FR-1025, brominated polyacrylate (see properties in Figure 1), is a proprietary polymeric flame retardant offered by ICL-IP and is particularly suitable for use with PBT, with or without fiber reinforcement. FR-1025 exhibits inherent advantages over other halogenated FR additives currently used for the same applications, as a result of its polymeric nature, high bromine content and excellent thermal stability. In addition, the processability of polymers containing FR-1025 is very good.

**Figure 1: Chemical structure and Properties of FR-1025**

(Brominated polyacrylate)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromine content, w %</td>
<td>71</td>
</tr>
<tr>
<td>Melting range, °C</td>
<td>190-220</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.5</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>~ 600,000</td>
</tr>
</tbody>
</table>

Visit us at [http://www.iclfr.com](http://www.iclfr.com)
The use of **FR-1025** is advantageous when the following properties are required:

- effective flame retardancy
- non-blooming
- good temperature stability and outstanding long term heat–aging stability
- easy processability and high melt flow properties for production of thin wall and/or large dimensions parts with short injection molding cycles and high precision.
- excellent compatibility with fiber reinforcement and polymer matrix
- excellent impact properties
- not solvent extractable
- chemical resistance
- good electrical properties
- enhancement of reuse of scrap plastic generated by injection molding operations.

### Thermal stability

Thermogravimetric analysis of **FR-1025** (Table 1) reflects its high thermal stability allowing high processing temperatures typical for PBT. Its thermal stability combined with excellent resistance to hydrolysis, makes it the product of choice when recycling is an issue.

<table>
<thead>
<tr>
<th>Table 1: Thermogravimetric analysis (TGA-10°C/min in air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight loss, %</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
</tbody>
</table>

### Processing conditions and Properties

**FR-1025** functions as a processing-aid enabling lower temperatures to be used and has been shown to be easy to compound with most engineering polymers with or without

Visit us at [http://www.iclfr.com](http://www.iclfr.com)

All information concerning this product and/or suggestions for handling and use contained herein are offered in good faith and are believed to be reliable as of the date of publication. However, no warranty is made as to the accuracy of and/or sufficiency of such information and/or suggestions as to the merchantability or fitness of the product for any particular purpose, or that any suggested use will not infringe any patent. Nothing herein shall be construed as granting or extending any license under any patent. Buyer must determine for itself, by preliminary tests or otherwise, the suitability of this product for its purposes, including mixing this product with other products. The information contained herein supersedes all previously issued bulletins on the subject matter covered.
reinforcement. Thanks to its processing aid effect, there is no need to process compounds containing **FR-1025** at a temperature higher than 280°C but its thermal stability allows processing temperatures up to a maximum of 290°C. Typical processing conditions to compound and mold PBT flame retarded with **FR-1025** are as follow:

**Compounding**

Compounding in a co-rotating twin-screw extruder (L/D = 32)


Screw speed, Rpm: 275

**Injection molding**

<table>
<thead>
<tr>
<th>Temperature profile, °C</th>
<th>250-260-260-275-280</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold temperature, °C</td>
<td>100 – 120</td>
</tr>
<tr>
<td>Pressures, Bar</td>
<td>Injection: 1200 - Holding: 800 - Back: 20</td>
</tr>
<tr>
<td>Cycle time, sec</td>
<td>30</td>
</tr>
</tbody>
</table>

**Properties**

Tables 2, 3 and 4 provide indicative formulations and properties achievable in non- and glass-reinforced PBT.

- **Processing-aid**

The processing-aid effect of **FR-1025** is of particular interest in glass reinforced PBT as it is beneficial at each processing steps:

1. Energy savings during compounding as one can see from the comparative values of specific energy consumptions (SEC) shown in Figure 2.
Fig. 2: Specific Energy Consumption (SEC) in 30% glass reinforced PBT

Fig. 3: Pressure during injection molding (30% glass reinforced PBT)

2. Lower pressure during injection molding as one can see in Figure 3.

3. When processed in its softening range, FR-1025 contributes to significant improvement in melt flow properties during injection molding. Enhanced flow is an especially important feature for electronic devices made of glass-reinforced PBT and often designed with thin wall dimensions and complicated shapes.
FR efficiency

The unique combination in FR-1025 of 70% aromatic bromine and an acrylic moiety, provides good flame retardant efficiency and very good thermal stability. Figure 4 shows comparative UL 94 V testing where total burning times in non-reinforced PBT are significantly lower with FR-1025.

In order to get class V-0 with a minimum content of FR-1025, it is recommended to add small quantities of polytetrafluoroethylene (PTFE) to eliminate the risk of dripping. Taking this into account, minimal FR-1025 loadings enabling class V-0 (0.8mm) in non- and glass-reinforced PBT are indicated in Table 2.

PTFE is preferably added in the compound via a masterbatch concentrate to ensure a homogeneous blend.

![Figure 4: Flame retardancy in non reinforced PBT (UL 94 - 0.8 mm)](image-url)

All information concerning this product and/or suggestions for handling and use contained herein are offered in good faith and are believed to be reliable as of the date of publication. However, no warranty is made as to the accuracy of and/or sufficiency of such information and/or suggestions as to the merchantability or fitness of the product for any particular purpose, or that any suggested use will not infringe any patent. Nothing herein shall be construed as granting or extending any license under any patent. Buyer must determine for itself, by preliminary tests or otherwise, the suitability of this product for its purposes, including mixing this product with other products. The information contained herein supersedes all previously issued bulletins on the subject matter covered.
Table 2: Minimal FR-1025 loadings in non- and glass-reinforced PBT for UL 94 V-0 at 0.8mm

<table>
<thead>
<tr>
<th>Type</th>
<th>PBT Non reinforced</th>
<th>PBT Glass reinforced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition, weight %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PBT</td>
<td>88.0</td>
<td>55.9</td>
</tr>
<tr>
<td>Glass fiber</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>FR-1025</td>
<td>7.9</td>
<td>9.3</td>
</tr>
<tr>
<td>Antimony trioxide</td>
<td>3.9</td>
<td>4.7</td>
</tr>
<tr>
<td>PTFE (antidripping agent)</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>UL 94 class (0.8 mm)</td>
<td>V-0</td>
<td>V-0</td>
</tr>
</tbody>
</table>

- High melt flow during injection molding

The softening range of FR-1025, between 190°C and 220°C, is lower than that of PBT, leading to good mixing of the melt. Use of FR-1025 enhances flow during injection molding. The comparative values of MFI of various flame retarded PBT shown in Figure 5 explains in part the productive effect FR-1025 has in cutting cycle times and lowering walls thickness of produced articles.

![Figure 5: Melt Flow Properties in FR PBT with 30% glass reinforcement (UL 94 V-0; 0.8mm)](http://www.iclfr.com)

* High MW BE = high molecular weight brominated epoxy polymer
* Br PC = brominated polycarbonate
* Modified Br PC = tribromophenol end-capped brominated polycarbonate

Visit us at [http://www.iclfr.com](http://www.iclfr.com)

All information concerning this product and/or suggestions for handling and use contained herein are offered in good faith and are believed to be reliable as of the date of publication. However, no warranty is made as to the accuracy of and/or sufficiency of such information and/or suggestions as to the merchantability or fitness of the product for any particular purpose, or that any suggested use will not infringe any patent. Nothing herein shall be construed as granting or extending any license under any patent. Buyer must determine for itself, by preliminary tests or otherwise, the suitability of this product for its purposes, including mixing this product with other products. The information contained herein supersedes all previously issued bulletins on the subject matter covered.
Good impact properties

**FR-1025** is also the flame retardant of choice when good impact properties are needed. High Izod notched impact values are achievable with glass reinforced PBT as can be seen in Tables 3 and 4. Figure 6 shows the contribution of **FR-1025** to high impact properties in PBT when compared with other commonly used FRs.

Compatibilizer between glass fiber reinforcement and PBT matrix

**FR-1025** being a brominated polyacrylate acts as an excellent compatibilizer between the glass reinforcement and the PBT matrix. Electroscan pictures of surface fractures shown in Figure 7 show very well the adhesion enhancement of the PBT matrix to the glass fibers obtained by addition of **FR-1025**.

Figure 6: Izod notched impact in FR PBT

![Impact Chart](chart.png)

- Neat
- FR-1025
- *Modified Br PC
- *Br PS
- *High MW BE

* High MW BE = high molecular weight brominated epoxy polymer

* Br PS = brominated polystyrene

* Modified Br PC = tribromophenol end-capped brominated polycarbonate

Visit us at [http://www.iclfr.com](http://www.iclfr.com)

All information concerning this product and/or suggestions for handling and use contained herein are offered in good faith and are believed to be reliable as of the date of publication. However, no warranty is made as to the accuracy of and/or sufficiency of such information and/or suggestions as to the merchantability or fitness of the product for any particular purpose, or that any suggested use will not infringe any patent. Nothing herein shall be construed as granting or extending any license under any patent. Buyer must determine for itself, by preliminary tests or otherwise, the suitability of this product for its purposes, including mixing this product with other products. The information contained herein supersedes all previously issued bulletins on the subject matter covered.
Figure 7: Electroscan of fractures of glass reinforced PBT

Reference PBT not flame retarded

PBT Flame retarded by FR-1025

PBT Flame retarded by FR-1025 (enlargement)

Another clear indication of the coupling effect of FR-1025 is improvement of mechanical properties in glass reinforced PBT with increased loadings of FR-1025 (Table 3).
Table 3: Properties of glass reinforced PBT flame retarded by FR-1025
Influence of FR-1025 loading

<table>
<thead>
<tr>
<th>Composition, weight %</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PBT</td>
<td>54.9</td>
<td>48.9</td>
</tr>
<tr>
<td>Glass fiber</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>FR-1025</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>Antimony trioxide</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>PTFE (antidripping agent)</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Bromine content %</td>
<td>7</td>
<td>9.7</td>
</tr>
</tbody>
</table>

**Properties**

**Flame retardancy:**
- UL 94 class (0.8 mm): V-0, V-0
- LOI, %: 32, 38

**Tensile:**
- Maximum strength, Mpa: 118, 139
- Elongation at break, %: 2.4, 2.4
- Modulus, Mpa: 10,600, 12,000
- IZOD notched impact, J/m: 106, 119
- HDT (1820 kPa), °C: 205, 206

The good compatibility between FR-1025 and PBT might cause a delay in the onset of the PBT crystallization during cooling and it can consequently increase the cycle time during injection molding. It is recommended to add some ultra fine talc that will act as a nucleating agent and enable the crystallization to start at a significantly higher temperature. Figure 8 indicates how increasing loading of ultrafine talc (for instance Ultra talc 609 – Barrets Minerals) influence the crystallization start in a 25% glass reinforced PBT measured by DSC.
Figure 8: Crystallization temperature of PBT (25% glass reinforced) - DSC

Table 4: Properties of non- and glass reinforced PBT flame retarded by FR-1025.

<table>
<thead>
<tr>
<th>Composition, weight %</th>
<th>Type</th>
<th>Non reinforced</th>
<th>10% glass reinforced</th>
<th>25% glass reinforced</th>
<th>30% glass reinforced</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBT</td>
<td></td>
<td>84.8</td>
<td>74.9</td>
<td>59.9</td>
<td>54.9</td>
</tr>
<tr>
<td>Glass fiber</td>
<td></td>
<td>0</td>
<td>10</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>FR-1025</td>
<td></td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Antimony trioxide</td>
<td></td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>PTFE (antidripping agent)</td>
<td></td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Bromine content %</td>
<td></td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

Properties

Flame retardancy:
- UL 94 class (0.8mm): V-0, V-0, V-0, V-0
- Glow wire test, 960°C: Pass, Pass, Pass, Pass
- MFI (250°C-2.16Kg), g/10min: 30, 25, 24, 22

Tensile:
- Maximum strength, MPa: 55, 84, 104, 118
- Elongation at break, %: 35, 3.6, 2.9, 2.4
- Modulus, MPa: 3500, 4900, 8500, 10,600
- IZOD notched impact, J/m: 35, 60, 88, 106
- HDT (1820 kPa), °C: 82, 198, 200, 205
- CTI (Comparative tracking index): 250, 250, 300, 300

Visit us at http://www.iclfr.com

All information concerning this product and/or suggestions for handling and use contained herein are offered in good faith and are believed to be reliable as of the date of publication. However, no warranty is made as to the accuracy of and/or sufficiency of such information and/or suggestions as to the merchantability or fitness of the product for any particular purpose, or that any suggested use will not infringe any patent. Nothing herein shall be construed as granting or extending any license under any patent. Buyer must determine for itself, by preliminary tests or otherwise, the suitability of this product for its purposes, including mixing this product with other products. The information contained herein supersedes all previously issued bulletins on the subject matter covered.
Thermal aging and thermal and light color stability

Thermal aging properties of flame retarded PBT play an important role in simulating long term behavior of finished parts with high working temperatures.

In this respect, **FR-1025** exhibits inherent advantages over other halogenated FR additives currently offered for the same applications as a result of its polymeric nature and excellent thermal stability. After a 1000h thermal aging treatment at 190°C of glass reinforced PBT flame retarded by **FR-1025**, tensile properties are maintained above 50% of their initial value while non flame retarded PBT would fail during this test (Figure 9).

![Figure 9: Thermal Aging at 190°C](image)

Another interesting feature of **FR-1025** is its good thermal color stability under light exposure. Comparative testing at various temperatures shows that glass reinforced PBT flame retarded with **FR-1025** has significantly better color stability at high temperatures than with high molecular weight brominated epoxy (High MW BE) (Figure 10).

Visit us at [http://www.iclfr.com](http://www.iclfr.com)

All information concerning this product and/or suggestions for handling and use contained herein are offered in good faith and are believed to be reliable as of the date of publication. However, no warranty is made as to the accuracy of and/or sufficiency of such information and/or suggestions as to the merchantability or fitness of the product for any particular purpose, or that any suggested use will not infringe any patent. Nothing herein shall be construed as granting or extending any license under any patent. Buyer must determine for itself, by preliminary tests or otherwise, the suitability of this product for its purposes, including mixing this product with other products. The information contained herein supersedes all previously issued bulletins on the subject matter covered.
Figure 10: DE Color thermal stability under halogen light exposure of 5% GFR PBT V-0 (0.8mm)
(ASTM D-2244-79)

Recycling

Recycling studies with scrap from non- and glass-reinforced PBT flame retarded by FR-1025 (UL 94 class V-0 1.6 mm) have shown that a loading of 50% scrap in virgin compound can undergo five recycling steps without losing its flame retardancy and with no significant change in properties.

Moreover the results of the analyses performed by Institut Fresenius Chemische und Biologische Laboratorien GmbH on these samples for presence of polybrominated dibenzo-para-dioxins/dibenzofurans (PBDD/PBDF), have shown them to be in full compliance with the requirements of the global most strict criteria of the German Dioxin Ordinance1.

Health – Safety - Environmental aspects

FR-1025 is designed and developed to be safe and environmentally friendly in usage and environmentally friendly in end of life products, including recycling or waste incineration.

1 Further information available upon request

Visit us at http://www.iclfr.com

All information concerning this product and/or suggestions for handling and use contained herein are offered in good faith and are believed to be reliable as of the date of publication. However, no warranty is made as to the accuracy of and/or sufficiency of such information and/or suggestions as to the merchantability or fitness of the product for any particular purpose, or that any suggested use will not infringe any patent. Nothing herein shall be construed as granting or extending any license under any patent. Buyer must determine for itself, by preliminary tests or otherwise, the suitability of this product for its purposes, including mixing this product with other products. The information contained herein supersedes all previously issued bulletins on the subject matter covered.
**FR-1025** has undergone extensive toxicological and environmental testing\(^2\), and has been proven to pose no risk to health and the environment. The results of the analyses performed by Institut Fresenius Chemische und Biologische Laboratorien GmbH on **FR-1025** itself and under conditions simulating a modern municipal solid waste incinerator for presence of polybrominated dibenzo-para-dioxins/dibenzofurans (PBDD/PBDF), have shown it to be in full compliance with the requirements of the global most strict criteria of the German Dioxin Ordinance and EPA TSCA 40 §766.27 Final Rule requirements\(^1\).

As part of an ongoing Product Stewardship Program and Customer oriented policy, ICL-IP is committed to implement further toxicological and environmental tests if needed.

- **Applications**

As a result of its outstanding combination of properties, **FR-1025** is recognized as ideally suited for the production of PBT electro-mechanical/electronic parts, automobile and other precision parts. Typical examples of application are shown in Figures 11 to 15: connectors in the computer, telecom and automotive industries, high quality keyboards, mini-fans inside computers and laptops.

In these applications, **FR-1025** exhibits its inherent advantages over other products, with its processing aid effect for thin injection molding, good light/thermal stability, good impact and good electrical properties (high comparative tracking index) and excellent dimensional stability even for large dimension parts. It is often preferred over other flame-retardants if good chemical resistance and non-blooming properties are needed for applications in a wide range of hostile environments. **FR-1025** also permits processing compounds with 50% regrind without compromising thermomechanical properties of the finished molded parts.

\(^2\) Further information available upon request.

---

All information concerning this product and/or suggestions for handling and use contained herein are offered in good faith and are believed to be reliable as of the date of publication. However, no warranty is made as to the accuracy of and/or sufficiency of such information and/or suggestions as to the merchantability or fitness of the product for any particular purpose, or that any suggested use will not infringe any patent. Nothing herein shall be construed as granting or extending any license under any patent. Buyer must determine for itself, by preliminary tests or otherwise, the suitability of this product for its purposes, including mixing this product with other products. The information contained herein supersedes all previously issued bulletins on the subject matter covered.
All information concerning this product and/or suggestions for handling and use contained herein are offered in good faith and are believed to be reliable as of the date of publication. However, no warranty is made as to the accuracy of and/or sufficiency of such information and/or suggestions as to the merchantability or fitness of the product for any particular purpose, or that any suggested use will not infringe any patent. Nothing herein shall be construed as granting or extending any license under any patent. Buyer must determine for itself, by preliminary tests or otherwise, the suitability of this product for its purposes, including mixing this product with other products. The information contained herein supersedes all previously issued bulletins on the subject matter covered.
All information concerning this product and/or suggestions for handling and use contained herein are offered in good faith and are believed to be reliable as of the date of publication. However, no warranty is made as to the accuracy of and/or sufficiency of such information and/or suggestions as to the merchantability or fitness of the product for any particular purpose, or that any suggested use will not infringe any patent. Nothing herein shall be construed as granting or extending any license under any patent. Buyer must determine for itself, by preliminary tests or otherwise, the suitability of this product for its purposes, including mixing this product with other products. The information contained herein supersedes all previously issued bulletins on the subject matter covered.