**F-3100**

Proprietary polymeric fire retardant

**Application Data Sheet for Polybutylene terephthalate (PBT)**

**F-3100**, (see properties in Table 1), is a proprietary polymeric flame retardant (FR) offered by ICL-IP which is particularly suitable for use with PBT, with or without fiber reinforcement. **F-3100** exhibits inherent advantages over other halogenated FR additives currently used for the same applications, as a result of its polymeric nature, excellent thermal stability and non-adherence to metal surfaces. In addition, the processability of polymers containing **F-3100** is improved.

**Table 1: Properties of F-3100**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromine content, w %</td>
<td>52-54</td>
</tr>
<tr>
<td>Softening range, °C</td>
<td>180-220</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.9</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>15,000</td>
</tr>
</tbody>
</table>

The use of **F-3100** is advantageous when the following properties are required:

- cost/effective flame retardancy
- non-blooming
- good temperature stability and long term heat–aging stability
- easy processability and high melt flow properties for production of parts with thin walls and/or large dimensions with short injection molding cycles and high precision.
- impact properties
- enhancement of reuse of scrap plastic generated during injection molding operations.
- freedom from metal adhesion during lengthy injection molding operation

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Thermal stability

Thermo-gravimetric analysis of **F-3100** (Table 2) reflects its high thermal stability allowing high processing temperatures typical for PBT. Its thermal stability combined with excellent resistance to hydrolysis, makes it a product of choice when recycling is an issue.

| Table 2: Thermogravimetric analysis (TGA-10°C/min in air) |
|-----------------------------|-----------------------------|
| Weight loss, % | Temperature, °C |
| 2 | 343 |
| 5 | 352 |
| 10 | 358 |

Processing conditions and Properties

**F-3100** 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 reinforcement. Thanks to its processing aid effect, there is no need to process compounds containing **F-3100** at high temperature but its thermal stability allows processing temperatures up to a maximum of 310°C. Typical processing conditions to compound and mold PBT flame retarded with **F-3100** are as follows:

**Compounding**

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


Screw speed, RPM: 275

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Injection molding

Temperature profile, °C  250-260-260-275-280
Mold temperature, °C  100 – 120
Pressures, Bar Injection: 1200 - Holding: 800 - Back: 20
Cycle time, sec  30

Properties

Table 3 provides indicative formulations and properties achievable in glass-reinforced PBT.

- **Processing-aid**

  The processing-aid effect of **F-3100** is of particular interest in glass reinforced PBT as it is beneficial at each processing step:

  1. Energy savings during compounding as one can see from the comparative values of specific energy consumptions (SEC) shown in Figure 1.
  2. Lower pressure during injection molding (see Figure 2).
  3. When processed within its softening range, **F-3100** 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 intricate shapes.
  4. Freedom from metal adhesion during lengthy injection molding operation.
Fig. 1: Specific Energy Consumption (SEC) in 30% glass reinforced PBT

![SEC Graph]

Fig. 2: Pressure during injection molding (30% glass reinforced PBT)

![Pressure Graph]

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FR efficiency

The unique proprietary polymeric structure of **F-3100** provides good flame retardant efficiency and very good thermal stability. In order to get class V-0 with a minimum content of **F-3100**, it is recommended to add small quantities of polytetrafluoroethylene (PTFE) to eliminate the risk of dripping. PTFE is preferably added in the compound via a master-batch concentrate to ensure a homogeneous blend.

High melt flow during injection molding

The softening range of **F-3100**, between 180°C and 220°C, is lower than that of PBT, leading to good mixing of the melt. Use of **F-3100** enhances flow during injection molding. The comparative values of MFI of various flame retarded PBTs shown in Figure 3 explains in part the positive effect **F-3100** has in cutting cycle times and reducing wall thickness of produced articles.

![Fig. 3: Melt Flow Properties in FR PBT with 30% glass reinforcement (UL 94 V-0; 0.8mm)](image)

**F-3100**
**High MW BE**
**Br PC**
**Modified Br PC**
**Neat**

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

*F-3100* contributes to an improvement of impact properties in PBT when compared with other commonly used FRs. Fairly high izod notched impact values are achievable with glass reinforced PBT as can be seen in Table 3.

Thermal aging 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, *F-3100* exhibits good performance as a result of its polymeric nature and excellent thermal stability. After a 1000h thermal aging treatment at 180° C of glass reinforced PBT flame retarded by *F-3100*, tensile properties are maintained above 50% of their initial value (Figure 4).

Recycling

Simulation studies of recycling of PBT compound based on *F-3100* compared to a commercial high MW Br-epoxy have been made. Examination of MFI stability in a flow indexer as a function of time, demonstrates the beneficial phenomenon of increase in MFI, whereas in high MW Br-epoxy there is a definite tendency of MFI decrease, probably indicating some molecular cleavage (Figure 5).
Table 3: Properties of glass reinforced PBT flame retarded by F-3100.

<table>
<thead>
<tr>
<th>FR Type</th>
<th>F-3100</th>
<th>High MW BE*</th>
<th>Modified Br PC*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Composition, weight %</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PBT</td>
<td>50.1</td>
<td>50.1</td>
<td>51.6</td>
</tr>
<tr>
<td>Glass fiber</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Flame retardant</td>
<td>14.4</td>
<td>14.4</td>
<td>12.9</td>
</tr>
<tr>
<td>Antimony trioxide</td>
<td>5.4</td>
<td>5.4</td>
<td>5.4</td>
</tr>
<tr>
<td>PTFE (antidripping agent)</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Bromine content %</td>
<td>7.6</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td><strong>Properties</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flame retardancy:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UL 94 class (0.8mm)</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
</tr>
<tr>
<td>Glow wire test, 960°C</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>MFI (250°C-2.16Kg), g/10min</td>
<td>66</td>
<td>56</td>
<td>38</td>
</tr>
<tr>
<td><strong>Tensile:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum strength, MPa</td>
<td>118</td>
<td>112</td>
<td>121</td>
</tr>
<tr>
<td>Elongation at break, %</td>
<td>2.2</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Modulus, MPa</td>
<td>11,000</td>
<td>9,800</td>
<td>10,400</td>
</tr>
<tr>
<td>IZOD notched impact, J/m</td>
<td>88</td>
<td>83</td>
<td>76</td>
</tr>
<tr>
<td>HDT (1820 kPa), °C</td>
<td>204</td>
<td>202</td>
<td>203</td>
</tr>
</tbody>
</table>

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

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Figure 4: Thermal aging F-3100 in GFR PBT
(180°C - 1000h)

Figure 5: MFI thermal stability 30% GFR PBT

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Health – Safety - Environmental aspects

The proprietary polymeric structure of **F-3100** is designed and developed to be safe and environmentally friendly in usage and in end of life products, including recycling or waste incineration. **F-3100** is not expected to pose any risk to health and the environment. 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, **F-3100** is recommended for the production of PBT electro-mechanical/electronic parts, automotive and other precision parts. Typical examples of application are shown in Figures 7 to 11:

- Connectors in the computer, telecom and automotive industries, high quality keyboards, mini-fans inside computers.

In these applications, **F-3100** exhibits its inherent advantages over other products, with its processing aid effect for thin injection molding, good thermal stability, good impact and good electrical properties and excellent dimensional stability even for large dimension parts.

It is often preferred over other flame-retardants if non-blooming properties are needed.

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For further advice and assistance, contact our representatives in your area:

**Head Office**

**ICL-IP Ltd.**  
Phone: +972 8 6297 608  
Fax: +972 8 6297 846  
E-mail: frinfo@icl-ip.com

**North America and Mexico**  
**ICL-IP America Inc.**  
Phone: +1 877 661 4272  
Fax: +1 314 983 7610  
E-mail: fr.nam@icl-ip.com

**South America**  
**ICL Brasil Ltda**  
Phone: +55 11 2155 4539  
Fax: +55 11 2155 4507  
E-mail: fr.sam@icl-ip.com

**Europe**  
**Main Office**  
**ICL-IP Europe B. V.**  
Phone: +31 20 800 5800  
Fax: +31 20 800 5805  
E-mail: fr.europe@icl-ip.com

**Italy**  
**PM Chemicals Italy**  
Phone: +39 02 204 87225  
Fax: +39 02 204 9449  
E-mail: fr.it@icl-ip.com

**Asia Pacific**

**China**  
**ICL China**  
Phone: +86 21 5386 3322  
Fax: +86 21 5386 3336  
E-mail: fr.china@icl-ip.com

**Japan**  
**ICL-IP Japan Ltd**  
Phone: +81 3 6801 8430  
Fax: +81 3 6801 6970  
E-mail: fr.japan@icl-ip.com

**Asia Pacific**  
**ICL Asia Ltd**  
Phone: +852 28277761  
Fax: +852 2824 1502  
E-mail: fr.asia@icl-ip.com

**Other Parts of the World**  
**ICL-IP Sales Office**  
Phone: +972 8 6297 633  
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E-mail: fr.row@icl-ip.com

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