevent sink marks and to guarantee 100% filling. The hold time should be set as short as possible.

Possible effects of high hold pressure:
- overfilling of cavities
- difficulties in demoulding
- layer formation
- deformation around the sprue
- improved adhesion at flow lines
- additional information concerning coinjection moulding is provided in Section 8. Processing Information for Coinjection Moulding starting on page 34

Possible effects of low hold pressure:
- sink marks in thick-walled parts
- increased shrinkage

THERMOLAST® in Injection Moulding

Moulds

1. The Runner System in the Mould

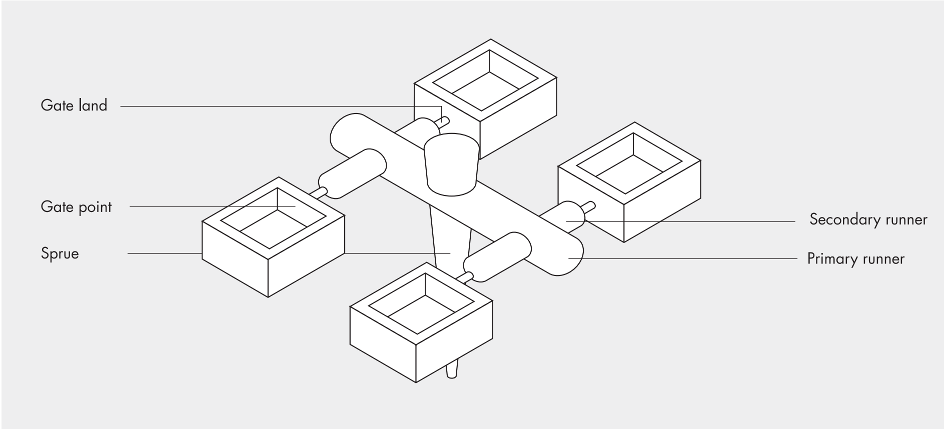


Figure 2:
Overview of runner system with individual components as designated in the following text.

2. Balancing the Runner System

- A balanced runner system in the mould is important in order to ensure that all cavities are filled evenly (see Figure 3).
- In an unbalanced system cavities closer to the sprue are overfilled and those further away are not filled completely (see Figure 4).

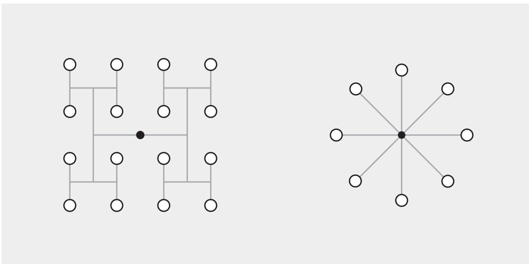


Figure 3: Balanced runner system
The flow path from the sprue to the cavity is always the same distance. The primary and secondary runners are also properly dimensioned relative to one another.

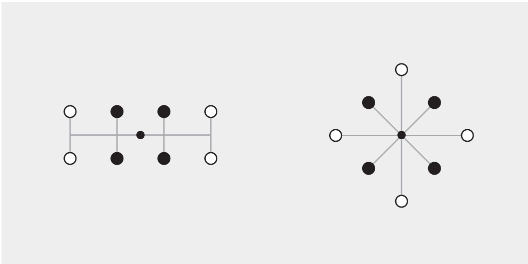


Figure 4: Non-balanced runner system
Flow paths from the sprue to the individual cavities differ in length. Cavities nearer to the sprue are overfilled and those further away are not filled completely.

3. Gate Points

The excellent rheological characteristics of THERMOLAST® compounds often eliminate the need for multiple gate points in large cavities or cavities with long flow paths. The following point should be noted with regard to THERMOLAST® rheology: As friction increases, viscosity decreases. The gate point should therefore be located such that the melt contacts a wall or core shortly after entering the cavity. Unrestricted flow, i.e. jetting, is to be avoided under all circumstances.

The ratio between the part wall thickness and the sprue diameter is a factor of decisive importance. Systems designed in accordance with these points will permit longer flow paths and provide improved part surfaces. Ideally the diameter of the gate point should be between 0.4 and 0.6 mm, with a maximum of 1.0 mm. A small depression (with a lens-like curve) will ensure that the gate point on the part is very clean.

THERMOLAST® in Injection Moulding

Moulds

4. Sprue

For processing THERMOLAST® compounds we recommend standard sprues with a draft angle of at least 1.5°. When compounds with hardness ratings less than 70 Shore A are processed, the draft angle should be at least 2.5°.

„Z" type sprue pullers (undercuts) can be used except when processing soft THERMOLAST® compounds. Conical pullers can be used with most compounds.

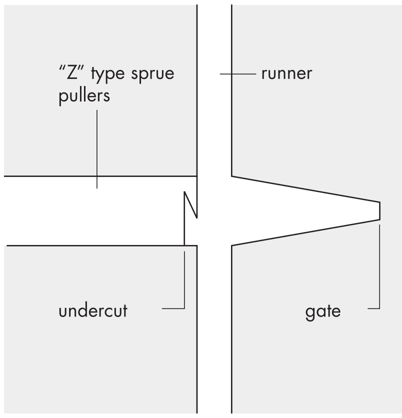


Figure 5:
„Z" type puller

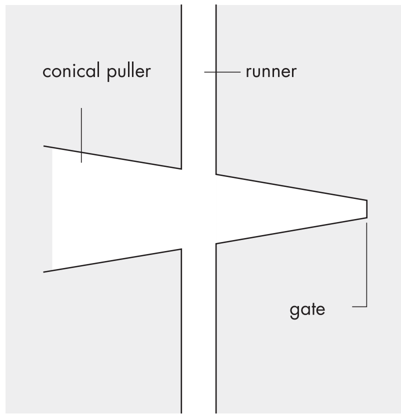


Figure 6:
Conical puller

5. Primary and Secondary Runner System

Normally semi-circular or trapezoidal runner channels can be used; however, round runner channels are best as they have a smaller surface area for a given cross-section. The secondary runner channels to the moulds should be large enough to allow the hold pressure to be maintained for a sufficient length of time. The diameter of the secondary runners should be slightly smaller than that of the primary runner.

All types of hot runner systems are suitable for use with THERMOLAST® compounds. Internally heated systems offer some slight advantages. Diameters should be chosen such that the volume of the hot runner is smaller than the finished part. If this is not the case, the hot runner should be empty after a maximum of 2 – 3 shots.

6. Types of Gates

Mechanical properties such as tensile strength and elongation of THERMOLAST® injection moulded parts are dependent on the direction of flow in injection. The resultant molecular orientation normally results in increased tensile strength and elongation at break perpendicular to the flow path.

The gate should therefore be selected in accordance with the part moulded:
In general, submarine or pin gates can be used with THERMOLAST® compounds. As noted above, the gate must be located such that the material contacts a wall or a core shortly after entering the cavity. Unrestricted flow, i.e. jetting, is to be avoided under all circumstances. The optimum ratio of sprue diameter to wall thickness must be carefully determined and employed to obtain surfaces with optimum visual appearance.
When moulding thin walled parts with large surface areas, a film gate is often used in order to achieve a parallel orientation across the entire width, to achieve uniform shrinkage in the direction of flow and the transverse direction and to prevent visual defects such as gate marks on the surface.

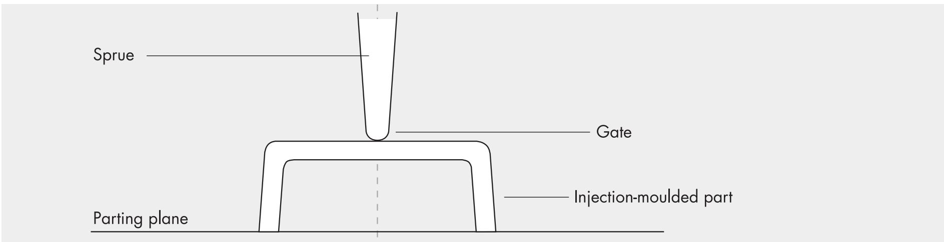


Figure 7: Pin gate

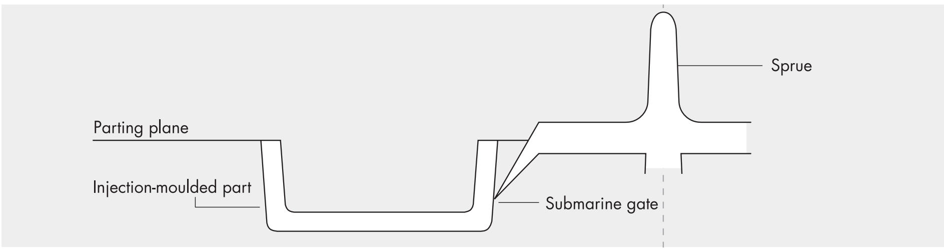


Figure 8: Submarine gate

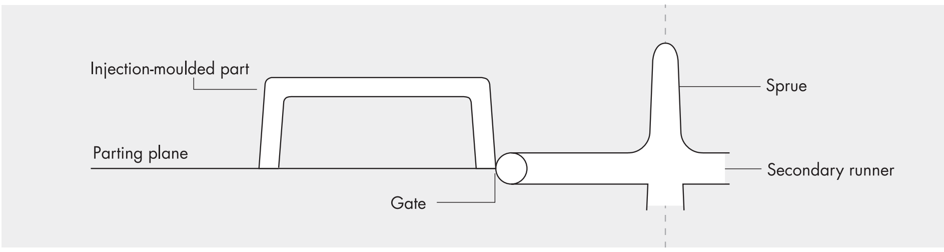


Figure 9: Film gate

THERMOLAST® in Injection Moulding

Moulds

7. Venting

Insufficient venting usually results in
- incomplete filling of cavities
- surface defects
- burn marks
- insufficient adhesion within coinjected parts

Apart from avoiding the above problems, optimum venting can also reduce cycle times in some cases. Venting can take place at the mould parting line. Usually we recommend that venting is done at a position furthest away from the gate point or at the position of the joint line. A filling study can be carried out to determine the correct venting position.
Usually vent channel depths of between 0.01 mm (0.0004 in.) and 0.02 mm (0.001 in.) are sufficient to ensure good venting.

8. Recommendations for Tooling Steels

The standard tooling steel grades listed below can normally be used in processing equipment for THERMOLAST® compounds:

Material No.	Quality	HRC	Properties	Applications	Etchable	High Gloss	Coatable
1.2083		through hardened 52 - 54	Cr alloyed steel corrosion resistant	mould surfaces	yes	yes	yes
1.2343	ESU	through hardened 52 - 54	hot-worked steel	mould surfaces	yes	(yes)	yes
1.2344	ESU	through hardened 52 - 54	hot-worked steel	mould surfaces	yes	(yes)	yes
1.2311		through hardened 52 - 54	hot-worked steel	mould surfaces (particularly when large in size)	yes	yes	yes
1.2764		surface hardened 58	case-hardened steel	mould plates and inserts	yes	yes	
1.2767	ESU	through hardened 54 - 56	cold-worked steel	mould surfaces	yes	yes	yes

Hot-worked steels, e.g. 1.2343 or 1.2344 grades, are suitable for general applications. Cold-worked steels such as grade 1.2767 exhibit outstanding compressive and flexural strength and as such are well suited e.g. for injection moulding of articles over long, unsupported cores.
1.2311 grades (suitable for surface graining) and 1.2312 grades (not suitable for surface graining) are well suited for moulds for large-sized articles.
Corrosion-resistant steels (e.g. 1.2083) are superb materials for precision multiple-cavity moulds as their outstanding properties (e.g. corrosion resistance, hardness, abrasion resistance) ensure long service life.

For more detailed information please consult your mould supplier.

9. Mould Surfaces and Demoulding

Parts made from THERMOLAST® compounds usually exhibit high surface friction. Soft compounds also tend to suction themselves to smooth mould surfaces. Spark-eroded moulds decrease adhesion to the moulded part and hence facilitate demoulding.

Ejectors should be selected in accordance with the hardness of the compound processed. When processing soft grades, large-area ejectors are preferable to ejector pins.

Due to the elasticity of THERMOLAST®, undercut parts can frequently be ejected from simple undercut moulds without need for a pusher, i.e. by simply pressing the parts out of the mould. Air-pressure supported ejectors are beneficial with soft compounds and more pronounced undercuts.

When moulding coinjected articles please note: if the hard component incorporates a polished surface (i.e. the bonding surface contacting the soft component), this can impair adhesion. Improve adhesion by spark erosion treatment of the surface (see Section 8. „Processing Information for Coinjection Moulding“, starting on page 34).

THERMOLAST® in Injection Moulding

Moulds

10. Shrinkage

Due to the anisotropic behaviour of THERMOLAST® compounds, shrinkage normally differs in relation to the flow direction in moulding. Our engineering staff can assist you in design of your moulds and will provide shrinkage data for our test plaques and the process conditions used in their fabrication.

Please note that shrinkage values from laboratory samples will not correlate on a 1:1 basis with values obtained in practice as shrinkage can be influenced by a large number of factors:

- processing parameters
- runner system (hot runner / cold runner)
- mould temperature
- mould design
- part geometry
- melt temperature
- flow direction
- material processed

Effects on shrinkage when injection moulding conditions are changed:

	Changes in injection moulding conditions	Effect on shrinkage
△ T melt - mould	▲	▲
cooling time in mould	▲	▼
mould temperature	▲	▼
injection rate	▲	▼
hold pressure	▲	▼

THERMOLAST® in Injection Moulding

Special Information on Coinjection Moulding

1. General Information

Coinjection moulding, also known as 2-component injection moulding, offers numerous benefits as it reduces the need for assembly work, shortens production times and therefore reduces manufacturing costs.
Coinjected combinations of hard and soft materials are used most frequently e.g. in fabrication of seals, anti-slip components and grip handles.
THERMOLAST® compounds are also used in conjunction with differentcoloured thermoplastics for aesthetic reasons. In addition, the pleasantly soft and warm feel of THERMOLAST® has led to its frequent use as a coinjected surface coating. The possibilities are endless; new ideas and shapes which can be realized using coinjection moulding processes are evolving every day.

2. Advantages of Coinjection Moulding:

- allows different hardness and flexibility within same component
- more freedom in aesthetic design e.g. thanks to colour diversity,
- transparent surfaces or other interesting characteristics of other
- THERMOLAST® compounds
- higher productivity
- reduced floor space requirements
- no need for part assembly
- quality control required for one article only
- reduced part weight
- additional value for end users (design aesthetics, quality, function …)

THERMOLAST® in Injection Moulding

Special Information on Coinjection Moulding

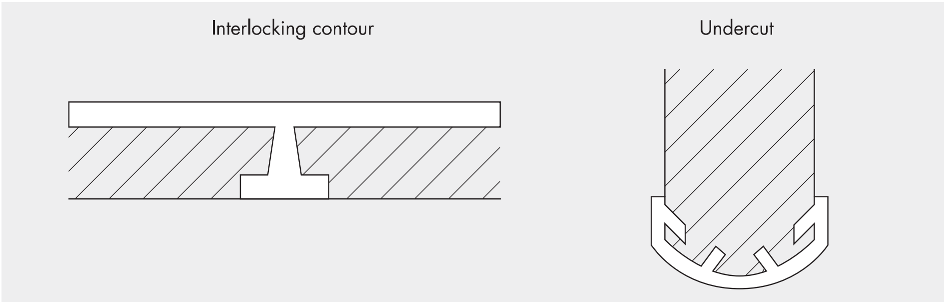
3. Alternative Bonding Methods

In coinjection moulding, bonding between adjacent components can be realized via
- ▶ mechanical anchoring, or
- ▶ adhesion bonding

Both alternatives are described in detail below, although adhesion bonding is by far more widespread in modern coinjection processes.

4. Mechanical Anchoring

Mechanical anchoring involves no physical bonding between the adjacent materials. Connection is realised e.g. by undercuts or interlocking contours in the semi-finished injection-moulded part.



The drawings shown above illustrate examples of coinjected moulded parts incorporating interlocking and undercut anchoring. Our applications engineering team can provide more information concerning mechanical anchoring and its feasibility in your specific application.

5. Adhesion

The base polymers used in THERMOLAST® compounds permit outstanding modification flexibility for optimum adhesion to a wide variety of thermoplastics.

The term adhesion is used to describe physical bonding between adjacent materials. Occasionally this type of bonding may be referred to as a “chemical connection”. This is in fact incorrect as bonding between thermoplastics and TPE definitely does not occur via chemical reactions.

Adhesion is caused by intermolecular attraction (Van der Waals forces) and by molecular entanglement (interdiffusion).

- Van der Waals forces: attraction forces due to molecular interactions
- Interdiffusion: mechanical, intermolecular entanglement of macromolecules driven by thermal energy. Sections of neighbouring macromolecules penetrate into each other, forming a mechanical connection.

A brief overview of THERMOLAST® bonding to a wide variety of thermoplastics is given in “Table Comoulding Systems” on page 34.

6. Machinery for Coinjection Moulding

In general the information given before in this text in the section 1. Processing Machinery on page 18 applies also to coinjection.

Various options are available in fabrication of coinjected compositeparts as described below:

Maschine(s)	Possible moulds	Process	Result
Coinjection moulding machine (with two injection units)	Coinjection pusher mould Coinjection rotary table mould Coinjection index plate	First material is injected, followed immediately by the other	Ideal conditions for excellent adhesion
Transfer process using two injection moulding machines	Two moulds with different cavities	Semi-finished part is transferred into the 2nd mould/injection moulding machine (by robot or by hand)	Good adhesion to certain thermoplastics (see „Comoulding Systems“)
Transfer process using one injection moulding machine (insert moulding)	Two moulds with different cavities	Intermediate storage of semi-finished part, mould is changed, 2nd material is injected	Good adhesion to certain thermoplastics (see „Comoulding Systems“)

THERMOLAST® in Injection Moulding

Special Information on Coinjection Moulding

Hard/soft combinations using THERMOLAST® can be produced using all configurations of machinery and possible moulds as mentioned in the table above. The decision about which technique to choose, and which gives the most cost-effective solution, depends on many factors. It will be necessary to take into account, for example, the material that the THERMOLAST® must bond to, contact surface area and flow length, part geometry, number of parts to be produced, and machine availability.

7. Adhesion Testing of Coinjected Systems

Important notes concerning the table “Comoulding Systems” on page 34:

Evaluation of adhesion quality is normally highly subjective. As a uniform test procedure for adhesion evaluation has not yet been established, comparison of different materials by test data alone is often unreliable.

Evaluation of THERMOLAST® coinjected parts is best done by comparative testing using our in-house test procedure based on the Renault D41 1916 Standard.
The experimental set-up shown on the following page shows how a tensile testing machine is used to measure peel force (units: N/mm) as a function of upper clamp displacement („peel path“). Displacement prior to peeling is due to the inherent elasticity of the TPE material. This test method is a highly useful tool in optimization of adhesion quality in THERMOLAST® coinjected articles.

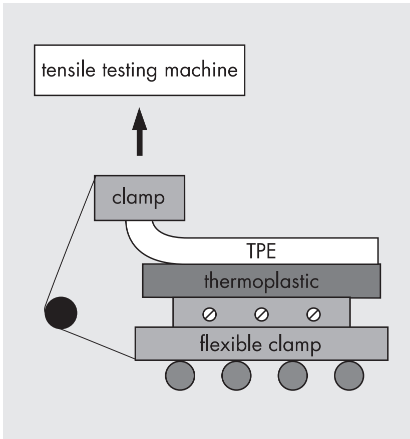
Test piece dimensions:

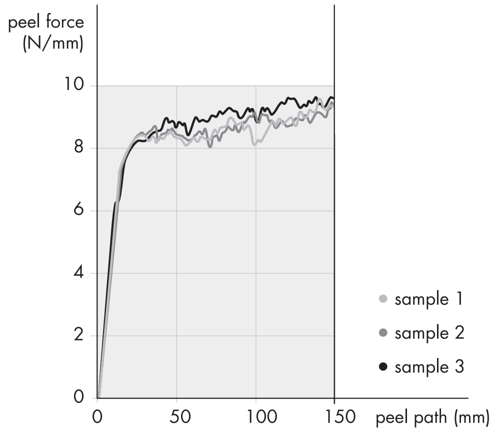
Thermoplastic part:	130 x 22 x 2 mm (5.118 x 0.866 x 0.079 in.)
TPE part:	130 x 20 x 2 mm (5.118 x 0.787 x 0.079 in.)

Peel Test According to Renault D41 1916 Standard

test setup

adhesion to thermoplastics





On request we will be happy to provide coinjected sample plaques made with materials you wish to evaluate.

A number of factors can significantly influence THERMOLAST® adhesion results including the manufacturing process and process parameters used, part geometry and composition of the hard material. We therefore strongly recommend tests under the actual conditions prevailing in the application.
Please also note that the final adhesion quality is only achieved after a storage period of approximately 24 h.

Our application engineering department can provide advice on design, material selection and tests.

THERMOLAST® in Injection Moulding

Special Information on Coinjection Moulding

Materials are available from our standard compound series providing adhesion to the following thermoplastics:

THERMOPLAST	Adhesion quality in Coinjection Moulding with THERMOLAST®	Transfer Processes Providing Good Adhesion Results	
ABS	≥ 30 Shore A		•
ABS/PC	≥ 30 Shore A		
PC	≥ 30 Shore A		
PC/PBT	≥ 30 Shore A		
PETG	≥ 30 Shore A		
PMMA	≥ 50 Shore A		
PBT	≥ 30 Shore A		•
PP	≥ 0 Shore A		
PE	≥ 49 Shore A		
PA6	≥ 25 Shore A		
Pa6.6	≥ 25 Shore A		
PA 12	≥ 25 Shore A		
POM (Copolymere from Ticona)	≥ 47 Shore A		
PS	≥ 50 Shore A		•
HIPS	≥ 50 Shore A		•
SAN	≥ 50 Shore A		
ASA	≥ 50 Shore A		

Description of adhesion quality

Very good adhesion, separation in cohesive mode	
Good adhesion, separation in adhesive mode, TPE is difficult to pull off	

Good results possible in robotic or manual transfer processes (insert moulding) without intermediate storage		
Good results possible in transfer processes (insert moulding) with intermediate storage		
Preheating of semi-finished part recommended		•

Table Comoulding Systems

Application problems requiring adhesion to other thermoplastics, e.g. PET, PC/PET, PPO/PS, CAP, CAB etc., are often best solved by custom-engineered compounds. Please contact us for more information.

8. Processing Information for Coinjection Moulding

The points given below presume use of the normal injection sequence, i.e. injection of the hard component in the first process step, followed by THERMOLAST® in the second step.
The following information and procedures are normally beneficial for optimum adhesion:

- Always use the processing temperatures for adhesive compounds given at www.kraiburg-tpe.com.
- Inject the THERMOLAST® compound processed initially at a medium rate and then increase the rate as required for optimum part quality.
- Use the correct tooling temperature as required by the thermoplastic processed and the wall thickness of the article moulded.
- In general do not use hold pressure as it can cause material displacement at the bond interface, i.e. destruction of adhesion achieved immediately in coinjection.
- Do not use any demoulding aids such as lubricants, etc.
- Increase the surface area of the bonding surface (e.g. by spark erosion treatment).
- Improved results may be achieved if the two materials are injected into the mould from opposite directions.

Further advice can be found in our Injection Moulding Trouble Shooter on page 38.

Special points with regard to transfer processes:
- The surfaces of the semi-finished part moulded onto must be absolutely free of grease and dust (machine operators should wear gloves if necessary).
- Semi-finished parts which are processed after intermediate storage normally should be preheated prior to encapsulation or coating with THERMOLAST®. The preheating process should last for only a short period of time (very important especially in the case of semi-crystalline thermoplastics) and should heat the surface of the part only (use e.g. IR heating, surface temperature attained should be approx. 80 °C - 100 °C).

Please note our recommendations on the previous page contained in the right column of the “Table Comoulding Systems” (Transfer Processes Providing Good Adhesion Results).

Special points with regard to shrinkage:

In the case of hard/soft parts, the shrinkage is generally impeded due to adhesion to the pre-injected part, i.e. the shrinkage values of the hard material play a determining role. Therefore, it is important that the stability of the hard preinjected part is sufficient. Through the injection of the soft component, internal stress that was built up in the pre-injected part would cause warpage of the finished part. Integrating reinforcements (reinforcing ribs) into the hard part may be necessary, especially in the case of very thin-walled parts and/or extensive coverage with TPE.
Please note that shrinkage will vary depending on the particular compound processed. Your KRAIBURG TPE representative will be happy to provide more information relating to your specific application.

THERMOLAST® in Injection Moulding

Trouble Shooter Injection Moulding

Problem	Possible Causes	Possible Solutions
Incomplete fill	Air entrapment due to insufficient venting	1. Check for obstruction of vents. 2. Check vent locations. 3. Enlarge vents. 4. Change filling behaviour by reducing or increasing injection rate and / or pressure. 5. Add vacuum assist to vents.
	Runner system	1. Check for obstruction of gate. 2. Enlarge gate. 3. Enlarge runners.
	Melt and / or mould too cold	1. Increase barrel and nozzle temperatures. 2. Increase mould temperature. 3. Increase injection rate. 4. Increase screw speed.
Sink marks (not to be confused with air entrapment)	Hold pressure too low	1. Increase holding pressure.
	Melt and / or mould too hot	1. Reduce barrel and nozzle temperatures. 2. Reduce mould temperature. 3. Reduce screw speed.
Charring	Melt and / or mould too hot	1. Reduce barrel and nozzle temperatures. 2. Reduce mould temperature. 3. Reduce screw speed.
	Heater(s) stuck on	1. Check thermocouples and heater bands.
Odour or yellowing	Melt and / or mould too hot	1. Reduce barrel and nozzle temperatures. 2. Reduce mould temperature. 3. Reduce injection rate. 4. Reduce screw speed and back pressure. 5. Check temperature of hot runners (if used).
Flashing	Injection pressure / rate too high	1. Reduce injection pressure / rate. 2. Increase clamp pressure. 3. Reduce injection rate.
	Melt and / or mould too hot	1. Reduce barrel and nozzle temperatures. 2. Reduce mould temperature. 3. Reduce screw speed.

Problem	Possible Causes	Possible Solutions
Part distortion	Too much orientation	1. Increase melt and mould temperature. 2. Reduce injection rate.
	Part is over-packed	1. Reduce back pressure. 2. Match injection time to mould fill time.
	Uneven mould fill	1. Change gate locations. 2. Ensure uniform mould temperature. 3. Increase injection rate and back pressure.
Black specks or undispersed particles	Contamination	1. Purge with high-MFI PP or HDPE. 2. Check that colour concentrate is based on PP or PE, **not** PVC.
Sticking in mould	Part is too hot	1. Reduce barrel and nozzle temperatures. 2. Reduce mould temperature. 3. Increase cooling time.
	Part is over-packed	1. Reduce shot weight and find correct fill point.
	Mould design	1. Increase draft angles. 2. Use non-stick surface treatment. 3. If necessary, erode mould.
Clump formation at gate	Moisture	1. Dry pellets. 2. If using vented screw, check for obstruction of vent. 3. Add vacuum assist to vents.
Flow lines	Melt and / or mould too cold	1. Increase barrel and nozzle temperatures. 2. Increase melt and / or mould temperature. 3. Increase injection rate. 4. Increase screw speed and back pressure. 5. Check suitability of screw.
	Mould design	1. Change gate location. 2. Enlarge gates. 3. Enlarge runners. 4. Add additional flow-restricting zones (e.g. sprue pullers) to runners.
Voids (not to be confused with air entrapment)	Melt freezes too quickly	1. Increase mould temperature. 2. Increase screw speed and back pressure.
	Moisture	1. Dry pellets. 2. If using vented screw, check for obstruction of vent. 3. Add vacuum assist to vents.
	Back pressure too low	1. Increase back pressure.

THERMOLAST® in Injection Moulding

Trouble Shooter Injection Moulding

Problem	Possible Causes	Possible Solutions
Poor or no adhesion in coinjection at the beginning / in the middle of the melt flow path	Hold pressure too high (displacement of cooled materials at bond interface)	1. Reduce hold pressure.
	Injection rate too low	1. Increase injection rate.
Poor or no adhesion in coinjection at the end of the melt flow path	Processing / mould temperatures too low	1. Increase Processing / mould temperatures.
	Injection rate too low	1. Increase injection rate.
	In transfer processes, (insert moulding) semifinished part is too cold	1. Preheat part (caution: heat surface only to approx. 80 °C – 100 °C (175 °F – 210 °F). The preheating process should last for only a short period of time; very important when hard component is semicrystalline.
	Insufficient venting	1. Reduce clamping force. 2. Reduce injection rate. 3. Add ejector bore. 4. Add venting system.
Poor or no adhesion in coinjection in general	Inappropriate material combination	1. Check the material compatibility.
	In transfer processes, (insert moulding) semifinished part is not free of grease and dust.	1. Clean semi-finished part (use gloves if necessary).

1. Machines and Processing

Machine specifications:

Standard injection moulding machine

Compression ratio:	at least 2:1
L/D ratio:	at least 20

Purging materials:

PP

Process parameters:

Melt temperature: Mould temperature: Injection pressure: Injection rate:	please refer to processing instructions at www.kraiburg-tpe.com
Back pressure:	20 – 50 bar (285 – 710 psi)
Screw speed:	25 – 75 rpm
Hold pressure:	if possible, none
Hold time:	as short as possible

2. Moulds

Runner system:

Balanced runner system

Gate:	Diameter: 0.4 – 0.6 mm, max. 1.0 mm
Sprue:	Standard, draft angle min. 1.5°, For hardnesses < 70 Shore A, min. 2.5°
Runners:	Semi-circular, trapezoidal shapes possible best shape: round
Gate types:	Pin gate, submarine gate, film gate
Venting:	0.01 – 0.02 mm (0.0004 – 0.001 in.) vent channels
Mould surface:	See page 27, Section 9. Mould Surface and Demoulding
Shrinkage:	See page 28, Section 10. Shrinkage

3. SPECIALS POINTS IN COINJECTION MOULDING
See information provided in “Special Information on Coinjection Moulding”, starting on page 29.

THERMOLAST® in Extrusion

Machines and Processing

1. Machine Specifications

Extrusion of THERMOLAST® compounds normally does not require use of special extruders. Standard extruders (e.g. universal or polyolefin extruders) designed for conventional plastics can be used to process THERMOLAST® compounds in most cases. Some restrictions apply to PVC extruders. Please contact us for futher information.

2. Cleaning of Machines

Before processing THERMOLAST® compounds, urge the extruder with polyethylene or polypropylene. Purge particularly thoroughly if the material run beforehand was PVC.

If another material is to be processed afterwards, run system until empty and purge again with PE or PP.

3. Screws, Screens, Breaker Plate

Experience has shown that 3-zone screws are best suited for processing THERMOLAST® compounds. The screw length should be at least 25 D. The compression ratio should be at least 3.5 : 1. The screw must be able to provide sufficient shearing. A breaker plate and a screen pack are normally recommended in the extruder configuration in order to increase pressure.

4. Process Parameters

The following sections 5. - 7. provide information and general recommendations for processing THERMOLAST® compounds. Please keep in mind that your experience with your machines and the particular machine processed should always be taken into consideration as well. As THERMOLAST® compounds are frequently custom-developed to individual customer requirements, differences in processing can result.

Our applications engineers will be happy to provide any advice you may require and to come to your plant upon request to observe processing of sample materials.

5. Process Temperatures

Typical extrusion process parameters for THERMOLAST® are as follows:

Feed zone:	140 – 160 °C (285 – 320 °F)
Compression zone:	150 – 170 °C (300 – 340 °F)
Metering zone:	160 – 180 °C (320 – 355 °F)
Extruder head:	170 – 180 °C (340 – 355 °F)
Die:	180 – 220 °C (355 – 425 °F)

The maximum processing temperature should not exceed 250 °C (480 °F). Higher process temperatures or excessive residence times in the processing unit can result in thermal degradation.
Recommended process temperatures for THERMOLAST® compounds can be found at www.kraiburgtpe.com.

6. Die Temperature

The die temperature should normally be 185 °C (355 °F). More information can be found at www.kraiburg-tpe.com. Our applications engineering department will also be pleased to provide you further information upon request.

7. Calibration

Calibration is normally not required. Support elements may be required when extruding THERMOLAST® compounds with high hardness or when coextruding with standard thermoplastics.

Dies

1. Extrusion Dies

Simple matrix dies will suffice for processing THERMOLAST® compounds in many applications. The die land should be as short as possible, i.e. max. 3 - 4 mm (0.12 - 0.16 in.), particularly if the surfaces of the die are not finely polished.

More elaborate multi-component dies with flow correction capability provide benefits including reduced machine direction shrinkage and reduced profile distortion. They also allow attainment of higher production rates. When extruding hollow profiles, internal air support can be advantageous.

Coextrusion

1. Combination Possibilities

THERMOLAST® compounds can be coextruded with many different kinds of thermoplastics. Compounds are offered in a wide range of hardness ratings and other physical properties for adhesion to:

- PP
- PE
- ABS
- PS
- PC
- rigid PVC

Of course, THERMOLAST® compounds can be coextruded together as well. The wide spectrum of THERMOLAST® extrusion compounds available provides numerous possibilities of combination (hardness, transparency, colour, feel, ...).

THERMOLAST® in Extrusion

Trouble Shooter Extrusion

Problem	Possible Causes	Possible Solutions
Rough extrudate	Melt too cold	1. Increase extruder temperature. 2. Increase die temperature.
	Inhomogeneous melt / undispersed particles	1. Use screw with higher compression ratio or screw with mixing zone.
	Poor die design	1. Reduce land length. 2. Check dimensions.
Uneven cross section	Surging	1. Reduce throughput. 2. Use screw with longer feed or metering section. 3. Use more restrictive screen pack – e.g. tighter mesh – to increase back pressure. 4. Reduce die temperature.
Black specks / Undispersed particles	Contamination	1. Purge with high-MFI PP or HDPE. 2. Check that colour concentrate is based on PP or PE - not PVC.
Odour or yellowing	Melt too hot	1. Reduce barrel temperature. 2. Reduce die temperature. 3. Reduce screw speed. 4. Use less restrictive screen pack – e.g. larger mesh – to reduce back pressure. 5. Use screw with lower compression ratio.
Voids, porosity, craters	Moisture	1. Dry pellets.
High pressure / low throughput in extruder	Melt too cold	1. Increase extruder temperature. 2. Increase die temperature.
	Obstructed screens	1. Clean or replace screens.

THERMOLAST® in Extrusion

Summary Extrusion

1. Machines and Processing

Machine specifications:

Universal or polyolefin extruders with 3 screw zones

Compression ratio:	min. 3.5 : 1
L/D ratio:	min. 25

Purging materials:

PE or PP

2. Process Temperatures:

Feed zone:	140 – 160 °C (285 – 320 °F)
Compression zone:	150 – 170 °C (300 – 340 °F)
Metering zone:	160 – 180 °C (320 – 355 °F)
Extruder head:	170 – 180 °C (340 – 355 °F)
Die:	180 – 220 °C (355 – 425 °F)

3. Dies

Simple matrix die is sufficient in most cases

Die land: max. 3 – 4 mm (0.12 – 0.16 in.)

Die temperature

185 °C (355 °F)

Other Processing Methods

THERMOLAST K Melt Compounds

1. THERMOLAST® K Melt Compounds

THERMOLAST® K Melt compounds feature extremely low melt viscosity. The main advantage provided by these compounds is their processability without need for shearing, i.e. their extremely low melt viscosity at the specified processing (melt) temperature permits casting, spraying or other coating procedures on surfaces.

THERMOLAST® K Melt compounds can be held at their specified processing temperature for up to a day without substantially reducing viscosity.

2. Supply Mode

THERMOLAST® K Melt compounds are supplied as pellets. Please note that these compounds are TPE and they should not be mistaken for hotmelt adhesives.

3. Possible Application Sectors

The pressure-free processability of THERMOLAST® K Melt compounds makes them ideal for coating of textiles, cardboard etc. – for instance in removable protective coatings.

Further information regarding application sectors, advantages and processing recommendations for THERMOLAST® K Melt compounds can be obtained from us or at www.kraiburg-tpe.com.

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References

Figures 2, 5, 6 and 7
(s. THERMOLAST® in Injection Moulding/Moulds) are based on „Spritzgieß-Werkzeuge"
(5. issue, 1999), edited by Menges, Michaeli and Mohren, published by Carl Hanser Verlag (S. 161, 165 and 166)

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