

State of California
AIR RESOURCES BOARD

Small Off Road Engine Evaporative Emission System Components

Component Executive Order Q-08-001
Cyclics Corporation - Innovative Product

WHEREAS, Pursuant to California Health and Safety Code, sections 39600, 39601 and 43013, the California Air Resources Board (ARB) has established a certification process for evaporative emission system components designed to control gasoline emissions from small off-road engines, as described in title 13 California Code of Regulations (13 CCR), section 2767.1;

WHEREAS, Pursuant to California Health and Safety Code, section 43013, ARB has established criteria and test procedures for determining the compliance of evaporative emission system components with the design requirements in 13 CCR, section 2754;

WHEREAS, Pursuant to 13 CCR, section 2767.1, ARB Executive Officer may issue an Executive Order if he determines that the small off-road engine evaporative emission system component conforms to the applicable performance requirements set forth in 13 CCR, section 2754;

WHEREAS, Pursuant to Health and Safety Code, sections 39515 and 39516, ARB Executive Officer issued Executive Order G-05-008 delegating to the Chief of ARB Monitoring and Laboratory Division (MLD) the authority to certify small off-road engine evaporative system components; and

WHEREAS, On October 25, 2007, Cyclics Corporation submitted an application for certification, attached as Attachment A and incorporated herein, as an innovative product under 13 CCR, section 2767(c) for CBT® material injection molded fuel tanks.

NOW, THEREFORE, I, William V. Loscutoff, Chief of the MLD, find that the Cyclics Corporation CBT® resin produced following the process and material specifications set out in Attachment A constitute an innovative fuel tank pursuant to 13 CCR, section 2767(c). Fuel tanks produced following Cyclics Corporation process and material specifications are hereby deemed equivalent to those tanks listed in 13 CCR, section 2752(a)(5). This finding is based on Cyclics Corporation demonstration that such tanks have a permeation rate substantially lower than 1.5 grams per square meter per day set forth in 13 CCR, section 2754 when tested at a constant temperature of 40 °C pursuant to TP-901 using an approved test fuel of California Phase II Certification Fuel.

IT IS ORDERED AND RESOLVED that no tank permeation data is required to be submitted in the certification process for equipment using the Cyclics Corporation CBT® resin for a rotationally molded fuel tank.

IT IS ORDERED AND RESOLVED that all fuel tanks made from Cyclics Corporation CBT® resin with minimum average barrier thicknesses equal to or greater than the value listed in Table 1 attached hereto and incorporated herein, and with minimum barrier coverage of at least 90 percent of the internal fuel tank surface area due to molding tolerances, are certified for use in small off-road equipment.

Table 1
Specifications for Cyclics Corporation CBT® Fuel Tanks

Minimum Average Barrier Thickness (mm)	Minimum Average Inner CBT® Resin Thickness (mm)
4	1

IT IS FURTHER ORDERED that equipment manufacturers utilizing Cyclics Corporation CBT® resin for fuel tanks shall provide a warranty. The warranty must conform to the requirements of 13 CCR, section 2760.

IT IS FURTHER ORDERED that the certified fuel tank made from Cyclics Corporation CBT® resin shall be installed in accordance with the manufacturer's installation and use instructions. A copy of this Executive Order and fuel tank installation and use instructions shall be provided to manufacturers purchasing Cyclics Corporation CBT® resin for fuel tanks for installation on small off-road engines and equipment introduced into commerce in California.

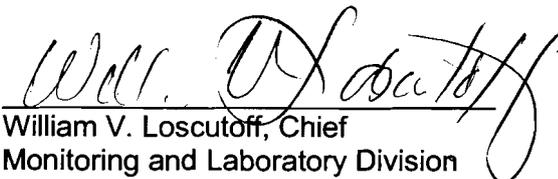
IT IS FURTHER ORDERED that fuel tanks listed in Table 1 shall be clearly identified by a permanent identification that allows ARB to identify manufacturer's name, executive order number, and model number.

IT IS FURTHER ORDERED that any modification of Cyclics Corporation approved process and material specifications for producing a fuel tank made from CBT® resin hereby are prohibited. Any alteration or modification of the process or material specifications set out in Attachment A of this Executive Order will require the manufacturer to apply for a new Executive Order.

IT IS FURTHER ORDERED that fuel tanks made from Cyclics Corporation CBT® resin shall be compatible with fuels in common use in California at the time of certification and any modifications to comply with future California fuel requirements shall be approved in writing by the Executive Officer or Executive Officer's delegate.

IT IS FURTHER ORDERED that the component certification obtained by testing fuel tanks made from CBT® resin submitted by Cyclics Corporation can be referenced in certification applications for small off-road engines and equipment that use small off-road engines unless the Executive Officer finds that fuel tanks made from Cyclics Corporation CBT® resin no longer meets the performance requirements set forth in 13 CCR, section 2754 when tested pursuant to 13 CCR, section 2765.

Executed at Sacramento, California, this 4th day of February, 2008.


William V. Loscutoff, Chief
Monitoring and Laboratory Division

PE-PBT Dual-Layer Fuel Tank System Produced by Rotational Molding: Materials and Process Specifications

Exhibit A:

1.0 Process Specifications – The following material and rotational molding process characteristics are important components of a dual-layer PE-PBT fuel tank to pass the ARB SORE permeation regulations:

- a) The use of Cyclics Corporation rotomolding grade CBT® resins which polymerize to polybutylene terephthalate (PBT) or co-polyesters of PBT during the molding process. The PBT polyester materials possess low fuel permeation characteristics and are designed to form an inner layer within a polyethylene (PE) tank.
- b) Use of rotomolding grades of linear PE (e.g. HDPE, LDPE) that offer adequate compatibility with rotomolding grade CBT resins so as to allow formation and good inner layer coverage of PBT material and to achieve an overall durable fuel tank.
- c) A minimum average layer thickness for the PBT inner layer that substantially covers the inside area of the tank.

1.1 Wall Thickness:

- 1.1.1 **Overall thickness** – The minimum average overall thickness of both layers combined should be 4 mm. This can be measured by dissecting a representative tank and obtaining at least 5 thickness measurements over the part using calipers, micrometer or similar device.
- 1.1.2 **PBT inner layer thickness** – The minimum average inner layer thickness should be 1 mm. This is controlled by the weight of CBT resin introduced to the mold based on the fuel tank surface area according to the following formula:

$$\text{Avg. Inner Layer Thickness (mm)} = \left(\frac{\text{Weight of CBT}^{\text{®}} \text{ Resin (g)}}{1.3 \text{ g/cm}^3 \times \text{Part Surface Area (cm}^2\text{)}} \right) \times 10$$

1.2 Rotomolding Process Parameters:

- 1.2.1 **Method for introducing materials** – Both PE and pre-dried, rotomolding grade CBT resin are weighed and charged into the mold prior to starting the molding process.
- 1.2.2 **Molding process** – The mold is rotated on two axes and typically heated by placing in an oven set at >500°F (>260°C). As the mold temperature increases, the PE material sticks to the mold walls first and sinters to form the outer layer of the fuel tank. CBT resin, in pellet or granular form, will then begin to melt to a low viscosity liquid and polymerize to PBT or co-polyesters of PBT. During polymerization, which takes place at internal mold air temperatures >180°C, the formation of PBT results in an increase in viscosity which coats the inside of PE and forms the fuel permeation barrier layer.
- 1.2.3 **Temperature profile** – The temperature of the mold prior to charging with PE and CBT resin should be <212°F (<100°C). A peak internal air temperature of the molded part is typically allowed to increase to 428-500°F (220-260°C) while in the oven. The mold is removed from the oven and cooled to <212°F (<100°C) for part demolding.

- 1.2.4 **Cooling method** – Either forced air or water spray cooling may be employed to cool the mold and part for demolding.
- 1.2.5 **Inert atmosphere flushing** – The use of a low flow of inert gas (i.e. nitrogen) can be beneficial, but not required, to obtain consistent quality of molded fuel tanks. The inert gas is introduced through a vent opening in the mold at typical rate of 0.5-3.0 scfh for every 1 gallon of tank volume.

1.3 Fuel Tank Performance Criteria: Fuel tanks having a durable structure need to possess the following characteristics:

- 1.3.1 **Inner layer coverage** -- PE and CBT resin are designed to work as a system in a rotational molding process. PE forms the outer layer and CBT resin polymerizes to form PBT or co-polyesters of PBT as an inner barrier layer providing fuel permeation resistance. After demolding, inspection of the PBT inner layer can be performed by visual observation through the fuel tank's vent area opening with the assistance of a light source. The inner layer must appear to have substantial coverage throughout the inside surface area of the tank. Taking into account the permeation rates and minimum average thicknesses of PE and PBT layers, it can be estimated that 90% or greater of the internal tank surface area should be covered with PBT for a tank to have low fuel permeation (see Appendix A, "Inner Layer Coverage and Thickness Model for PE-PBT Fuel Tanks"). Alternatively, observation of inner layer coverage can be made by cutting apart the tank prior to inspection.
- 1.3.2 **Inner layer durability** – PBT inner layer durability is obtained by achieving adequate molecular weight build during the polymerization of CBT resin which occurs during the rotomolding process. Inadequate molecular weight build can be determined by visual inspection of inner layer cracking through the fuel tank opening. Alternatively, inner layer molecular weight build can be measured by gel permeation chromatography (GPC). The weight average molecular weight of rotomolding grade CBT resins are ~700 g/mol and will polymerize to PBT during the rotational molding process. For the PBT inner layer to possess an adequate durable structure, the weight average molecular weight should be greater than 60,000 g/mol as determined by GPC relative to polystyrene standards.
- 1.3.3 **PE-PBT inter-layer integrity** – In addition to coverage and durability, the PBT inner layer should be adhered adequately to the PE such that the two layers are not spontaneously delaminated. Delamination can be observed in either of two ways: 1) Visual observation of separation between the two layers in the part opening area; or 2) By cutting a test panel from a flat section of a representative part and visually observing that the two layers are not separated from each other.
- 1.3.4 **Pressurized leak testing** – PE-PBT dual-layer fuel tanks are pressurized with 3-5 psi compressed air and placed underwater. There must not be visible signs of bubbles escaping from the tank due to wall formation defects such as pinholes, blowholes, voids and thin wall sections.

Exhibit B:

1.0 Material Specifications -- The materials used for producing a PE-PBT dual-layer rotationally molded fuel tank are as follows:

- 1.1 Polyethylene** – Rotational molding grades of linear PE including HDPE, LDPE and LLDPE. Specific manufacturers and product grades of PE must be tested in combination with rotomolding grade CBT resins to show adequate compatibility to achieve inner layer formation and coverage and overall fuel tank durability (see Exhibit A section 1.3).
- 1.2 Cyclics Corporation CBT® Resins** – Cyclics Corporation rotomolding grade CBT resins will form an inner layer having low fuel permeation characteristics within a PE tank during the molding process. Rotomolding grade CBT resins, utilized in granular or pellet form, consist of at least 80% of the total composition being cyclic polybutylene terephthalate (c-PBT), a polymerization catalyst, a processing stabilization package and possibly a polymer modifier. Polymerized rotomolding grades of CBT resins all possess fuel permeability values substantially less than 1.5 grams per square meter per day at an average minimum thickness of 1.0 mm. CBT resins are typically dried to a moisture content of <75 ppm prior to introduction into the rotomolding process.