

Best Practices and Industry Standards in PET Plastic Recycling

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Best Practices and Industry Standards in PET Plastic Recycling

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 its beginning, the PET plastic packaging industry has demonstrated its 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 the 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 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

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.

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 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.

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.

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 plastic is to manufacture new PET bottles and containers. However, recycled PET can be made 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

Best Practices and Industry Standards in PET Plastic Recycling

PERMITTING AND REGULATORY ISSUES AT PET PLASTICS RECYCLING FACILITIES

Operations at PET plastics recycling facilities are subject to a wide range of codes and regulations at the federal, state and local level. The regulations that apply will vary with the type of PET processing operations taking place at the facility. It is the facility operator's responsibility to determine which regulations apply to their particular operation and to ensure that the facility is in full compliance with all applicable regulations at every level of government. One important aspect of this determination is to identify which regulatory agency has jurisdiction over a particular regulatory category. This will vary from region to region around the country, and can sometimes be confusing. For example, water discharges may be regulated by a local or regional sewer commission in some areas while in others it is the jurisdiction of a local or state environmental regulatory agency, while in still others it is regulated by a public works department. Therefore, it is not only important to determine which regulations apply to your facility, but also which regulatory body has jurisdiction. These agencies can provide full details on regulatory compliance to facility operators.

Certain activities within recycling facilities require operating permits or certifications. Once again, it is the responsibility of the facility operator to make sure that all required certificates and permits for operation are in place. Demonstrating compliance with regulatory agencies may involve submission of test results. If such test results are required to demonstrate compliance, it is the financial responsibility of the facility operator to provide them. Given the number and complexity of applicable regulations, many PET plastic recycling companies have a designated compliance officer who is responsible for identifying and complying with all regulations that might affect a facility's operations.

Failure to comply with regulations is subject to civil as well as criminal penalties, in certain instances. Full regulatory compliance is the only responsible way to operate a PET plastics recycling facility. The simple best practice is to maintain compliance with all applicable regulations at the federal, state, and local level.

What follows is a listing of some major categories where regulatory compliance is known to be required within the PET plastic recycling industry and what agency might have jurisdiction in those areas. This review is merely a guide to where regulatory compliance or operating permits and certificates might be required. It is not intended as a checklist for, nor does it ensure, full regulatory compliance.

The design, construction, and operations of PET recycling facilities are subject to a number of zoning and building codes.

PET recycling facilities are subject to compliance with local building and fire codes for such things as material storage, loading considerations, space allowances, and required fire protection equipment within a facility.

Facilities that use propane fueled forklifts will require operating and storage permits from their local fire department. Propane storage may also be subject to building codes.

Many laws and regulations deal with worker safety at the federal, state and local levels of government. The most important law in workplace safety is the federal Occupational Safety and Health Act. This law is administered by the Occupational Safety and Health Administration (OSHA), a division of the federal Department of Labor. OSHA regulations are extensive and relate to almost every aspect of a facility's operation (see *Safety Issues at the PET Intermediate Processing Facility* section of this document for a more complete discussion). Some of the more important areas for a PET recycling facility relate to worker exposure levels to noise, dust, electromagnetic frequencies, blood borne pathogens from hypodermic needles and general safety.

Cyclones used in regrind evacuation systems are subject to OSHA requirements for venting dust exhaust and may require operating permits from other state or local agencies.

Scales used throughout the PET recycling industry are subject to the regulations of local department of consumer affairs or state agencies for weights and measures for certification regarding their accuracy.

Transport of recycled PET is subject to Department of Transportation regulations at all levels. In addition, the transport of recycled PET may be subject to regulations with local departments of sanitation or consumer affairs.

Waste disposal from PET recycling facilities is regulated by a number of agencies, including local departments of sanitation, public works, or solid waste, as well as state and federal environmental agencies.

All facilities must comply with federal Environmental Protection Agency, and state and local environmental regulations regarding air or water discharges and emissions.

All facilities must comply with the National Electrical Codes.

Facilities that use auto-sort technologies based on X-ray detection may require registration or certification from the Nuclear Regulatory Commission as well as other state and local environmental regulatory agencies.

As can be seen, there are regulations that apply to almost every aspect of a facility's design, construction, and operation.

In certain cases demonstration of regulatory compliance is required for certain permits or certificates. Test results may be required to demonstrate adequate compliance. In cases where testing is required, it is the financial responsibility of the facility operator to provide for the proper testing. For example, PET recycling facilities that operate cleaning operations will require test results demonstrating compliance with certain regulatory discharge thresholds for discharging waste water into the local sewer system. This will usually involve providing test results that the water discharge is within regulatory limits for such measurable items as pH (acidity), TSS (total suspended solids), BOD (biological oxygen demand), COD (chemical oxygen demand), oil & grease, and what are known as priority pollutant metals, such as lead, cadmium, and mercury.

Where testing is required to demonstrate regulatory compliance or to obtain permits or certificates, best practice is to contract with a reputable testing firm that is familiar with regulatory compliance issues and testing protocols. While these tests may be expensive, regulatory non-compliance will cost far more.

Best Practices and Industry Standards in PET Plastic Recycling

BEST PRACTICES IN PET COLLECTION

Designing Your Community's PET Plastic Recycling Collection Program

Issue: Properly designed PET plastic recycling collection programs greatly increase the quantity and quality of PET plastics collected and can reduce overall recycling system costs.

Best Practices: In order to maximize the recovery and value of PET plastic containers in your community's recycling collection program, two best practices should be followed when designing your program. The first is to establish an effective and ongoing consumer education program (the elements of which are described in the *Consumer Education Best Practice*), regardless of collection system design. Studies by the American Plastics Council indicate that participation in local recycling programs can increase 10% to 20% immediately following educational and promotional campaigns. However, it has also been shown that participation will decline unless the educational and promotional efforts are maintained.

The content and design of consumer education programs can greatly impact both the quality and the quantity of PET plastics collected, resulting in a more cost-effective recovery program. The improved quality that results from properly designed and implemented consumer education programs ensures that the PET plastics that your program collects yield the highest market value for your community and can be recycled into new products that conserve natural resources.

Numerous studies of recycling collection programs around the United States consistently demonstrate the more public education provided, the better the recycling collection program in terms of increasing the quantity of materials collected for recovery and reducing program costs. In addition, through effective consumer education, major sources of potential contaminants can be eliminated from the PET recycling process at the outset. This can greatly reduce the costs associated with sorting, removal and disposal of contaminants at recycling facilities that process PET plastic. This reduces the total cost of recycling post-consumer PET plastic bottles and containers back into new products, making it more competitive with raw materials made from virgin natural resources.

Finally, effective public education programs emphasize the importance to consumers of purchasing products made from recycled post-consumer materials as the most important element to ensuring the long-term demand and economic infrastructure for the recovery of post-consumer PET plastic collected through their local programs.

There are a number of trade organizations that can provide assistance in designing your community's PET plastic recycling collection program, or in some cases provide promotional and educational literature tailored to the needs of your community. Some of these organizations include the American Plastics Council (APC), the National Association for Plastic Container Recovery (NAPCOR), and the National Soft Drink Association (NSDA). A resource list is contained at the end of this Best Practice.

Some of these organizations can provide detailed information and design criteria on crucial plastics collection program elements such as predicting material collection volumes, selecting and properly sizing collection containers and collection vehicles, practical suggestions on efficient routing, and revenue sharing options (for example, see How to Collect Plastics for Recycling, published by the American Plastics Council in 1995). These elements must be considered when designing your community's PET plastic recycling collection program to optimize material collection efficiencies and economics.

The second best practice in designing your PET plastic recycling program is to designate *all* PET bottles and containers with screw-neck tops as acceptable for recycling. Numerous studies have indicated that accepting all PET containers for recycling (soft drink bottles and custom-PET containers), as opposed to programs that collect only PET carbonated beverage containers, will greatly increase the amount of PET plastic your program collects. In addition, programs that include *all* PET bottles and containers with screw-neck tops will collect greater quantities of soft drink containers than programs that designate PET soft drink containers only.

RESOURCES:

American Plastics Council
1801 K Street NW, Suite 710-L
Washington, DC 20006-1301
1-800-2-HELP-90 (243-5790)
<http://www.plasticsresource.com>

National Association for Plastic Container Recovery
3770 NationsBank Corporate Center
100 North Tryon Street
Charlotte, NC 28202
(704) 358-8882
<http://www.napcor.com>

National Soft Drink Association
1101 16th St. NW
Washington, D.C. 20036
(202) 463-6740

Best Practices and Industry Standards in PET Plastic Recycling

BEST PRACTICES IN PET COLLECTION

Consumer Education Programs

Issue: The content and design of recycling consumer education programs can greatly impact both the quality and the quantity of PET plastics collected, resulting in a more cost-effective recovery program. The improved quality that results from properly designed and implemented consumer education programs ensures that the PET plastics that your program collects yield the highest market value for your community and can be recycled into new products that conserve natural resources.

Best Practice: There are numerous ways to design and implement consumer education programs that promote your local recycling program and inform the public how to participate. While there is no best practice related to the overall design of your community's consumer education program, there is a best practice as to the basic elements of what should be contained in an effective consumer education program aimed at the collection of post-consumer PET bottles and containers.

There are seven basic messages that should be included in any consumer education or promotional program aimed at the collection of PET bottles and custom containers:

1. Only PET bottles and containers with screw-neck tops should be placed out for collection or brought to a collection location. PET bottles and containers can be identified by looking for the “#1, PET or PETE,” resin identification code found on the bottom of PET bottles and containers. Any non-bottle PET items, like laundry scoops, or microwave trays, should be excluded. These materials introduce contaminants or create technical or economic problems in the PET recycling process.
2. Only PET containers that are clear or transparent green should be included for recycling. PET containers of any other color should be excluded. Pigmented PET bottles and containers other than those listed can cause technical or economic problems in the recycling process and limit the recycling of acceptable PET bottles and containers into new products.
3. Consumers should remove lids, caps and other closures from PET bottles and containers placed out for recycling. This includes safety seals that may secure the closure to the container. Caps and safety seals introduce aluminum and plastic materials that are not made from PET that can contaminate or add cost to the PET recycling process. Cap removal also encourages consumers to rinse containers (*Step 4* below) and allows for easy flattening (*Step 5* below).

4. All PET bottles and containers that are set out for recycling should be completely free of contents and rinsed clean. This reduces logistical difficulties such as odor and attraction of vermin and insects at recycling facilities due to the presence of food residues on bottles and containers.
5. Consumers should flatten PET plastic bottles and containers prior to setting them out for collection or delivery to a collection center. The simple act of flattening containers decreases collection costs by increasing the amount of materials collected by curbside collection vehicles or placed into containers at collection centers. It has been estimated that by simply flattening PET bottles and custom containers, truck collection volumes can be increased by as much as 50%.
6. Consumers should never place any material other than the original contents into PET bottles and containers intended for recycling. Many consumers use old plastic containers to store household chemicals, hardware, etc. Placing these containers into your local recycling program can add contamination to the recycling process or introduce materials that could cause injury to personnel or damage to equipment at recycling processing facilities.
7. Hypodermic needles are an increasing safety concern at recycling processing facilities. Many communities have special collection programs for community residents that have medical conditions that require regular intravenous injections. Very often, these programs request residents to place used needles into sealed plastic containers. Recycling consumer education programs should emphasize to residents that participate in hypodermic needle collection programs that they should never include containers with needles with recyclable materials set out for curbside collection or delivered to a collection center.

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BEST PRACTICES IN PET COLLECTION

Curbside Recycling Collection - Compaction vs. Loose Collection Systems

Issue: Some curbside recycling collection programs use compaction vehicles to collect designated recyclables. While this will yield greater amounts of material on a collection route than collecting materials loose and placing them in non-compaction vehicles, there is a greater possibility of introducing contaminants to the PET recycling process.

Best Practice: Collecting recyclables in compaction vehicles -- like the trucks used to collect household trash -- is the most efficient way to collect and transport recyclables. However, many curbside collection programs request their residents to commingle recyclable glass, metal and plastic containers together. When commingled containers are compacted, there is a greater tendency for glass breakage. When this happens, small pieces of glass can get trapped inside PET bottles and containers. This trapped glass can cause serious damage to processing equipment throughout the PET recycling process. Therefore, the best practice for curbside collection of PET plastics is to collect PET plastic containers commingled with other recyclable containers *except glass* in compaction vehicles.

Glass containers can be collected in the same vehicles as PET plastics and other commingled recyclables as long as they are placed in a different collection compartment when collection workers sort materials at the curb. Glass containers can be collected through a separate companion program just for glass when recyclable materials are collected in an automated fashion where no curbside sorting takes place.

Curbside collection programs that have used compaction vehicles and excluded glass from their collection program report the best collection efficiencies and economics. Glass is such a contaminant at subsequent stages in the PET recycling process, that overall recycling economics are enhanced when glass and plastics containers are not mixed together when compaction collection vehicles are used. Many programs around the country have successfully done this by providing convenient drop-off locations for glass containers, while other recyclable materials are collected from the curbside in a commingled fashion.

References:

American Plastics Council, How to Collect Plastics for Recycling, (American Plastics Council, Washington, D.C.), 1995.

Best Practices and Industry Standards in PET Plastic Recycling

BEST PRACTICES IN PET COLLECTION

Drop-Off Recycling

Issue: When implementing drop-off recycling collection centers for community residents to bring their designated recyclables, there are a number of best practice design elements that can improve the quality and quantity of materials collected and reduce recycling collection costs.

Best Practices: The best practices to be employed in establishing drop-off collection locations for PET plastics are:

- drop-off recycling collection sites should be located at the front end of waste disposal locations or facilities
- drop-off centers should be staffed (paid or volunteer)
- drop-off centers should be equipped with some type of compaction or densification device
- drop-off centers should have educational displays to assist residents in proper material separation and general recycling information

Drop-off recycling collection centers are preferably sited in conjunction with a location where community residents can also dispose of non-recyclable or non-compostable household trash, such as at solid waste landfills or transfer stations. This increases the convenience for community residents to participate in the drop-off collection program. It also reinforces the habit of recycling before and rather than disposal. Educational displays at drop-off centers can also increase residents' awareness of the range of materials they can recycle.

There are two basic types of drop-off recycling sites. The first are self-serve drop-off programs, where there is no staff at the collection site to monitor collections. The second are sites that are only open when a staff is present. Increasingly, staffed sites are considered the best practice. Staffed sites can greatly reduce material contamination and increase material value, decrease the financial costs associated with vandalism at unattended sites, provide minimal densification processing to increase collection efficiencies and transportation economics, and provide "one-on-one" community education on recycling. Combined, these benefits can improve program economics beyond the cost of funding staff. In addition, many drop-off centers around the country have successfully used volunteers from their communities to staff

drop-off centers, when funds for paid staff were not available. Many of the early recycling drop-off centers established in the 1970s were operated in this fashion.

There are many types of collection containers used at drop-off recycling centers. Regardless of the type of container used, proper signage is the best practice in ensuring that only the designated recyclable materials are deposited into them. The signage should use understandable language(s), in clear graphics that illustrate the acceptable recyclable material or materials to be placed into collection containers. Signage for PET plastic bottles and containers should include examples of acceptable and unacceptable containers.

The final best practice to follow at drop-off collection centers used to collect post-consumer PET bottles and containers is to provide on-site compaction or densification. Compacting PET plastic bottles greatly increases the quantity of materials that can be picked up and transported to a processing facility. In addition, on-site densification means that collection containers can be emptied and processed on site and stored for collection at a later time rather than having to arrange for a collection each time a container is full. Therefore, compacting materials greatly reduces the frequency of collections (which means less truck activity) and the cost of transportation. Finally, compacted materials provide the greatest market flexibility for your collected PET plastic bottles and containers.

References:

American Plastics Council, How to Collect Plastics for Recycling, (American Plastics Council, Washington, D.C.), 1995.

Best Practices and Industry Standards in PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Introduction and Contamination Issues

In general, plastics intermediate processors receive plastic containers (primarily in baled form, but in some cases loose) that have been separated from other recyclable materials at MRFs, buy-back or drop-off centers, and then granulate them for sale as “dirty regrind” to reclaimers and end-users. In most cases, plastic intermediate processors take in loose plastic bottles and produce baled plastics for sale to PRFs, reclaimers or end-users. Most PRFs are designed to separate plastics into their individual resin categories (if they accept bales of mixed plastic bottles), and then further separate each plastic resin type by color or other market specification parameters. These color segregated plastic resins are then fed into granulators at PRFs or reclaimers to produce dirty regrind. Another major function of the plastics intermediate processor is the sorting and removal of contaminants from the plastic resin streams they process.

Contamination limits the ultimate marketability of the full range of PET plastic containers collected by local recycling programs. Contamination reduces the value of recyclable PET; it hinders processing and causes unproductive downtime and clean-up expenses for PET processors, reclaimers and end-users; and, it results in unnecessary manufacturing waste from the PET recycling process. The specifications detailed in these *Best Practices* documents, were designed to prevent the introduction of the major contaminants that have been identified by the PET recycling industry and to provide PET suppliers with a guide that can meet their particular purchaser’s specifications.

To the general public -- and even to trained personnel operating plastics sorting, recycling and reprocessing systems -- PET containers can be confused with food and liquid containers that are made from other plastic resins that pose major contamination problems for the PET recycling process. In addition, some PET containers are manufactured with barrier resins, closures, labels, safety seals, or contain product residues which can introduce incompatible materials that contaminate the PET recycling process. The increase in recycling collection programs that commingle different kinds of recyclable materials can also introduce non-plastic contaminants, like broken glass, or dirt. These contaminants can create operational or technical problems, quality-control problems, financial costs and unnecessary wastes for the PET recycling industry.

Packaging manufacturers are beginning to adopt “design for recycling” criteria that aim to limit the package’s impact on the overall recycling process. Many materials that pose contamination problems for PET recycling are contained on the PET bottle itself. As a general rule, the best practice for reducing the incidence of these contaminants is to design PET bottles and containers that do not contain materials that contaminate the PET recycling process. Materials necessary in a package design should be designed to reduce their impact on the recycling process. Design for Recycling guidelines and protocols have been established in a number of important areas by the Association of Postconsumer Plastic Recyclers.³ These protocols and guidelines are routinely updated as new practices and procedures are developed.

While any material that is physically present on a PET bottle or custom container by virtue of its manufacture and marketing is considered acceptable within the PET recycling industry, there are a number of design elements that can be implemented that significantly increase the efficiency and reduce the cost of the PET recycling process. These design for recycling efforts have been aimed at reducing the impact of such materials as labels, the adhesives used to affix them and the inks used to print them.

What follows is a detailed discussion of the major contaminants to the PET recycling process. Much of this discussion will be directed at what facility operators need to do to remove these contaminants and to prepare materials that are of acceptable quality to their purchaser. However, it cannot be overemphasized enough that good public education programs can go a long way towards enlisting the public in removing some of these contaminants prior to collection.

Polyvinyl chloride (PVC)

The primary contaminant to the PET recycling process is any source of polyvinyl chloride (PVC) plastic resin -- the Society of the Plastics Industry “#3 (PVC)” resin identification code. The presence of PVC when reprocessing and remanufacturing post-consumer PET resin may cause one of several problems, even at very low concentrations.

PVC can form acids when mixed with PET during processing. These acids break down the physical and chemical structure of PET, causing it to turn yellow and brittle. This will render the PET material unacceptable for many high-value end-use applications. In addition, the presence of PVC may result in out gassing of chlorine vapors during certain stages of PET reprocessing. This can increase the cost of control systems or regulatory compliance for the facility operator.

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There are four primary sources of PVC contaminants that can enter the PET recycling process. The first are PVC “look-alikes,” that is, PVC bottles that resemble PET bottles. While it is possible to distinguish transparent PVC bottles from transparent PET bottles by the presence of white “crease” marks, or by the molding mark on the bottom of the bottle, looking for these distinguishing characteristics can be time-consuming and limit processing throughput in manual sorting systems.

The second is PVC safety seals that are used on certain product containers, such as mouthwash. Every effort should be made to remove safety seals, if they are present, prior to baling PET bottles and containers. Safety seals should absolutely be removed prior to granulating.

The third potential source is PVC liners found inside some caps and closures. While the use of PVC as cap liners has virtually been discontinued in the United States, it is still possible to encounter the occasional cap with a PVC liner. The fourth source is PVC labels that are affixed to some PET containers. However, as a general rule, purchasers of PET bottles and containers will accept any material that is attached to the PET bottle or container.

The sensitivity of PET to PVC contamination is based on the ultimate end-use application for which the recycled PET is intended, but in general the tolerance for PVC contamination is extremely low. The negative impacts of PVC contamination can occur with concentrations as low as 50 parts per million (ppm). This is an amount equal to less than one PVC bottle ground into an 800-pound container of recycled PET regrind or “flake,” made from thousands of PET bottles. However, many end-use applications have tolerances even lower than that.

Other Resins

The presence of plastic resins other than PET may also pose problems in the processing and remanufacture of PET. While some of these are acceptable to the PET recycling industry, many are not. The presence of closures may introduce plastics other than PVC that may contaminate the PET recycling process or add separation costs. In addition, some closures are made from aluminum, which can pose problems for some PET reclaimers and end-users or increase cleaning costs.

Plastic closures are made from plastics different than PET. While these plastics (e.g., polypropylene) are lighter than PET, which sinks in water, and can be removed in the “float-sink” stage of the process used to clean granulated post-consumer PET, the removal of caps early in the recycling process can reduce or eliminate the costs associated with this separation step.

There are a growing number of PET containers and other PET packaging materials which are marked with the SPI #1 resin identification code that pose a number of specific problems to PET reclaimers. In some cases these containers are manufactured with modified PET plastic

resins or in laminated forms that contain barrier resins that are either incompatible with the recycling of “bottle-grade” PET plastic resin, or are difficult to distinguish from acceptable materials with current sorting technology. In addition, there are identical packaging items to those made from PET that are made with incompatible resins that current sorting technology cannot distinguish. Most recycling collection programs that collect PET plastics request the public to look for the #1 code before placing materials in their collection container or bag. Therefore, it is reasonable to expect that some of these materials may find their way to an intermediate processing facility.

These modified PET resins may have physical or chemical properties that make them incompatible with “bottle-grade” PET resin during the recycling process. However, very few of these modified PET resins are used to manufacture bottles or containers with screw-neck tops. And, the exceptions are very identifiable. This is why many recycling programs that collect PET plastic will request that only PET bottles and containers with screw-neck tops be included in the materials that are set out for collection. What follows is a brief review of the most common incompatible items.

PET Microwave Trays - these are manufactured from crystallized PET, known as C-PET, and are incompatible with bottle-grade PET resin and must be excluded. These C-PET trays are often solidly pigmented (opaque), adding to their incompatibility.

PET Drinking glasses, “Clamshells,” and “Blister-pak” - other items that should be sorted out from PET carbonated beverage bottles and custom-PET containers are PET drinking glasses (like the ones used on commercial airlines), which are manufactured from A-PET (amorphous PET); PET salad/food take-out trays or "clamshells," and, PET “blister-pak” -- the clear plastic thermoformed cover affixed to a cardboard placard containing a product. While some of these materials are technically compatible with the recycling of bottle-grade PET, there are “look-alike” packaging items that are made from incompatible resins (e.g. oriented polystyrene) that current sorting technologies cannot distinguish from PET, and must be excluded.

PET Laundry Scoops - plastic laundry scoops with the SPI #1 (PETE) recycling code should also be excluded from your PET mix. While technically it is possible to recycle laundry scoops with PET bottles if they are clear or transparent green, it is best to exclude them as many laundry scoops are opaque and may introduce contaminants due to pigmentation.

PET-G - many custom-PET bottles and containers are now manufactured from a glycol-modified PET resin known as “PET-G.” PET-G containers are manufactured differently than other PET containers and are generically known as extrusion-blown containers (referred to as E-PET containers). PET-G and other E-PET containers have a lower melting point than bottle-grade PET resin and can cause a number of technical and operating problems to PET reclaimers. Many of these PET-G and other E-PET containers are marked with the SPI #1 resin identification code and are difficult to distinguish from PET bottles that are acceptable for

recycling, even with automated sorting technology. The best way to ensure that E-PET gets removed to the greatest practical extent is to remove any #1 container that contains a built-in handle. These handleware containers are manufactured exclusively with E-PET resins.

Multi-layer PET containers - an increasing number of PET containers on the market are manufactured with a multi-layer construction. Some these containers are manufactured with a barrier resin known as ethyl vinyl alcohol (EVOH). The presence of EVOH is a problem for some reclaimers as it effects the clarity of the finished product or can cause a change in the intrinsic viscosity (IV) of the recycled PET that renders it unacceptable for certain end-use applications. Like PET-G, however, it is very difficult to distinguish a multi-layer PET container from a single-layer PET container. Once again, it is important to determine whether a particular purchaser has any specific restrictions on the presence of these materials.

Colored PET

While PET containers are manufactured in many different colors, PET reclaimers and end-users are generally only interested in clear and transparent green containers, as they have the best end-use applicability. While there are a growing number of transparent blue PET bottles and containers entering the marketplace, some reclaimers have restrictions as to the presence of blue containers, while other reclaimers are able to “blend” them off into certain end-use applications. Once again, it is essential to understand the exact specification of your particular PET purchaser. The presence of any pigmentation other than transparent green is unacceptable to most PET reclaimers and no other colors of PET bottles or containers should be included for recycling. These restrictions include any opaque colored PET containers as well as transparent amber (brown) or blue PET bottles or containers.

Labels

While most paper and plastic labels used on custom-PET containers and the glues used to affix them can be removed from granulated PET during the cleaning process, certain PET containers, including coffee containers, liquor bottles and mustard jars, may contain metallized labels that pose problems for some reclaimers. Not all reclaimers encounter these problems, but enough do to make it worth noting. Once again, check with your PET purchaser on specific restrictions they may have. However, as a general rule, PET purchasers will accept PET bottles and containers with whatever materials are physically affixed to the bottle or container.

Best Practices and Industry Standards in PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Bale Specifications

Issue: The lack of standardization and the resulting variability of the quality and content of baled post-consumer PET bottles and containers adds economic cost to and limits the efficiency of the PET recycling process.

Introduction: The proposed best practice, post-consumer PET bale specifications that follow are not intended to meet any one company's individual specifications, but to represent a standard that will be acceptable to most PET purchasers and ensure a quality standard that can reduce the cost of the PET recycling process. While the proposed specifications may represent a standard which is acceptable to most of the PET recycling industry, every PET processor has specific requirements based on their particular processing system and the end-use application for which the recycled PET is intended. Therefore, suppliers must always determine the exact levels of contamination that a particular purchaser accepts as well as other unique purchasing specifications they might have.

Bale specifications include a number of factors. They include both physical and quality characteristics such as bale size, bale density, levels and types of contamination, etc. The physical properties can improve operating, handling, and safety factors such as ease and efficiency of truck loading and unloading, and in-plant storage. Physical bale characteristics can also impact the efficiency and throughput of some "auto-sort" technologies which are used by intermediate processors, PRFs, reclaimers and end-users who process baled PET plastic bottles and containers (see *Sorting Best Practices*). Finally, the quality of the bale impacts the technical and economic ability to reclaim PET resin from the post-consumer wastestream and remanufacture it into new products.

There are essentially three generic types of PET bales that are purchased in the PET recycling industry. These are: 1) bales consisting solely of PET carbonated beverage bottles -- referred to throughout the industry as "soda bales"; 2) those that consist of a mixture of soda bottles and "custom" PET containers and referred to in the industry as "curbside bales"; and, 3) bales composed solely of custom-PET bottles -- referred to as "custom bales." The increase of curbside recycling programs around the United States has made curbside bales the most prevalent form of PET offered for sale. (In cases where curbside bales are offered for sale, it is imperative to confirm with a particular purchaser if they have restrictions on the percentage of custom-PET containers that they allow relative to PET carbonated beverage containers.)

Best Practice: To ensure the marketability of post-consumer PET plastic bottles and containers collected through your local recycling program, a best practice is to design a baling system that can achieve the following specifications:

Other Considerations: Some PET purchasers offer differing price structures for the bales they purchase based on the actual composition of the bales in terms of the types and color of PET plastics they contain. In some cases, this may require that bale suppliers meet more stringent specifications. Once again, suppliers should check with their particular purchaser to match these differing prices with their production capacity and the costs necessary to meet these specifications. While many of the prohibited materials identified in these bale specifications will remove the major sources of contamination to the PET recycling process, a supplier must always confirm a buyer's specifications as some may have different requirements for specific plastic resin contaminants that are unique to their process and end-use application.

Discussion: The levels and type of contaminants allowed by baled PET purchasers will depend on the end-use application the recycled PET is intended for as well as the specific processing equipment and system design used by a particular processor. The levels of allowable contamination proposed in these specifications should yield bales that are acceptable to most PET purchasers. The common sense criteria to preparing a high-quality PET bale is that PET purchasers are purchasing exactly that, PET plastic resin from bottles and containers. And, nothing should be added to a bale that is not a PET bottle or screw-neck container.

However, most PET purchasers understand the difficulty for baling operations to produce bales that are 100% free of contaminants, particularly from curbside programs where different recyclable materials are commingled, and therefore allow for some flexibility in the types and levels of contaminants that are acceptable. While contaminants may be allowable, every reasonable effort should be made to remove contaminants prior to baling.

The allowable levels of PVC are based on the rationale that the relative percentage of PVC containers to PET containers is shrinking in the packaging waste stream. Estimates of bottle-grade vinyl resin sales for 1996 provided in the January 1997 issue of *Plastics Recycling Update* indicate monthly sales of approximately 14 million pounds/month or about 170 million pounds in total for 1996. This compares to 1996 sale figures of approximately 2.2 billion pounds of bottle-grade PET resin. Therefore, the natural incidence of PVC to PET bottles in the post-consumer waste stream is no more than 8% by weight. If every reasonable effort to remove PVC containers is made, a 1% or less level is achievable, while providing a realistic tolerance for plastic bale suppliers. In addition, most reclaimers and end-users have sortation capacity to handle this level of contamination, particularly with the increased use of auto-sort technologies.

Many PET markets prohibit *all* PET-G and other extrusion-blown PET (E-PET) containers, most commonly used in containers with built-in handles. These containers have a lower melting point than bottle grade PET resin and can cause a number of technical and operating problems

to PET reclaimers. These specifications prohibit the most common E-PET handleware containers, however, there are some PET-G and other E-PET containers without handles in the post-consumer wastestream that are difficult to distinguish with current sorting technology. The incidence of these containers in the post-consumer wastestream relative to bottle-grade PET is on the order of only 1%. Like multi-layer PET containers, identifying PET-G and other E-PET bottles or containers that do not contain handles is difficult via manual or automated sorting techniques. While some reclaimers specifically prohibit all E-PET containers, others maintain they have developed systems to deal with E-PET to the extent that it occurs in incoming bales. Once again, the concern is in balancing the general quality of baled PET bottles and containers with the costs to the bale suppliers in meeting these specifications.

The proposed PET bale size will allow for the most efficient truck loading and unloading. Standard 48-foot trailers, probably the most popular means of over-the-road transport, have interior loading dimensions of 47.5' long, 101.5" wide and 96"-108" high. With these bale dimensions and these truck dimensions it is possible to stack a truck "row" with six bales, that is, 2 bales wide (with the 48" side stacked in the horizontal direction), and three bales high (the 30" dimension in the vertical direction). This will result in a total of thirteen rows of bales, for a total of 78 bales/truck ($47.5'/42" = 13.6$ rows, therefore 13 rows).

At a bale density of 15-18 lbs/ft³, this will yield bales weighing between approximately 525 and 630 lbs., yielding a truckload shipping weight of 40,000 to 49,000 lbs. This should satisfy any purchaser's minimum shipping weight requirements. While the latter weight is possible with these bale characteristics, it would exceed the maximum legal shipping weight for most 48' tractor trailers, requiring that less than 78 bales be loaded.

While other bale sizes with the same density range can be packed to obtain the desired minimum shipping weights of most purchasers, it will usually require that bales be stacked on end, or some other deviation from the packing structure proposed above. While a trained forklift driver is capable of this type of truck packing, it takes far more time than the configuration proposed.

These bale dimensions should allow for sufficient clearances of the truck walls and ceiling, particularly for those facilities that use forklifts with a two-stage hydraulic system, and therefore facilitate ease and efficiency of loading and unloading. These bale dimensions also allow for meeting minimum shipping weight requirements without packing the truck so tightly that it will be difficult to unload.

The proposed bale densities pose several industry advantages. First is that these bale densities are not high enough to cause significant "sandwiching," that is, clusters of two or more bottles becoming inseparable without pulling them apart by hand. Bottles that become stuck together can lessen the efficiency of some auto-sort technologies for the removal of incompatible resins or colors, particularly those that rely on surface scanning techniques, where one bottle can

“hide” another from the auto-sort detector. In addition, these densities should yield material volumes to achieve the throughput that most auto-sort technologies are designed for.

Second, higher density bales can cause PVC bottles to shatter under pressure, yielding PVC pieces that can migrate into the opening of PET containers, or create pieces so small that they cannot be recognized by manual or automated sortation systems. Even these small amounts of PVC entering a grinder could yield a box of regrind that exceeds acceptable levels of PVC contamination for many end-use applications.

Third, this bale density will yield the required minimum shipping weights required by most processors (30,000 lbs. - 40,000 lbs/truckload). This bale configuration will also satisfy most export shipping weight requirements.

The bale wire configuration proposed should limit the amount of metal that a processor needs to handle as a by-product. Using a non-corrosive galvanized metal wire prevents bale wires from “popping” due to corrosion if stored for prolonged periods of time. Single direction wire wrapping makes it easier and safer for debaling. All in all, these bale wire specifications should lead to bales that maintain their integrity throughout loading, shipping, unloading and storage. Bales that break open during shipment are a tremendous cost burden to purchasers, and most will apply price penalties for any bales that do break, particularly if it occurs repeatedly by the same supplier.

Best Practices and Industry Standards in PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Safety Issues at the PET Intermediate Processing Facility

Maintaining a safe workplace environment is essential for reducing the incidence of worker injury, complying with safety regulations at the federal state and local levels, reducing liability costs associated with worker injury, and is corporate best practice in maintaining the health and well-being of its employees.

There are many laws and regulations that deal with worker safety at the federal, state and local levels of government. It is every facility operator's responsibility to make sure that they are in compliance with all laws and regulations. The most important law in workplace safety is the federal Occupational Safety and Health Act. This law is administered by the Occupational Safety and Health Administration (OSHA), a division of the federal Department of Labor. Unlike other regulatory agencies that may have jurisdiction over the operations of recycling facilities, OSHA does not issue permits for construction or operation, which could help define worker safety requirements for specific types of operations. Given the number and complexity of safety regulations, many plastics recycling companies have a designated compliance officer who is responsible for identifying and complying with all regulations that might effect a facility's operations.

OSHA regulations and standards are contained in two volumes and are quite extensive (CFR 29, Parts 1900 to 1910.999, and CFR 29, Part 1910, Secs. 1910.1000 to end). OSHA regulations relate to almost every aspect of a facility's operation and include such generic regulatory categories as processing, receiving, shipping and storage practices; the general condition of the building and grounds; exiting or egress; general in-plant housekeeping practices; electrical equipment; lighting; heating and ventilation; machinery, personnel, hand and power tools, chemicals, fire prevention, maintenance, personal protective equipment and transportation, that must be complied with in specific detail.

Hazards at plastics recycling facilities can be divided into three general categories: 1) health and hygiene hazards (noise, dust, climate, EMFs -- electromagnetic frequencies), 2) safety hazards (vehicle and machine hazards) and, 3) ergonomic hazards (fatigue and musculoskeletal). Compliance with worker safety regulations and proper system design and maintenance are the best practices to be followed to minimize the incidence of workplace hazards. In addition,

reducing fatigue through proper ergonomic design can increase worker productivity and improve material quality at PET processing facilities.

While a discussion of regulatory compliance for all OSHA regulations is beyond the scope of this document, there are a number of major safety issues and safety best practices at PET recycling facilities that should be discussed. Once again, it is the responsibility of the facility operator to ensure that all safety regulations that apply to their specific operations are complied with at all levels of government. And, the Best Practices presented below are not intended as a comprehensive listing for regulatory compliance.

General Safety Best Practices:

Provide all employees with adequate personal protection equipment, which may include such items as safety glasses, ear protection, gloves, hard hats, protective footwear, back-support belts, dust masks, etc.

Make sure all conveyors, balers, grinders, and other processing equipment are equipped with emergency power-cut-off switches (often referred to as “kill” switches) and machine guards. This will allow plant personnel to react to safety hazard or emergency situations or to ensure worker safety during normal equipment operation and when performing equipment repair or maintenance.

Make sure all grinders and regrind evacuation systems (blowers) are insulated or enclosed in a separate room to maintain noise levels below the OSHA regulated noise exposure level for workers.⁴

Make sure that all cyclone discharges from grinders are properly exhausted into baghouse or other dust collection systems, or are otherwise properly filtered in compliance with regulatory requirements, to maintain ambient dust levels within OSHA guidelines.⁵

Ensure that all equipment is properly maintained for safe and efficient operation through the implementation of a regular and preventative maintenance schedule for all equipment within the facility.

Ensure that ergonomic considerations are factored into system design. For example, the width of sorting conveyors must not exceed to ability of the line inspector to

⁴ See CFR 29, Sec. 1910.95. In general, employee noise exposure levels should be maintained below an 8-hour time-weighted average sound level of 85 decibels (as measured on the A scale).

⁵ See CFR 29, Sec. 1910.94(b) and Sec. 1910.94 (b)(4) for a discussion of OSHA regulations pertaining to dust exhaust and ventilation at grinding operations.

comfortably reach the material on the belt, whether single-sided or double-sided sorting stations are used. In addition, proper belt speeds on manual sorting lines can greatly decrease worker fatigue and improve overall material quality.

Provide adequate space for vehicle and worker activities.

Ensure that adequate lighting is provided for general plant visibility and to prevent worker eye fatigue.

Ensure that adequate fire protection equipment is in place based on the nature of the materials being processed and stored, the types of equipment being used, local fire codes and insurance requirements.

Make sure that proper signage is maintained throughout the facility.

If the facility is equipped with sorting systems that use electromagnetic frequencies (EMFs), like x-rays or ultraviolet light, as the detection signal, make sure that the equipment is properly shielded to eliminate worker exposure to EMFs.

Ensure that only trained personnel operate specific equipment and that designated operators have any required operating certificates or licenses for that type of equipment.

Provide adequate disposal containers that are in regulatory compliance for the disposal of oily, hazardous, or combustible wastes.

Finally, hypodermic needles are an increasing safety concern at plastic recycling facilities. Many recycling programs request community members who require intravenous injections to store used needles in plastic containers that are then collected through special needle collection programs. Unfortunately, many of these containers make their way into plastic recycling facilities, increasing the safety concerns of worker exposure to blood borne pathogens. Every plastics recycling facility should have at least one employee who is trained in the proper handling and disposal of used hypodermic needles and has been inoculated for the hepatitis B virus. If a hypodermic needle is identified by an employee, they should hit the emergency cut-off switch for their conveyor or particular piece of equipment. Without handling the hypodermic needle or the plastic bottle containing it, they should notify their supervisor to summons properly trained and inoculated personnel to remove the hypodermic needle from the system. Removed hypodermic needles should then be placed in approved medical waste “sharps” containers for removal by trained medical or medical waste disposal professionals. In addition, if employees should be stuck with hypodermic needles encountered in the workplace, OSHA guidelines for

proper medical attention should be followed for vaccination and post-exposure evaluation and follow-up.⁶

References:

Occupational Safety and Health Administration, OSHA Handbook for Small Businesses, (OSHA 2209, US Department of Labor, Washington D.C.), 1996.

Pytlar, Theodore, S., Jr., "Protecting workers at processing facilities: Solutions and costs," Resource Recycling, (March, 1996) pp. 32-39.

⁶ See CFR 29, Sec. 1910.1030 for the OSHA regulations and procedures related to worker exposure to blood borne pathogens

Best Practices and Industry Standards in PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Sorting Systems: Introduction and Overview

Due to the increase in curbside collection programs that collect recyclables in a commingled fashion, there has been an increase in the need for reliable and effective sorting systems that separate post-consumer PET plastics from other plastic and non-plastic containers and to remove other contaminants that might be present. To recover PET plastic bottles and containers from commingled recyclables, they must be delivered to a MRF and separated from other recyclable materials to prepare them for sale to an intermediate processor, PRF, reclaimer or end-user.

There are two generic types of sorting systems used at plastics recycling facilities. These are manual sorting systems and automated sorting systems. Manual systems rely on plant personnel who visually identify and physically sort plastic bottles traveling over a conveyor belt system. Automated systems employ a detection system, or combination of detection systems, that analyze one or more properties of the plastic bottles passing through and automatically sorts these plastics into several categories, either by resin type, color, or both.

The sorting system chosen for a particular facility is a function of several important factors. While cost factors influence system purchasing decisions, sorting system design is primarily a function of incoming plastic quality and level of commingling of plastic containers of different resin types. For example, bales of resin-segregated PET bottles and containers lend themselves to one type of sorting, while bales of two or more commingled plastic container types may require a different approach.

In addition, sorting system design will depend on whether the plastics recycling facility is baling or granulating the plastics they receive from their suppliers. For example, baling operations at MRFs, IPCs or PRFs generally use less expensive and less sophisticated sorting systems than PRFs that debale, sort and granulate incoming bales of plastic into individual resin and color categories for sale to reclaimers and end-users. PRFs that granulate PET plastic bottles and

containers often combine manual and automated sorting systems to ensure the highest level of quality control for the regrind they produce.

Regardless of the specific type of plastic recycling facility and the sorting system used, there are several design elements that can be incorporated into a sorting line that will help minimize the presence of contaminants that must be removed either manually or automatically and improve the overall quality of the PET recovered. Whether plastic bottles or containers are entering a facility in loose or baled form, most system designs will feed plastic bottles via an inclined conveyor system to a horizontal conveyor system from which containers will be sorted. A best practice for sorting system design is to install a screening device over which incoming material will pass prior to moving on to the next stage of the sorting process. Screening will remove grit, dirt, broken glass and other non-plastic contaminants and pieces of non-PET plastic caps, base-cups and bottles that can get trapped inside bottles and potentially contaminate regrind. This can be accomplished by using various commercially available screening devices, such as trommel screens, or vibrating screens (also called “shaker tables”) that the PET bottles and containers pass over before they are discharged onto the sorting line.

In some cases simpler systems can be used, for example, screen tables onto which incoming plastic bottles are placed and then raked across by plant personnel into the feed hopper of the sorting system. Screens can also be installed in the conveyor system where materials drop from one conveyor to another. This design feature can greatly reduce the amount of smaller contaminants that might be difficult to identify and remove later in the sorting process by either manual or automated systems.

What follows is a brief description and discussion of manual and automated sorting systems. This discussion is directed towards plastics intermediate processing facilities that are granulating PET plastic bottles and containers for sale to reclaimers or end-users. This is followed by Best Practices for each system category.

Manual sorting systems

Manual sorting systems use trained inspectors to visually identify and sort PET bottles and containers into designated categories from a stream of plastic bottles passing over a conveyor. Manual sorting systems are generally one of two types -- positive or negative sort systems. In a positive sort system, PET bottles and containers are removed from a stream of plastic containers being carried over a conveyor system. In a negative sort system, PET bottles and containers are left on the conveyor system and unwanted materials or contaminants are removed from the conveyor line.

When PET bottles and containers are removed in a positive, manual sort, they are either fed directly into a granulator or onto a second conveyor system that feeds into a granulator. The advantage of a system where line inspectors feed a second conveyor is that the second

conveyor can be designed to incorporate an automated sorting system as a final check for PVC prior to feeding the granulator.

Throughout the plastics recycling industry, positive sort systems are considered best in generating the highest quality materials. However, they may not always result in the most efficient system as positive sorts are generally more time consuming than negative sorts. The sorting capacity of plant personnel working on manual sorting lines is a function of the quality of incoming materials, system design and belt speed.

Negative manual sort systems are generally considered to have a potential for greater levels of contamination as many negative sort systems are configured to discharge materials left on the conveyor belt directly into a baler or grinder. If the removal of unwanted materials is not complete, these unwanted materials will enter the next stage of processing and possibly yield contaminated material. However, negative sort systems work well if materials have been “pre-sorted” into specific categories. (Negative sort systems also work well for baling operations). For example, it is easier to pick out contaminants from a stream of predominantly PET soda bottles, rather than to pick out the soda bottles. Some negative sort systems are designed to have inspectors sort from both sides of a conveyor that feeds directly to a baler or grinder to increase material throughput.

Ultimately the choice between positive and negative sort system designs will depend on program budget and the supply characteristics of incoming materials. For example, mixed plastic bottles, whether loose or in bales, are best sorted with a positive sort system, whereas resin segregated plastic bottles may lend themselves towards a negative sort system.

Studies of commercial, manual, visual sortation systems conducted by Plastic Technologies, Inc. (PTI), of Toledo, Ohio, indicate that trained inspectors are capable of sorting 500 to 600 pounds of PET per hour and are more than 80% effective at identifying and removing PVC from the line. However, sorting capability is always a function of the density of plastic bottles feeding the line, belt speed, and the number of plastic bottle types mixed in the stream.

It is often difficult to visually distinguish PVC bottles from PET bottles without individually inspecting a bottle for a characteristic molding mark or looking for crease marks that occur on PVC bottles when pinched. This is particularly true when a large number of bottles are passing over a conveyor surface and such individual bottle inspection is not cost effective. The efficiency of visual, manual sorting systems in removing PVC from PET can be improved through the use of ultraviolet (UV) light. While ultraviolet light is not visible to the human eye, certain materials, because of their unique chemical structure, emit visible light when exposed to ultraviolet light which can then be detected by the human eye. When materials emit light when exposed to UV light they are said to fluoresce.

PET is fluorescent and appears blue when exposed to UV light. The chemical structure of PVC does not cause fluorescence, but many of the additives used in the manufacture of PVC bottles

do. These additives will cause PVC bottles and containers to appear yellow or green when exposed to UV light. By designing systems that expose bottles passing over a conveyor to ultraviolet lights, removal efficiencies for PVC by trained personnel can increase to as much as 99% under the proper conditions, according to PTI. Because of the concentration required by this kind of identification procedure, it is recommended that line inspectors work no more than two hours at a time.

However, there are limits to the effectiveness of sortation with UV light. “Pre-sorting” is necessary prior to UV sorting of PVC from PET. For example, green PET bottles must be sorted out, as green PET bottles will remain green when exposed to UV light and can be confused with PVC. Because UV light can degrade certain plastics over time, many PVC and PET containers are manufactured with additives to absorb the UV portion of natural sunlight to protect the products contained in them. These containers will appear dark under UV light and are difficult to detect. Some blue tinted PVC bottles can fluoresce blue under UV light and be confused with PET bottles, adding to its limitations. Finally, some forms of UV light have been linked to the formation of cataracts and skin cancer. Although the type of UV light used in sort systems is considered safe, systems should be designed with shields and viewing windows that filter out UV light to prevent worker exposure and avoid any possible exposure risks.

Automated Sorting Systems

Automated sorting technologies (referred to generically as “auto-sort” systems) are increasingly used at the intermediate processing level and even more extensively by reclaimers and end-users to obtain contaminant free streams of PET bottles and containers for subsequent processing. There are many different types and manufacturers of auto-sort technologies on the market today, but they can be classified into a few general types. These technologies employ some type of detection signal that can differentiate plastic bottles based on chemical or physical characteristics when that signal is detected and analyzed by a sensor.

There are three basic types of detection systems used in the plastics recycling industry today. The first are optical sorting systems. Optical sorting systems use visible light to separate plastic bottles by color. The second are systems based on “transmission technologies” whereby a signal passes directly through the bottle and is read by a sensor on the other side of the bottle. Each plastic resin has a characteristic response to the signal based on its unique chemical composition. The third are surface scanning devices where the signals bounce off the surface of the bottle and are reflected back to the sensor for identification. Similarly, each plastic resin type has its own unique response. When a sensor detects what it is looking for, it will generally activate an air jet that will eject or direct the item it has positively identified. The major sortation technologies in use today include optical, X-ray transmission (XRT), X-ray fluorescence (XRF), and near-infrared (NIR).

Some auto-sort technologies are capable of multiple sorts, by both resin type and color, while some are known as “binary-sort” systems -- namely those that identify just one item and

separate it from a stream of bottles. The first generation of auto-sort technologies were binary-sort systems primarily developed to provide reliable separation of two visually similar, yet highly incompatible plastics from a recycling perspective -- namely PVC and PET. As has been discussed elsewhere in this document, PVC is a major contaminant in PET recycling even at very low concentrations.

The current state-of-the-art in auto-sort technology combines several types of sensors to provide multiple sorting functions for streams of commingled plastic resin types. For example, one commercial system uses an XRT sensor to separate PVC bottles, then an infrared sensor that separates bottles into clear, translucent and opaque categories, followed by optical sensors that sort bottles by color, and finally an NIR sensor to separate the bottles by resin category. What follows is a brief overview of the major types of auto-sort systems in use today at PET plastics recycling facilities, including their limitations and advantages.

X-Ray Sortation: Auto-sort technologies based on X-ray detection are generally considered to be the most reliable binary-sort method to sort PVC from a stream of predominantly PET bottles. This is because X-rays sensors only detect the presence of a single element, the chlorine atom found in PVC bottles but absent from PET bottles. This makes it extremely accurate for differentiating between PVC and PET, but not for identifying other plastic resin types.

There are two kinds of X-ray detectors currently available. The first is X-ray transmission (XRT) and the second is X-ray fluorescence (XRF). XRT signals pass through a bottle and are read by a sensor on the other side. Because XRT signals pass right through a bottle, they ignore such items as labels and other surface contaminants that can lead to false readings with other detection systems. This technology has additional benefits in that it can read the chemical content of bottles when they are stuck together, which is a common occurrence when bales are packed too densely. For example, if a PVC bottle is stuck to the bottom of a PET bottle as it passes over the sensor, the signal will pass through the two bottles and detect the PVC bottle and eject both bottles from the stream.

The primary drawback to XRT systems is that flattened or partially flattened bottles can scatter the detection beam, which prevents the sensor from getting a reading on the other side. XRT systems are programmed to eject bottles that it cannot read. A good way to prevent losses of PET that may result from this or from bottles that are stuck together and ejected is to physically separate rejected bottles by hand and pass them through the system again.

In XRF detection systems, the X-ray detection signal bounces off the bottle surface and the reflected signal is read by the sensor. The limitation with all surface scanning techniques is that it will not detect a PVC bottle that is shielded from the signal by another bottle. Therefore it will not detect a PVC bottle that is stuck to the back of a PET bottle as it passes over the sensor. In addition, surface scanning signals might be affected by surface contaminants such as labels and caps and may cause PET bottles it be incorrectly ejected. If using XRF or other surface

scanning auto-sort technologies it is important that the system be designed to provide a “singulated” stream of bottles (one bottle at a time) passing over the signal and sensor. This is usually a function of debaling and how well bottles are separated prior to entering the auto-sort system. This will prevent the shielding effect described above that can allow PVC to stay in the PET bottle stream.

Because X-rays are a form of radiation, precautions must be taken to protect workers from exposure. X-ray systems include sophisticated shielding to eliminate worker exposure. In addition, X-ray detection systems must be registered with the Nuclear Regulatory Commission.

Near Infrared Sortation: Near infrared (NIR) is a portion of the light spectrum that is invisible to the human eye. When plastic bottles are exposed to NIR signals, each plastic resin will absorb the light in its own unique way, which can then be detected by the sensors. Therefore NIR it has the ability to differentiate between a wide range of plastic resin types, depending on the specific system design.

Like XRT, NIR signals pass completely through the scanned plastic bottle and can detect bottles that are shielded by other bottles when passing over the sensor. An advantage of NIR systems is their ability to detect multi-layer and composite container structures. Some of these containers can pose contamination problems in the PET recycling process and are difficult to identify visually. The ability of NIR to distinguish these containers is increasingly important for PET processors, given the proliferation of multi-layer and composite container constructions in the packaging wastestream.

However, also like XRT, NIR detection signals can scatter inside partially flattened containers, which prevents the signal from being read by the sensor, causing the container to be ejected. NIR is limited when incoming PET containers are extremely dirty and dirty clear containers may incorrectly identified as green or “opaque.” The advantage to X-ray detection systems is that NIR systems involve no known workplace hazard issues.

Best Practices and Industry Standards in PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Sorting

Issue: To meet the quality standards represented in these Best Practice specifications for PET bales and PET regrind, sorting systems should be installed that are designed to remove contaminants to the PET recycling process. Regardless of the actual sorting system design used, it should at a minimum be able to sort out and remove the following materials from acceptable PET bottles and containers for recycling:

- ANY *PET* BOTTLE WITH A BUILT IN HANDLE
- ANY *PET* BOTTLE OR CONTAINER THAT IS NOT CLEAR OR TRANSPARENT GREEN
- ANY NON-BOTTLE *PET* ITEMS SUCH AS SCOOPS, TRAYS, CLAMSHELLS, DRINKING GLASSES, ETC.
- ANY OTHER NON-BOTTLE PLASTICS
- ANY NON-*PET* PLASTIC BOTTLES
- ANY BOTTLES OR CONTAINERS WITH CONTENTS
- ANY FORM OF PVC PLASTIC
- ANY PLASTIC CONTAINER OR BOTTLE THAT PREVIOUSLY CONTAINED ANY HAZARDOUS OR POTENTIALLY HAZARDOUS MATERIAL (including but not limited to agricultural products, pesticides, herbicides, automotive fluids, medical products -- drugs, IV solutions, flammable, corrosive or reactive liquids, grease and solvents)

Best Practices: Manual Sorting Systems

The overriding best practice in manual sorting systems used at plastics intermediate processing facilities is adequate training of plant personnel in the identifying characteristics that will visually distinguish PET plastic bottles from plastic bottles of different resin types, and in distinguishing acceptable PET items from unacceptable PET items for recycling. This discussion will assume that the PET processor is accepting baled PET bottles and containers and sorting them to

produce high quality PET regrind. Properly trained inspection personnel can become quite proficient in producing high quality PET regrind with little or no unacceptable contamination.

Throughout the PET plastic recycling industry, positive manual sort systems are considered to produce the highest quality PET regrind. However, the quality and production capacity of manual sort granulating operations are dependent upon a number of factors including the quality and level of commingling of incoming plastic bottles and containers, how consistently material is fed to the sorting line, and matching belt speeds with material quality.

The quality of the feed stream to sorting lines is a function of proper debaling. Whether done manually or with debaling equipment, debaling should accomplish bottle singulation to the greatest extent possible (minimum bottles sticking together), while providing a consistent and uniform flow of materials to line inspectors at the operating belt speed.

Due to the differing nature of bales from various suppliers, manual sort systems should be equipped with variable speed conveyor belts. In this way, the speed of the belt can be matched to the quality of material passing over the line. Higher quality incoming bales can usually be sorted more quickly than lesser quality bales. Belt speeds used by intermediate processors vary widely based on incoming feedstocks and system design and can range anywhere from 30 feet/minute up to 120 feet/minute. However, the best practice in determining belt speed is to match belt speed with material quality and the ability of line inspectors to achieve an effective sort.

Regardless of where line operators feed PET bottles after they have been positively picked from the sorting line (i.e. directly into the throat entrance of a grinder, or to another conveyor that feeds a grinder), best practice is that the feed entrance be located in front of the operator, so that their feed motion is in the forward direction. This will reduce ergonomic hazards than can occur from excessive twisting motions and reduce worker fatigue.

There are two best practices in manual sort system design and configuration, provided they are within your system's budget. The first is a multi-level conveyor system design that provides a return loop. In this way, unsorted PET bottles and containers that reach the end of the sorting conveyor drop down to a return conveyor and are returned to the feed hopper to start the sorting cycle over. This system design can greatly decrease processing waste.

Similarly, proper placement of grinders relative to multi-level conveyor configurations allows flexibility to adapt from positive sort feeds to negative sort feeds based on the quality of incoming materials. This is generally accomplished by an interchangeable discharge at the end of the sorting conveyor that can discharge to a return conveyor in a positive sort mode, or directly into a grinder in a negative sort mode.

Best Practices: Automated Sorting Systems

Like manual sort systems, the efficiency and throughput of many auto-sort systems is primarily a function of incoming bale quality and debaling capacity. As described in the summary of auto-sort systems, the effectiveness of these systems is often a function of how well bottles are separated from one another, or “singulated,” prior to passing over the detection head. Therefore it is critical that adequate debaling capacity is in place to achieve this level of bottle singulation. The density of incoming bales will determine the ease and rate at which they can be debaled and fed into the auto-sort system. Bale density will also determine the extent to which bottles are flattened which can adversely affect the performance of certain auto-sort technologies.

The rejected materials from auto-sort systems should be collected, manually sorted and passed back through the system to eliminate losses of mistakenly rejected PET bottles.

While auto-sort technologies provide a highly pure stream of PET plastic bottles and containers to feed granulating equipment, a best practice is to design sort systems that incorporate a double-pass through the system or a secondary sort that provides one last inspection for PVC prior to being fed into grinders. The secondary sort can be manual or automated.

Any facility operator that utilizes auto-sort technologies must ensure compliance with all safety and other regulatory requirements to which its use is subject. For example, all auto-sort technologies that use electromagnetic frequency (EMF) detection technologies should be properly shielded to eliminate any worker exposure to EMFs. And, the use of X-ray sorting technologies will require registration with federal, state, and/or local nuclear regulatory agencies.

Best Practices and Industry Standards in PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Baling Procedures and Best Practices

For IPCs and PRFs that bale PET bottles and containers for sale to reclaimers or end-users, there are a number of general considerations to be taken into account beyond the general quality issues described in the *Bale Specifications* section of this report. The choice of specific baling equipment for your facility will be a function of your recycling program design and budget, specific market specifications, and facility throughput requirements. The final decision on your baling system must balance cost and performance issues that fit within the limits and requirements of your particular PET recycling program.

There are essentially two types of baling equipment available on the market. The first are known as vertical or “downstroke” balers. The second are known as horizontal balers. These are distinguished by the orientation of the shaft that drives the compaction ram of the baler.

Generally, horizontal balers are considered superior, as they have a motor and piston/cylinder configuration that can achieve greater compression ratings than most vertical balers. Horizontal balers are best for achieving the desired packing densities that most PET bale purchasers require (15-18 lbs/ft³). Horizontal balers are generally more costly than vertical balers. Horizontal balers are generally more automated and may be equipped with features such as “auto-tie” systems that automatically wrap baling wire around the bale when it is finished, or automated compaction systems that have photoelectric sensors that can detect when the bale chamber is full and automatically begin a compaction cycle. Once again, the additional costs of these systems need to be compared to their performance benefits for your PET recycling program

Depending on the type of baler used by a particular facility, it may be necessary to remove caps from PET bottles and containers or to install perforators (*NOT* shredders) to puncture bottles that contain caps prior to baling them if your facility receives a high percentage of PET bottles and containers with caps. PET bottles and containers that have caps on them can trap air inside the bottles. Smaller balers that do not have adequate compression capacity to “burst” the air trapped in capped bottles can result in lighter bales that will not meet a purchaser’s minimum shipping weight specifications. When purchasing balers, it should be determined from a

manufacturer at what compression rating their equipment is capable of “bursting” bottles with caps, such that it is no longer necessary to de-cap or perforate. The costs and benefits of these systems should then be compared to make a final choice.

Regardless of the type of baler used at a facility, the following general rules should be applied when preparing bales of PET bottles and containers that meet the PET Bale Specifications provided in this document:

- wrap baling wire in one direction only
- use only non-corrosive galvanized metal baling wire to wrap bales
- do not use “headers” made of cardboard or other materials at each end of the bale (baling systems that achieve the desired bale densities of 15-18 lbs/ft³ will not require the use of headers to maintain bale integrity)
- do not double wrap baling wire
- properly maintain baling equipment by scheduling regular checks and necessary replacement of hydraulic fluid levels and filters

Following these simple rules will assist in providing uniform bales that will improve debaling operations and reduce processing wastes at PET intermediate processors, reclaimers or end-users. In addition, proper maintenance will maximize the performance and economics of your baling operations.

Best Practices And Industry Standards In PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Granulating

Issue: Properly designed and maintained PET granulating systems will optimize material quality, production efficiency and throughput, and general workplace safety.

Best Practices: To recap, the first best practice is to make sure that the quality considerations detailed in the *Introduction and Contamination Issues, PET Re grind Specifications* and *Sorting* sections of this document are adhered to when grinding PET bottles and containers for sale to reclaimers or end-users.

There is no best piece of granulating equipment that can be recommended for use at PET intermediate processors. There are many types, sizes and manufacturers of granulators, or grinders, and regrind evacuation systems currently available that provide quality grinding capacity. Grinders come in many design configurations in terms of infeed size and type, motor size, grinding chamber size, the type of cut performed, etc. The specific choice of granulation system for a facility is a function of program budget, anticipated throughput, overall system design and plant layout. However, there are some basic grinder design types that should be specified when purchasing grinders for your facility and some best practices for their proper maintenance and operation in your facility's grinding operation.

Granulators operate as follows. They generally contain two sets of cutting blades. One set is fixed. The fixed blades are known as bed blades. The other set is mounted on a spinning rotor that cuts PET bottles against the bed blades as material is fed into the cutting chamber. These are called the rotor blades. The number of bed and rotor blades used in grinders varies with the specific equipment. At the bottom of the cutting chamber is a metal "screen" with a specific hole size. When PET bottles are cut small enough, the granulated material will fall through the holes in the screen and enter a regrind evacuation system. A blower removes ground PET from the grinder and blows it through ducts to a cyclone, from which it is discharged into boxes.

Based on a survey of PET plastic grinding facility operators, the consensus is that the best grinder design is grinders with open rotors, that are tangentially fed and perform a "scissor-cut" of bottles entering the cutting chamber. The best cutting blades for these systems are known as

“back-angle” knives. It should be noted that this grinder design works best for whole bottles at intermediate processing capacities of less than 3,000 pounds per hour. PET plastic reclaimers and end-users that require greater processing capacity use completely different grinder types that are specially designed for larger processing volumes. These include “hog” grinders and wet grinding systems.

In addition to the grinder itself, granulating systems also consist of the regrind evacuation system which includes a blower, ductwork, and cyclone, where regrind is removed from the grinder and blown through the cyclone, which then discharges the regrind into a box, while venting small dust particles through an exhaust port (these small dust particles are known throughout the industry as fines, and are generally undesirable). It is very important when purchasing a granulation system to work closely with the equipment manufacturer or sales representative, and to provide adequate information to ensure that the grinder and evacuation system you purchase are properly and adequately sized to handle the anticipated throughput of PET plastics that will be processed and are consistent with overall facility design. In addition, it is important to specify to a manufacturer whether your facility will be grinding predominantly flattened, partially flattened bottles (i.e, from bales), or unflattened, whole bottles. Generally, grinders will have higher throughput when bottles are flattened. However, the volume and nature of the PET bottles fed to a grinder will impact such items as the entry feed, or “throat,” size.

Once a system has been selected, there are a number of installation best practices that will ensure safe operations of that equipment (and may be regulatory requirements). The first is that all grinding equipment and the conveyors that feed them should be equipped with emergency shut-off switches that will cut power to the system in an emergency or safety hazard situation, or when maintenance is required. Second, all employees feeding grinders should be trained in their proper operation. Third, grinders and regrind evacuation systems should be soundproofed to maintain noise levels within regulatory worker noise exposure limits. Finally, all cyclones should be properly vented and exhausted in a fashion consistent with applicable regulatory requirements. For example, applicable regulations may require the use of baghouse filters, or other dust collection systems.

There are several maintenance best practices that can greatly increase the performance and material throughput in your grinding system, and can ensure the quality and marketability of the regrind your facility produces. While trained grinder operators can usually hear or see when equipment needs maintenance, every facility should have a schedule of regular and preventive maintenance performed on their granulation system equipment.

Proper blade maintenance is crucial to material quality. The distance between the rotor and bed blades in a grinder are gapped to very small tolerances that must be maintained for efficient cutting. This gap distance may change during normal operation. In addition, blades need to be kept sharp for maximum operating efficiency. Proper blade sharpness and gapping are essential to produce quality regrind. Trained operators can tell from the quality of the regrind produced when blades are beginning to dull. This can usually be identified through the detection of excessive amounts of fines, or plastic dust, or regrind particles that do not have a “clean” cut. It

is a best practice to have a full, sharpened set of extra blades for each grinder in operation. When the blades are dull, the extra set can be installed and the dull set sent out for sharpening. It should be noted that blade life between sharpenings can be extended by re-gapping.

Maintaining clean screens in grinders will also maintain optimal material throughput. The size of the screen used in your grinder will depend on your particular regrind purchaser's specifications, however, 3/8" to 1/2" screens are probably the most common. If screens are clogged, plastics will remain in the cutting chamber of the grinder longer. When this occurs, the heat build-up in the cutting chamber can melt plastics to the screen, further clogging them. A best practice is to clean screens with a wire brush at the end of each shift. If the screen is excessively clogged it should be replaced while it is cleaned.

Another maintenance best practice is to keep a supply of spare parts for items that commonly fail in grinding systems, including, but not limited to, spare screens, heater coils, belts, and even starter motors. This will facilitate in-plant repairs and lessen downtime on equipment.

Another best practice is to perform all equipment maintenance "off-shift" so that production is not impacted. Finally, grinders should never be turned off with materials still in the cutting chamber, unless in an emergency. If too much ungranulated material is in the cutting chamber of a grinder when it is turned on, electrical failure is common, as it will impede proper movement of the rotor. If a grinder must be stopped for any reason while the cutting chamber is full, the cutting chamber must be cleared of all material prior to resuming operation.

One last best practice in PET plastic granulating is to properly mark or label each box of regrind produced, so that if a processing problem occurs at a reclaimer's or end-user's facility, the exact conditions of the regrind manufacture can be traced back. This is often helpful in resolving costly disputes regarding contaminated materials and the financial costs they can impose. At a minimum each box should be marked, or labeled, in such a way as to identify the source of the material (to inform suppliers of quality issues if they arise), the operator who prepared the material, the particular equipment it was ground in, the date it was produced, as well as the full, tare, and net weights of the box. If PVC test results are available, they should also be indicated.

Best Practices And Industry Standards In PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Dirty Regrind Specifications

Issue: The quality requirements for PET regrind are far more demanding than for baled PET. And, the allowable levels of contamination in PET regrind are in the parts per million range. The quality of PET regrind is crucial to the efficiency and economics of subsequent PET recycling processing stages. Producing dirty regrind that meets the following specifications will ensure the ability to market granulated PET.

Best Practice: The proposed best practice post-consumer PET “dirty” regrind specifications that follow are not intended to meet any one company’s individual specifications, but to represent a standard that will be acceptable to most PET purchasers and ensure a quality standard that can reduce the cost of the PET recycling process. While the proposed specifications may represent a standard which is acceptable to most of the PET recycling industry, every PET processor has specific requirements based on their particular processing system and the end-use application for which the recycled PET is intended. Therefore, suppliers must always determine the exact levels of contamination that a particular purchaser accepts as well as any other unique purchasing specifications they might have.

Unlike baled PET bottles, specifications for PET regrind vary by color and by the end-use application for which they are intended. As a general rule of thumb, higher value end-use applications demand higher quality regrind, particularly in regard to PVC contamination.

The following PET regrind specifications are broken down into four end-use categories as follows: *Packaging, Sheet and Film; Engineered Resins; Strapping; and, Fiber Applications.*

These specifications assume that all other quality and processing *Best Practices* presented in this document have been followed. The allowable levels of the contaminants listed in the specifications are the only types of contamination that are permitted. If a material does not have a specified level of contamination in a particular end-use category, its presence is not acceptable at any level.

Regardless of the particular specification for which you are preparing PET regrind, the following general best practices should be followed:

- mark or labels boxes of regrind with weight information (gross, tare and net weights)
- mark or label boxes to trace conditions of manufacture, including information to identify the supply source, the grinding equipment it was produced with, the operator who produced it, the date it was produced and any other quality data that is available
- boxes should be packed and shipped in sound corrugated “gaylord” boxes and on pallets that are capable of containing approximately 900 lbs. of regrind and that will maintain their integrity in handling and shipping
- all boxes should be clean to avoid contamination from previous contents
- if used corrugated “gaylord” boxes are used, liners are required
- all boxes should be capped and strapped with lids

Best Practices And Industry Standards In PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Storage: Baled PET

Issue: Properly stored bales help maintain the quality of prepared post-consumer PET plastics prior to sale and help improve workplace safety. Improperly stacked bales can fall causing serious injury to workers or damage to equipment at PET processing facilities.

Best Practices: In general, baled PET plastics should be stored in a fashion that keeps them clean and dry with limited exposure to sunlight (which can cause ultra-violet degradation of the PET plastic). Bales should be stored indoors. If they must be stored outdoors, they should be covered to limit exposure to moisture or sunlight. Bales should be stored on pallets or on clean, dry surfaces to avoid the introduction of contaminants. This is particularly true for plastic recycling facilities that handle more than one resin type of plastic.

When transporting bales throughout a facility, caution should be taken against pushing bales directly across the floor surface as this may embed unwanted contaminants into the bale. Bales should always be transported in a fashion that keeps them elevated off the floor surface. PET bales should not be stored in proximity to plastic granulators or other processing equipment to prevent the introduction of contaminants.

Proper stacking of bales is imperative to safe operations within a facility. Improperly stacked bales can fall, causing serious injury to workers or damage to plant equipment. The safe stacking height in a facility is a function of bale integrity, bale dimensions and ceiling height. In addition, there may be a number of regulatory limits to stack height and configuration based on local fire codes or buildings department regulations. For example, fire codes will require such things as proper clearances from sprinkler heads, that stored materials do not block aisles or points of exit or egress. Building codes may have limits on the amount of floor space that can be occupied with stored materials, or the load capacity for storage floors that are not on grade. Finally, the federal Occupational Safety and Health Administration (OSHA) requires compliance with all local requirements.

When stacking bales against a solid wall, it is important that the bottom bale of the first stack placed against the wall is not pushed flush against the wall, but set out about 6 inches so that the

upper bales on a stack can lean into the wall and not away from it. When bale stacks are not placed against a stationary wall, many facilities will “build” their stacks sequentially. That is, a forklift operator will not go to full height on an individual stack before starting another stack. In this way subsequent stacks reinforce the integrity and help brace the previous stack.

Baled material should be weighed and “tagged” with those weights prior to storage. This can help in weight determination when loading out truckload shipments (and ensuring that legal shipping weights for over-the-road transport are not exceeded) or in resolution of possible disputes regarding shipment weights.

Facilities that receive bales should store them in distinct “lots.” This is usually done in lots based on the material supplier. By storing materials in lots, it is easier to identify the source if inferior quality material is discovered during processing or if punitive price adjustments need to be made based on material quality or weight discrepancies. If the receiving facility is equipped with a platform or forklift scale, it is good practice to weigh a representative number of bales to verify the accuracy of packing list weights in the absence of weight tickets from certified truck scales.

Best Practices And Industry Standards In PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Storage: PET Regrind (dirty flake)

Issue: Properly stored boxes of PET regrind help maintain the quality of prepared post-consumer PET plastic regrind prior to sale and further processing, improve workplace safety, and limit the economic losses associated with improper storage. Improperly stored PET regrind subjects it to contamination, causing it to be rejected by a purchaser. Improperly stacked boxes can fall causing serious injury to workers, damage to PET processing equipment, or costly material losses.

Best Practices: PET plastic regrind produced by PET processors should be ground into and stored in clean, cardboard boxes (referred to throughout the recycling industry as gaylords⁷ and which are approximately one cubic yard in volume and capable of holding quantities of PET flake in the range of 600-1000 pounds) and on shipping pallets of adequate size and strength that will maintain their integrity during handling, storage, and transport. If the intermediate processing facility is equipped with a platform scale, tare weights should be determined for each pallet and box pair and recorded in some fashion on the box. This will help in determining the net weight of the PET contained in each box when full.

PET regrind should be stored indoors to keep it clean and dry with limited exposure to sunlight. Boxes of regrind should be stored in locations that limits introduction of contamination. This is best accomplished by “capping” and “strapping” all full boxes of PET regrind by strapping a cardboard top to each full box. In addition the use of lids helps prevent top boxes from falling into bottom boxes and splitting them when stacked. In cases where used boxes of sufficient quality are used to store PET regrind -- a common reuse practice within the plastics recycling industry -- it is best to line them with a plastic liner bag to prevent possible contamination from the previous contents of the box . The use of box liners eliminates the need for caps as they can

⁷ After a major cardboard container manufacturer of the same name.

be tied off when full. In lieu of the use of plastic box liners, all boxes should be thoroughly cleaned prior to use.

If the intermediate processing facility is equipped with a platform scale, the weight of each full box should be recorded on the box. The tare weight previously recorded should be subtracted from the gross weight to determine the net weight of the PET contained in the box. These weights can then be used to prepare a detailed packing list or shipping manifest to accompany bills of lading for each shipment and avoid potential shipping weight disputes that sometimes occur.

Proper stacking of boxes is imperative to safe operations within a facility. Improperly stacked boxes can fall, causing serious injury to workers, damage to plant equipment, and loss of finished product. Forklift operators should have the proper experience in matching boxes and pallets when stacking boxes to ensure stack integrity. Boxes of regrind should not be stacked greater than three high. Stack heights greater than this can exceed the structural capacity of the lower boxes, causing them to fall. Safe regrind stacking height in a facility is a function of box and pallet integrity and ceiling height. In addition, there may be a number of regulatory limits to stack height and configuration based on local fire codes or building department regulations. For example, local fire codes may require proper clearances from sprinkler heads, or that stored materials do not block aisles or points of exit or egress. Building codes may have limits on the amount of floor space that can be occupied with stored materials, or the load capacity for storage floors that are not on grade. Finally, the federal Occupational Safety and Health Administration (OSHA) requires compliance with all local requirements.

For facilities that grind more than one type of post-consumer plastic resin, PET regrind should be stored in separate locations from other plastic resins. It is best to provide a physical barrier - - for example, plastic curtains --between the storage locations for different plastic resin types to prevent contamination if stacked boxes should fall.

Finally, extreme caution should be exercised for any facility storing PET regrind that is known to contain a high percentage of edible oil bottles. The presence of excessive levels of edible oil contamination is the suspected cause of a number of spontaneous combustion fires of stored plastic regrind throughout the recycling industry. While the number of these incidents is small, regrind suspected of containing high levels of edible oil contamination should be stored in well ventilated areas with adequate fire protection equipment capable of suppressing a spontaneous combustion fire.

Best Practices And Industry Standards In PET Plastic Recycling

BEST PRACTICES IN PET INTERMEDIATE PROCESSING

Shipping/Truck Loading, Receiving and Weight Determination

Issue: Properly loaded trucks of PET bales and boxes of PET regrind can ensure regulatory compliance with maximum legal shipping weights, lessen the possibility of contamination, and prevent costly material losses and clean-up expenses due to improper loading. Proper paperwork and weight verification for shipments can help reduce disputes over material quality or quantity.

Best Practices: Prior to loading a truck with PET bales or regrind, the truck floor should be swept to remove any potential contaminants that may be present. Bales should never be pushed across the truck floor surface to prevent potential contaminants from becoming imbedded in the bales. Shipments of PET should always be accompanied with a completely filled out bill of lading, certified weight slips, and preferably, a detailed packing list or shipping manifest from the shipper.

The PET bale size proposed in these specifications (30" x 42" x 48") will allow for the most efficient truck loading and unloading. Standard 48-foot trailers, probably the most popular means of over-the-road transport, have interior loading dimensions of 47.5' long, 101.5" wide and 96"-108" high. With these bale dimensions and these truck dimensions it is possible to stack a truck "row" with six bales, that is, 2 bales wide (with the 48" side stacked in the horizontal direction), and three bales high (the 30" dimension in the vertical direction). This will result in a total of thirteen rows of bales, for a total of 78 bales/truck ($47.5'/42" = 13.6$ rows, therefore 13 rows). This bale configuration will not require special loading, such as standing bales on end, to achieve required minimum shipping weights.

Facility operators should never load broken or partially broken bales. Bales should never be "jammed," or wedged into trucks, as this will adversely affect unloading and could possibly damage equipment.

Based on the actual bale density and the particular truck's legal gross shipping weight, it may be necessary *not* to fill the truck to capacity. This can be determined by calculating the number of bales that can be accommodated without exceeding the maximum legal shipping weight provided to you by your carrier, based on the sum of individual bale weights. In addition, a best practice is to record individual bale weights on a packing list or shipping manifest that can be attached to the bill of lading for the shipment.

In cases where the truck cannot be filled to capacity, bales should be distributed evenly throughout the truck. This may require stacking some rows only two bales high instead of three bales high. The best practice is to distribute the bales along the entire truck floor, that is, from the nose to the tail, even if the maximum stack height is not achieved. In addition, when scheduling trucks for outgoing shipment, a best practice is to always request that the carrier be equipped with "load locks" that are placed across the width of the truck to prevent bales from falling and potentially breaking open during transport. It is also important to specify the truck size you require when scheduling a shipment to make sure that you receive a truck that can accommodate the required minimum shipping weight of your particular supplier. While most trucks use either 48- or 53-foot trailers, there are still some carriers that use 45-foot trailers.

When loading trucks with bales it is recommended that the bottom bale of each stack in a row be loaded singly, with the remaining two bales placed on top as a pair in a separate pass. In this way, forklifts with two-stage hydraulic systems will not hit the roof of the truck. Similarly, when unloading, operators should take off the top two bales of a stack first and then return for the bottom bale.

When loading regrind, boxes should be stacked in "rows" that are two boxes high and two boxes wide. When loading regrind for shipment, the same rules apply as for bales in terms of load distribution, preparation and documentation. Once again the individual weight of each box will determine how many can be put on the truck without exceeding the legal shipping weight of the truck. When loading regrind it extremely important that pallets are well matched to the box and that each stacked pair is stable. This means that boxes are matched such that the pallet under the top box is well positioned and completely straddles the top of the box underneath and that no pallet edge will fall inside the bottom box. If boxes "slip" in this fashion, the entire top box can fall causing material losses as well as costly and time-consuming clean-up. The use of box lids can further prevent boxes from falling into each other.

When receiving bales of PET, trained personnel should visually inspect the load prior to accepting it. The fact that most PET purchasers only accept bales of clear and transparent green PET bottles and containers means that trained facility personnel can usually identify excessive levels of contamination. Visual inspection will quickly identify the excessive presence of such contaminants as non-bottle materials, unacceptable colors, non-PET resins, etc. The basic rule of thumb throughout the industry is that if contamination is visible on the exterior of the bale it is likely to be contained in the interior of the bale. Therefore, poor bale appearance usually indicates poor overall material quality. Visual identification of excessive levels of

contamination is grounds for load rejection. To avoid disputes, it is always best to take photographs of any rejected materials.

The best practice for determining the weight of a shipment is to have trucks weighed empty and full (referred to throughout the industry as the light and heavy weight) on certified 65-foot truck scales that are as close as possible to where the truck is being loaded or unloaded. This will eliminate weight discrepancies that might result from differing fuel levels in the truck. Certified scales are those that have been inspected by their respective regulatory agency for weights and measures for accuracy.

In cases where trailers are dropped for loading and unloading and picked up at a later time, light and heavy weights can be taken on the trailer only. Many carriers that provide trailers in this fashion have the trailer's weight documented.

The sequence of weighing will vary depending on whether you are shipping or receiving. If you are shipping, the truck is first weighed empty, is loaded and then is weighed full. If you are receiving, the sequence is reversed. The difference in the empty and full weights will yield the net weight of PET bales. When shipping PET regrind, the difference in the two truck weights will yield the gross material weight from which the tare weight of the pallet/box pairs must be deducted for the net PET regrind weight. If individual tare weights for pallet/box pairs are not provided with the shipping paperwork, the PET recycling industry rule of thumb is to apply an average pallet/box tare weight of 65-70 lbs.

A general recommendation is that all plastics recycling facilities should be equipped with at least a platform scale, preferably with a digital read-out display. If platform scales are employed, metal guards should be placed around the perimeter to prevent accidental damage from forklifts. If the forks on a forklift hit the side of a scale inadvertently it may throw off the accuracy of the scale. Most platform scales have a load cell in each corner. A quick way to check the accuracy of your scale is to stand on each corner of the scale. The weight that is displayed should be the same at each corner. If it is not, the scale should be readjusted.

A general rule within the recycling industry is that the receiver's weight takes precedence. To ensure that the weights provided by your purchaser are accurate, or in cases where certified truck scales are not available or convenient to shipper or receiver, there are several ways that weights can be determined. If not using certified truck scales for weighing, the method used for determining weights should be determined by mutual consent of both the shipper and receiver. While it may require additional time, it will provide justification when there are disputes over a shipment's weight.

If a shipping facility is equipped with a platform or forklift scale, the best practice is to weigh each bale after it is prepared, and to "tag" it with a bale number and the corresponding weight. If this is done, a detailed packing list can be prepared that itemizes the individual weight of each bale loaded onto a truck. In this way, receivers have a double check against truck scale weights they receive.

Regardless of how bales are weighed, it should be noted that the accuracy of bale weights can be adversely affected by moisture, rain, snow and ice.

When shipping PET regrind, the best practice is to weigh and record the empty and full weight of the pallet/box pair and record these right on the box with a permanent marker. The difference in these two weights is the net PET regrind weight. Once again, a detailed packing list should be prepared from this information.

However, receivers also need to verify weights of incoming materials if they are not equipped with truck scales. One way to do this without weighing every single bale or box in the shipment is to check the accuracy of “tagged” bales or marked boxes. That is, if a bale supplier has supplied the weights of individual bales, weigh a few to verify that the weights provided are accurate. If bales or boxes of PET have not been marked with their individual weights, then it will be necessary to weigh a number of the incoming bales. One common practice is to weigh a representative sampling of approximately 10 bales or boxes. From these ten weights determine the average bale or box weight and then multiply by the total number of bales or boxes in the shipment. This weight can then be used as a check against any incoming weights that have been provided for the shipment.