CWC

Best Practices in PET Recycling

Drying Methods and Requirements

Issue: *PET is an extremely hygroscopic thermoplastic, in that it readily absorbs moisture from the atmosphere. The presence of minute amounts of moisture will hydrolyze PET in the melt phase, severely reducing molecular weight. As a result, mechanical properties of PET decrease and end-product quality is compromised. Therefore, PET must be thoroughly dry just prior to melt processing, and in some cases, recycled PET may have to be crystallized prior to drying.*

Background: Unlike the other major packaging resins (e.g., polyolefins, polystyrene, and PVC), PET is produced by a condensation reaction. Various starting materials are used and reacted in a series of steps to produce PET. This reaction, which also produces water, is reversible. Therefore, when undried PET is melted, the resin and water chemically react. Hydrolysis occurs and key mechanical properties of the PET are reduced. This hydrolysis reaction also changes PET melt viscosity and crystallization rate, making it very difficult to process into a quality end product.

PET is a "semi-crystalline" thermoplastic, meaning it has both crystalline and amorphous regions within its molecular structure. The crystalline portion develops where the molecules can align themselves in a very compact linear structure. Otherwise, the molecules are set in a random or amorphous pattern.

Virgin PET resin is sold in crystallized form so that it can be dried before being melt processed. Uncrystallized PET becomes sticky and clumps when its temperature reaches 175°F. This is PET's glass transition temperature; the point at which the amorphous portion begins to soften. Recycled PET may have to be crystallized prior to drying to avoid drying difficulties. Crystallization permits trouble-free drying in conventional equipment at 280°F-320°F.

End-product manufacture from clean, recycled PET flake introduces an additional variable to be considered when drying. A rule of thumb is that a crystallizer is not required if the amorphous portion of the feedstream is less than 40% of the total. However, this generalization ignores wide variation in the level of crystallinity in flake. For example, flake from clear thermoformed parts, trim scrap, or PET bottle preforms, is highly amorphous. Flake from whole soda bottles will be a mixture of crystalline and amorphous fractions, while that from strapping will be highly crystalline.

Most PET drying is done in dehumidifying hoppers using hot air at a very low dew point. The dehumidified air passes through a bed of PET to extract moisture from the resin. A desiccant material, such as silica, absorbs moisture from the circulating air. Dual desiccant bed systems are common, so that one bed is on-stream while the stand-by bed is being regenerated. Either a time cycle or a predetermined decrease in air dew point is used to shift airflow from one bed to the other.

Due to rapid growth in PET recycling, many new plastic converters are manufacturing end products from post-consumer PET. A number of these companies are just now learning how critical drying is when producing high quality PET end products. Others may not be aware of the differences in behavior between amorphous and crystallized grades of PET. It is important to note that inadequate drying, (ppm) causes 60% of all quality and molding problems in PET processing (1).

Best Practices: Drying. PET must be dried to <100 parts per million (ppm) moisture and maintained at this moisture level to minimize hydrolysis during melt processing. This is not optional with PET; it is absolutely essential. A dry resin will help control the Intrinsic Viscosity (IV) loss, which should be less than 0.04 dL/gram. An IV reduction greater than this can result in a product outside of the useful range (0.70-0.80 dL/gram) for several recycled PET applications. Controlling IV loss is critical to maintaining impact strength, stiffness, chemical resistance, melt viscosity, and other key properties of the starting material.

The PET should be dried at 280º-320°F, using dehumidified air with a dew point of -20°F or less. Higher drying temperatures can degrade the resin and cause discoloration. Lower drying temperatures will not dry the resin below 100 ppm moisture.

Dew point is an absolute measure of air moisture and is independent of air temperature. Dew point should always be used to control dryer performance, therefore, the dryer should be equipped with a dew-point monitor and alarm plus a temperature monitor on the dryer inlet line. Airflow to the dryer heats the resin and absorbs its moisture. Sufficient air flow maintains the resin at the proper temperature for its entire residence time. Airflow must be maintained at one cubic foot of air/minute for every pound/hour of PET being dried. A volumetric flow indicator is recommended to monitor airflow.

Pellets should be dried for four hours, while regrind should be dried for five to six hours.

Another best practice for minimizing moisture-related degradation of PET is to dry any blending ingredients, colorants, additives, or internal scrap that could potentially contribute moisture to the base resin. If any portion of the formulation is hygroscopic, it must be dried according to the supplier's recommendation. Some non-hygroscopic components may not have to be dried if their equilibrium moisture content and percentage of the formulation are small.

The manufacture of end products from clean, recycled PET flake may require that the PET feedstream be crystallized prior to drying. However, this generalization ignores the fact that the level of crystallinity in the flake is subject to wide variations. For example, flake from clear thermoformed parts, trim scrap, or PET bottle preforms is highly amorphous. Flake from whole soda bottles will be a mixture of crystalline and amorphous fractions, while that from strapping will be highly crystalline.

The sticking (or agglomeration) problem in dryers will worsen as a higher percent of the mix consists of amorphous material. A rule of thumb is that a crystallizer is not required if the amorphous portion of the feedstream is less than 40% of the total. For some end-product manufacturers, it is not feasible or cost-effective to maintain the amorphous portion at a content level low enough to prevent this phenomenon.

The clumps that form due to sticking of amorphous or partly amorphous resin do not break up as the temperature rises. In fact, they will stick to the container walls and thermocouples and cause bridging as the clumps grow. Drying of the non-sticking resin becomes inefficient and some of the bridged material will heat degrade and reduce product quality.

Crystallizers are drying hoppers equipped with agitators that break up the clumps. The crystallizers generally are positioned just above a series of dryers. Slow agitation is used to prevent agglomeration and creation of fines. The transition from amorphous to crystalline PET takes 5-10 minutes at 270º-300°F. The crystallized material then is conveyed into a hopper dryer.

Moisture Control. Drying must be coordinated with production at all times. Dryness of the PET must be maintained until it enters processing equipment. It is best to use dried material right away so it does not absorb ambient moisture. Depending on ambient conditions, dried PET that is not kept in a sealed enclosure can pick up enough moisture in five minutes to defeat most of the benefits of drying.

To maintain dryness, it is best to vacuum load the pellets and/or regrind directly from a centralized drying unit to feed hoppers above the processing equipment. In some instances, portable hopper dryers are used and the dried resin is conveyed directly to the feed hopper.

Moisture Analysis. The Best Practice for moisture analysis of dried samples is to check two to three samples at the end of each drying cycle to confirm that moisture content is below 100 parts per million. Goodyear's test method R-123b is used by several recycling companies. This procedure utilizes a Meeco electrolytic moisture analyzer.

Contact: For more information, contact CWC at (206) 443-7746 or e-mail at info@cwc.org.

Reference:

1) Kozielski, Gary. "Molding Reinforced PET: How to Do It Right", Plastics Technology, October 1988

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