Overview of the PET Plastic Recycling Process

One of the most familiar types of plastic packaging found in American households is made from a plastic called *polyethylene terephthalate*, or "PET" for short. Introduced to consumers as the plastic soft drink bottle in the 1970s, PET quickly gained acceptance among bottlers and consumers. Because it was lightweight, economical and shatter proof, PET plastic offered unique marketing and lifestyle benefits. PET plastic is now used as a packaging material for a whole range of consumer products in addition to carbonated beverages. These bottles and containers, known as "custom-PET" containers are used to package such consumer products as spring water, liquor, juice, peanut butter, salad dressing, dish detergent, mouthwash, household cleaners and tennis balls, to name just some. It is now estimated that 31% of all the plastic bottles produced in the United States are made from PET.

The Society of the Plastics Industry (SPI) established a resin identification code in 1987, that contains a number, surrounded by the "chasing arrows" recycling symbol, followed by an abbreviation for the specific plastic it represents. The use of this code has subsequently been adopted by legislation in 39 states. This identification code is imprinted on most plastic packages manufactured in the United States to aid in the identification of plastics for recycling. The SPI resin identification code for PET is "#1."

From the beginning, the PET plastic packaging industry has demonstrated commitment to environmental responsibility through recycling. Prior to the introduction of the PET soft drink bottle on grocery shelves, PET bottle manufacturers and consumer product companies worked with private recycling companies to demonstrate that this new packaging material could be recycled, a major concern for new packaging, given the popularity of recycling with the American public.

Reportedly, the first PET bottle recycling process was established by a company called St. Jude Polymers in 1976, that began recycling PET bottles into plastic strapping and paint brush bristles. In 1977, St. Jude became to first to "repelletize" post-consumer PET plastic. This was an important step, as many PET remanufacturing companies rely on plastic in pelletized form for their processes, increasing the variety of products that can be made from recycled, post-consumer PET plastic.

However, a major push in the development of both the demand and the capacity for post-consumer PET recycling occurred when a major plastic fiber manufacturer named Wellman, Inc., entered the picture. As early as 1978, Wellman began recycling PET bottles into a fiber product that was suitable for both carpet and fiberfill applications.

Wellman continued to increase its use of recycled PET and throughout the 1980s and early 1990s increased their processing capacity and consequently the market demand for post-consumer PET. The major event in Wellman's development of post-consumer PET processing capacity was the vertical integration of the recycled PET it processed into its own product lines. Another was the development of the first textile fiber manufactured from 100% recycled PET in 1993, called "Eco Spun," which is now a familiar fabric material particularly in sportswear where it was first used. Today, St. Jude and Wellman are joined by more than a dozen other companies, whose combined PET recycling processing capacity produces over 1/2 billion pounds of recycled PET resin annually.

With recent advances in PET recycling technology, it is now possible to "close the loop," by recycling bottles and containers back into bottles and containers, even in some food-contact packaging applications. The federal Food and Drug Administration (FDA) has issued "letters of non-objection" for the use of post-consumer PET in a number of food-contact packaging applications. This has greatly increased the demand for recycled PET plastic and the ability to produce new PET packages from 100%, post-consumer recycled PET plastic.

Based on data compiled from the FDA, at least 20 letters of non-objection for the use of post-consumer PET in food-contact packaging applications were issued between January, 1991 and July, 1996.[1] There are three generic types of food-contact packaging applications/processes for which the use of post-consumer recycled PET has been issued letters of non-objection. They are "depolymerization" processes that chemically break down PET plastic into its component chemicals, which are then "repolymerized" and made into new PET food contact packages; multi-layer, or laminated food-contact containers where post-consumer PET is combined with a virgin PET food-contact layer; and, full-contact food packaging containers where 100% post-consumer PET is used.

The first food-contact application using components derived from the depolymerization of post-consumer PET was issued a letter of non-objection in January of 1991. The first full-contact food packaging application to receive a letter of non-objection was in April, 1991, for the use of post-consumer recycled PET in quart and pint baskets for fruits and vegetables. The next major achievements came in August, 1992 when the FDA issued letters of non-objection for the use of post-consumer PET in tri-laminated clamshell containers, and containers for prepared bakery and deli products that contained a virgin PET food-contact layer. In April, 1993, the first letter of non-objection was issued for the

[1] This data was compiled through publicly-available information obtained from the FDA through the Freedom of Information Act by the law offices of Keller and Heckman, LLP (Washington, DC) on behalf of the Eastman Chemical Company.

use of recycled PET in tri-laminated soft drink bottles with a virgin PET food-contact layer. And, in 1994, a major PET soft drink bottle manufacturer was the first US company to receive a letter of non-objection to make a soft drink container from 100% recycled post-consumer PET plastic.[2]

Food-contact packaging applications are one of the largest uses of PET plastic resin in the United States. The ability to recycle these food-contact packages back into new PET food-contact packages will help ensure the long-term viability of PET plastics recycling and the ability to avoid the use of virgin PET in food contact package manufacturing. What follows is a description of how PET plastic soft drink bottles and custom-PET containers get recycled.

There are four basic ways in which communities around the United States offer recycling collection services for PET plastic bottles and containers (in addition, to other recyclable materials) to their residents. The first method is not up to individual communities but is created as a result of statewide laws known as Returnable Container Legislation, or "Bottle Bills." Many states around the country have passed such legislation, which establishes a redemption value on carbonated beverage (and, in some cases, non-carbonated beverage) containers. These containers, when returned by the consumer for the redemption value, facilitate recycling by aggregating large quantities of recyclable materials at beverage retailers and wholesalers to be collected by recyclers, while simultaneously providing the consumer with an economic incentive to return soft drink containers for recycling. Currently, ten states have enacted some form of Returnable Container Legislation in the United States (CA, CT, DE, IA, MA, ME, MI, NY, OR, and VT).

The second, and most widely accessible, collection method is *curbside collection* of recyclables. Curbside recycling programs are generally the most convenient for community residents to participate in and yield high recovery rates as a result. Research conducted by the Center for Plastics Recycling Research at Rutgers University estimates that curbside collection gathers 70%-90% of available recyclables. In addition, estimates by the National Association for Plastic Container Recovery (NAPCOR) indicate that approximately 55% of all the PET plastic containers collected for recycling are generated through curbside programs.

Communities that provide curbside collection generally request residents to separate designated recyclables from their household garbage and to place them into special receptacles or bags, which are then set out at the curb for collection by municipal or

[2] It should be noted that all of the letters of non-objection issued for these various food contact applications are specific to the manufacturing process used by the company to which the letter has been issued.

municipally-contracted crews. Some communities allow their residents to commingle recyclables, that is, mix recyclable materials of different kinds into the same receptacle. Others require some level of material segregation -- known as "source separation." For example, many curbside collection programs require that newspapers and cardboard be bundled separately and placed alongside the receptacle containing their commingled recyclable containers. Some communities will collect recyclables on the same day as normal garbage collection, while others have separate days for trash collection and collection of recyclables.

The third collection method is known as *drop-off* recycling. In this method, containers for designated recyclable materials are placed at central collection locations throughout the community, such as parking lots, churches, schools, or other civic associations. The containers are generally marked as to which recyclable material should be placed in them. Residents are requested to deliver their recyclables to the drop-off location, where recyclables are separated by material type into their respective collection containers. Drop-off centers require much less investment to establish than curbside programs, yet do not offer the convenience of curbside collection. However, drop-off collection centers work well in rural locations where curbside collection is impractical.

The last collection method employs the use of *buy-back* centers. While communities do not provide this service *per se*, as most buy-back recycling centers are operated by private companies, they often provide incentives, through legislation or grants and loan programs, that can assist in the establishment of buy-back centers for their residents. Buy-back centers pay consumers for recyclable materials that are brought to them. Most buy-back centers have purchasing specifications that require consumers to source separate recyclable materials brought for sale, in addition to other requirements they may have (for example, removal of caps from bottles). These purchase specifications can greatly reduce contamination levels and allow the buy-back center to immediately begin processing the recyclables they purchase, while providing consumers with an economic incentive to comply with the specifications.

Finally, many communities that offer curbside recycling collection services will augment this service with drop-off and buy-back centers where curbside is not as effective, such as near multi-family housing units. While buy-back centers may not be as convenient as curbside collection, they offer an economic incentive to the public that curbside collection does not.

After PET plastic containers are collected they must be sorted and prepared for sale. Each subsequent step in the recycling process adds value to the post-consumer PET and puts it into marketable form for other processors and end-users that will use them to manufacture new products. The amount and type of sorting and processing required will

depend upon purchaser specifications and the extent to which consumers separate recyclable materials of different types and remove contaminants.

Collected PET plastic containers are delivered to a materials recovery facility (MRF) or a plastics intermediate processing facility (IPC) to begin the recycling process. The value of the post-consumer PET plastic and its ability to be economically remanufactured into new products is dependent on the quality of the material as it passes through the recycling process.

MRFs accept commingled curbside collected recyclables and separate them into their respective material categories. PET plastic bottles and containers are separated from other recyclables and baled for sale to IPCs, plastics recycling facilities (PRFs), or reclaimers. Unlike MRFs and IPCs, plastic recycling facilities only accept plastic containers, either commingled or source separated from other plastic containers. PRFs will generally accept plastics in both loose and baled form. Very often, these materials are supplied by drop-off and buy-back centers, which require source separation of recyclable materials that are brought to them. Once again, PET plastic bottles and containers are sorted from other plastic containers at PRFs and, in most cases, further processed by color sorting and granulating PET for shipment to reclaimers as "dirty" regrind. Some PRFs merely separate PET and other plastic containers by resin category and bale them for shipment to reclaimers or end-users.

However, as defined throughout this document, IPCs shall generally refer to recycling facilities that take in loose, source separated plastic bottles and densify them for shipment to PRFs, reclaimers or end-users. And, PRFs will be used to describe sorting, baling, and/or grinding facilities.

However, sorting and grinding alone are not sufficient preparation of PET bottles and containers for remanufacturing. There are many items that are physically attached to the PET bottle or containers that require further processing for their removal. These items include the plastic cups on the bottom of many carbonated beverage bottles (known as "base cups"), labels and caps.

Dirty regrind from PRFs is then sent to reclaimers that process post-consumer PET plastic into a form that can be used by converters. Converters process the recycled PET plastic into a commodity-grade form that can then be used by end-users to manufacture new products. At a reclaiming facility, the dirty flake passes through a series of sorting and cleaning stages to separate PET from other materials that may be contained on the bottle or from contaminants that might be present. First, regrind material is passed through an "air classifier" which removes materials lighter than the PET such as plastic

or paper labels and "fines" -- very small PET particle fragments that are produced during granulating.

The flakes are then washed with a special detergent in a "scrubber." This step removes food residue that might remain on the inside surface of PET bottles and containers, glue that is used to adhere labels to the PET containers, and any dirt that might be present.

Next, the flakes pass through what is known as a "float/sink" classifier. During this process, PET flakes, which are heavier than water, sink in the classifier, while base cups made from high-density polyethylene plastic (HDPE) and caps and rings made from polypropylene plastic (PP), both of which are lighter than water, float to the top. The ability of the float/sink stage to yield pure PET flakes is dependent upon the absence of any other plastics that might also be heavier than water and sink with the PET. This is discussed later in the document in the section on contamination. It should be noted that some reclaimers use a different device known as a "hydrocyclone" to perform this same step. This device essentially operates like a centrifuge and separates materials based on their weight (density) differences. Following the float/sink stage the flakes are thoroughly dried.

After they have dried, the PET flakes pass through what is known as an electrostatic separator, which produces a magnetic field to separate PET flakes from any aluminum that might be present as a result of bottle caps and tennis ball can lids and rings. Some reclaimers use a number of different particle separation technologies where PET flakes are further processed to remove any residual contaminants that may still be present, such as x-ray separation devices for PVC removal, or optical sorting devices to remove other contaminants. The purity level to which PET flakes are processed depends on the end-use applications for which they are intended.

Once all of these processing steps have been completed, the PET plastic is now in a form known as "clean flake." In some cases reclaimers will further process clean flake in a "repelletizing" stage, which turns the flake into "pellet."

Clean PET flake or pellet is then processed by reclaimers or converters which transform the flake or pellet into a commodity-grade raw material form such as fiber, sheet, or engineered or compounded pellet, which is finally sold to end-users to manufacture new products.

Recycled PET is manufactured into numerous products. The five major generic end-use categories for recycled PET plastic are *1) packaging* applications (such as new bottles), *2) sheet and film applications* (including some thermoforming applications, such as laundry scoops), *3) strapping*, *4) engineered resins* applications (such as reinforced

components for automobiles), and, *5) fiber* applications (such as carpets, fabrics and fiberfill). There are a number of emerging technologies that are generically referred to as depolymerization processes. These processes -- like glycolysis and methanolysis – break down the PET plastic into its individual chemical components, which can then be recombined back into PET plastic. While not used extensively, these technologies are employed when the economics warrant and offer yet another market opportunity for post-consumer PET plastic containers.

One of the highest value end-uses for recycled PET is to manufacture new PET bottles and containers. However, PET can be recycled into numerous other products including:

- belts
- blankets
- boat hulls
- business cards
- caps
- car parts (bumpers, distributor caps, and exterior panels)
- carpets
- egg cartons
- furniture
- insulation
- landfill liners
- overhead transparencies
- paint brush bristles
- pillows
- polyester fabric for upholstery, T-shirts, sweaters, backpacks, athletic wear and shoes
- recycling bins
- sails
- scouring pads
- strapping
- stuffing for ski jackets, cushions, mattresses, sleeping bags and quilts
- tennis ball cans
- tennis ball felt
- twine
- welcome mats