The Association of Plastic Recyclers

The APR Design® Guide for Plastics Recyclability is the most comprehensive and user-friendly resource outlining the plastics recycling industry's recommendations in the marketplace today. The content has been updated to present a more easily accessed, clearer picture of APR's Recyclability Categories representing today's North American plastics recycling infrastructure. Although it is designed as an online resource, with links to all relevant information, a PDF of the full written document can be downloaded as well.

The APR Design® Guide specifically addresses plastic packaging, but the principles can be applied to all potentially recycled plastic items. APR encourages package designers to utilize its Champions for Change® and Responsible Innovation programs, as well as the APR Design® Guide to create the most recyclable packaging. Assistance is available through APR, APR members, and independent laboratories found in the member directory.

Furthermore, this guide is intended to identify potential areas of improvement, and encourage innovation both in package design and recycling process equipment.

Before accessing the APR Design® Guide for Plastics Recyclability the user should thoroughly understand the fundamentals of its concept. The information detailed throughout is based on the APR's Definition of Recyclable and APR Recyclability Categories outlined below.

SCOPE

This guide covers plastic items entering the postconsumer collection and recycling systems most widely used in industry today. Collection methods include single stream and dual stream MRF's, deposit container systems, mixed waste facilities, and grocery store rigid plastic and film collection systems. The impact of package design on automated sortation process steps employed in a single stream MRF, as well as high volume recycling processes is of primary consideration.

Items recovered in recovery systems where they are source-selected and sent to a recycler specializing in this particular item are specifically excluded from this guide.

APR's DEFINITION OF RECYCLABLE

An item is "recyclable per APR definition" if:

- At least 60% of consumers or communities have access to a collection system that accepts the package

- It is most likely sorted correctly into a market-ready bale of a particular plastic meeting industry standard specifications, through commonly used material recovery systems, including single-stream and dual stream MRFs, PRF's, systems that handle deposit system containers, grocery store rigid plastic and film collection systems.
- It can be further processed through a typical recycling process cost effectively into a postconsumer plastic feedstock suitable for use in identifiable new products.

APR's RECYCLABILITY CATEGORIES

The APR Design® Guide is itemized by package design feature. The recycling impact of each design feature is discussed within the Guide. The APR's position on the design feature is developed considering this impact and broken down into four categories which should be thoroughly understood:

- ***APR DESIGN GUIDE® PREFERRED:*** Features readily accepted by MRFs and recyclers since the majority of the industry has the capability to identify, sort, and process a package exhibiting this feature with minimal negative effect on the operation or final product quality. Packages with these features are likely to pass through the recycling process into the most appropriate material stream with the potential of producing high quality material.
- ***DETRIMENTAL TO RECYCLING:*** Features that present known technical challenges for the MRF or recycler's operations, yield or final product quality, but are grudgingly tolerated and accepted by the majority of MRFs and recyclers.
- ***RENDERS PACKAGE NON-RECYCLABLE PER APR DEFINITION:*** Features with a significant adverse technical impact on the MRF or recycler's operations, yield, or final product quality. The majority of MRFs or recyclers cannot remove these features to the degree required to generate a marketable end product.
- ***REQUIRES TESTING:*** In order to determine the appropriate APR recyclability category, testing per the APR testing protocol is required. The APR category is dependent on the test result.

DISCLAIMER

This guide has been prepared by the Association of Postconsumer Plastic Recyclers as a service to the plastic packaging industry to promote the most efficient use of the nation's plastics recycling infrastructure and to enhance the quality and quantity of recycled postconsumer plastics. The information contained herein reflects the input of APR members from a diverse cross-section of the plastics recycling industry, including professionals experienced in the recycling of all postconsumer plastic bottles discussed in this guideline. It offers a valuable overview of how package design impacts conventional plastics recycling systems and provides useful recommendations on how problems routinely encountered by plastics recyclers might be addressed through design changes that make plastic bottles more compatible with current recycling systems. Because new technological developments are always being made, this guide cannot anticipate how these new developments might impact plastic bottle recycling. Thus, while the information in this guide is offered in good faith by APR as an accurate and reliable discussion of the current challenges faced by the plastics recycling industry, it is offered without warranty of any kind, either expressed or implied, including WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, which are expressly disclaimed. APR and its members accept no responsibility for any harm or damages arising from the use of or reliance upon this information by any party. APR intends to update this document periodically to reflect new developments and practices.

The Association of Plastic Recyclers

APR Design® Guide for Plastics Recyclability
for
PET (Polyethylene Terephthalate, Resin Identification Code #1)

BACKGROUND: Due to its clarity and natural CO2 barrier properties, PET is one of the most widely used packaging resins. It is easily blown into a bottle or formed into a sheet, thereby becoming the resin of choice for many applications. PET does not normally have the desired properties for closures, handles, attachments or labels so other polymers are commonly used for these items and affixed to the PET package. PET properties can be enhanced with colorants, UV blockers, oxygen barriers/scavengers and other additives. Each modification and addition to the base, clear PET in a package must be considered for its effect on the recycling stream. Items should either be economically removed from the PET in the typical recycling process or be compatible with RPET in future uses. The density of PET is 1.38 and so it sinks in water. Closures, labels and attachments should be made from materials with a density less than 1.0 that will float in water and therefore be readily separated from the PET.

The APR's Champions for Change® Program encourages consumer product, plastic package and bottle component manufacturers to work with the APR protocols to determine whether new modifications to a regularly recycled plastic package will negatively impact the recycling process prior to introducing the modification.

The Association of Plastic Recyclers

THE APR DESIGN GUIDE® RECYCLABILITY CATEGORIES AT A GLANCE - PET						
					LINK TO	
FEATURE	APR DESIGN GUIDE® PREFERRED	REQUIRES TESTING	DETRIMENTAL TO RECYCLING	RENDERS PACKAGE NON-RECYCLABLE PER APR DEFINITION	SCREENING/BENCHMARK TEST (indicative only - See definition of Screening and Benchmark tests)	DEFINITIVE TEST
BASE POLYMER:						
PET with a crystaline melting point between 235-245 C	X					
Post consumer RPET content	X					
Blends of PET and other resins		X				PET critical guidance
BARRIER LAYERS, COATINGS & ADDITIVES						
Non-PET layers and coatings		X			Quick Test for Color	PET Critcal Guideance
Degradable additives		X			PET Degradable Additives Test	
Additives		X			Quick Test for Color	PET Critcal Guideance
Optical brighteners			X			
COLOR						
Clear unpigmented	X					
Transparent light blue	X					
Transparent green	X					
Transparent colors other than green and light blue			X			
Translucent and opaque colors including white			X			
Nucleating agents, hazing agents, fluorescers, and other additives for visual and technical effects			X			
Black color				X		
DIMENSIONS						
More 2 dimensional than 3 dimensional (one dimension <2")				X		
All three dimensions < 3"				X		
Greater than 2 gallons in volume			X			
CLOSURES AND DISPENSERS						
Polypropylene or Polyethylene	X					
Closure systems without liners	X					
EVA and TPE liners in plastic closures	X					
Metal parts and foils		X			New eddy current and magnetic test for attachments	Closure Test
Polystyrene or thermoset plastics			X			
Silicone polymer parts			X			
PVC				X		
LABELS INKS AND ADHESIVES						
PP or PE with specific gravity less than 1.0	X					
Full bottle sleeve labels		X				Sleeve Label Test
Pressure sensitive labels		X			Thermoform Label Test	Pressure Sensitive Label Test
Polystyrene labels		X			Labels, Closures and Attachments Floatability Test	
Label systems that sink in water because of substrate, inks, decoration, coatings, and top layer		X				PET Critical Guidance
Paper labels (for pressure sensitive use pressure sensitive category)			X			
Metal foil labels			X			
PVC and PLA labels				X		
Adhesives		X			PET Flake WashTest/Thermoform Label Test	PET Critical Guideance
Non-water soluble/dispersible adhesives			X			
Inks		X			Bleeding Label Test/Flake to Plaque Bleeding Label Test	See appropriate test for label type
Direct printing other than date coding		X			Bleeding Label Test/Flake to Plaque Bleeding Label Test	Direct Print Label Test
ATTACHMENTS						
Clear PET	X					
Tamper evident sleeves and safety seals		X			Labels, Closures and Attachments Floatability Test	PET Crtical Guidance
Non-PET attachments		X			Labels, Closures and Attachments Floatability Test	PET Crtical Guidance
Metal and metal containing		X			New eddy current and magnetic test for attachments	
Paper			X			
Welded attachments			X			
RFID's			X			
PVC and PLA				X		

This document is intended to be used as a summary and quick reference of some selected items within the Design Guide for Plastics Recyclability. In no manner is it intended or implied to be a replacement for the actual document.

BASE POLYMER:

PET and PET variants resins which have a crystalline melting point between 235 and 255C are preferred. Materials of a lower melt point or non-crystalline materials often become sticky in the reclaimers' pre-extrusion dryer when the dryer is operated at PET temperatures and prevent the material from flowing through the process. Materials of a higher melt point remain solid in the reclaimers' extruder and cause blockages in melt screens. Both conditions greatly hinder the ability of the reclaimer to operate.

Blends of PET and other resins require testing to determine the appropriate APR recyclability category. Other resins may be blended into the PET to enhance certain properties during the package's intended first use. The materials' effect on the RPET in future uses must be evaluated since it will not be removed in the recycling system.

One test protocol is available:
Definitive Test: PET Critical Guidance

BARRIER LAYERS, COATINGS & ADDITIVES

Non-PET layers and coatings require testing to determine the appropriate APR recyclability category. The use of non-PET layers and coatings can be detrimental to recycling of PET if not implemented according to APR test protocols. Layers and coatings must either separate and be removed from the PET in the recycling process or have no adverse effects on the RPET in future uses. When used, their content should be minimized to the greatest extent possible to maximize PET yield, limit potential contamination, and reduce separation costs. Some layers and coatings have been found compatible with PET or are easily separated in conventional recycling systems.

Two test protocols are available:
Screening Test: Quick Test for Color
Definitive Test: PET Critical Guidance

Degradable additives (photo, oxo, or bio) require testing to determine the appropriate APR recyclability category. Recycled PET is intended to be used in new products. The new products are engineered to meet particular quality and durability standards given properties of typical recycled PET. Additives designed to degrade the polymer diminish the life of the material in the primary use. If not removed in the recycling process, these additives shorten the useful life of the product made from the RPET as well, possibly compromising quality and durability.
Degradable additives should not be used without testing to demonstrate that their inclusion will not materially impair the full-service life and properties of any product made from the RPET that includes the additive. These additives must either separate and be removed from the PET in the recycling process or have no adverse effects on the RPET in future uses. When used, their content should be minimized to the greatest extent possible to maximize PET yield, limit potential contamination, and reduce separation costs.

One test protocol is available:

Screening Test: PET Degradable Additives Test

Additives require testing to determine the appropriate APR recyclability category. The APR recognizes that other types of additives may be required for the performance of a particular package but are not addressed in this document. Additives such as de-nesting, anti-static, anti-blocking, anti-fogging, anti-slip, UV barrier, stabilizer and heat receptor agents and lubricants should be tested to determine their compatibility with recycling. Of particular concern are additives which cause the RPET to discolor or haze after remelting or solid stating since RPET with poor haze or discoloration is greatly devalued and has limited markets. This is particularly troublesome since it is difficult to identify material with this effect until extremely late in the recycling process where a great deal of added cost has been imparted into the material.

Two test protocols are available:
Screening test: Quick Test for Color
Definitive Test: PET Critical Guidance

Optical brighteners are detrimental to recycling. Like many other additives, optical brighteners are not removed in the recycling process and can create an unacceptable fluorescence for next uses of RPET containing the brighteners. It is difficult to identify material with this negative effect until extremely late in the recycling process where a great deal of added cost has been imparted into a material of low value due to the additive.

- **COLOR**

Clear unpigmented PET is preferred. Clear material has the highest value as a recycled stream since it has the widest variety of end-use applications. It is the most cost effective to process through the recycling system.

Transparent light blue packaging is preferred. Light blue material is most often included with the clear material stream to act as a bluing agent and offset some yellowing. This not only adds volume to the high value clear stream, it improves its quality when used in limited amounts. Normally it can also be added to the green stream with little negative effect

Transparent green packaging is preferred. Green material has significant volume in the marketplace. At the MRF, it is baled along with the clear PET and may comprise up to 30% of the PET bale. The green material is separated from the clear by the original reclaimer, who may process it into a value-added product, or send it to a reclaimer dedicated to green material. Its value is second only to clear material. However, green is not without its issues. Because a consistent, clear color is critical to future products using clear RPET, the recycling process includes a great deal of machinery and manpower dedicated to separating colored material. This adds significant cost to the operation. Even so, small but significant amounts of colored material, including transparent green, pass into the clear stream, thereby affecting the quality of clear RPET. Markets such as clothing, carpet, soft drink bottles and thermoformed sheet depend on very precise colors using clear material as a basis

- Transparent colors other than green and light blue are detrimental to recycling. These colors when separated from the primary clear and green streams are small in volume with little market value. Some reclaimers are able to tolerate transparent amber tinted bottles in their systems but these are limited.

- Translucent and opaque colors including white are detrimental to recycling. There is very little market value for this material and it contaminates the other streams that have value. It can also be very difficult for automatic sorters to identify opaque colored polymers so additional labor must be employed to remove opaque materials

- Nucleating agents, hazing agents, fluorescers, and other additives for visual and technical effects are detrimental to recycling. Like many additives, these features are not removed in the recycling process and can affect the value of the RPET and its performance in future uses.

- Black color renders the package non-recyclable. NIR sorting technology is not capable of identifying a black polymer and manual sorting cannot distinguish one black polymer from another. Oth**er** separation techniques such as float-sink cannot be employed since many black polymers sink with PET. Therefore, black packaging is considered a contaminant for nearly all reclaimers.

DIMENSIONS

Size and shape are critical parameters in MRF sorting, and this must be considered in designing packages for recycling. The MRF process separates items by size and shape first, then by material. Screens direct paper, and similar two-dimensional lightweight items, into one stream; containers and similar three-dimensional heavier items into another steam; while broken glass and smaller but heavy items are allowed to drop by gravity to yet another stream, which may or may not be further sorted. Large, bulky items are typically manually sorted on the front of the MRF process.

- Items more two-dimensional than three-dimensional render the package non-recyclable per APR definition. Aside from not being captured in the plastic stream, they cause contamination in the paper stream. Items should have a minimum depth of two inches in order to create a three-dimensional shape for proper sorting. This issue is unrelated to the polymer type. The APR encourages and anticipates developments in MRF design and technology to improve capture and recovery of thin plastics; however, at the current time this technology either does not exist or is uninstalled in the majority of MRFs.

- Items smaller than 3 inches in all dimensions render the package non-recyclable per APR definition. The industry standard screen size loses materials less than three inches to a non-plastics stream, causing contamination in that stream, or directly to waste. These small packages are lost to the plastic recycling stream. It is possible that some small containers travel with larger ones when either the screens wrap with film or they are operated above their design capacity. Film wrapping reduces the effective size of the screen and over-running provides a cushion of large items on which the smaller items travel. The design guidelines use clean screens operating at their design capacity for the determination of the recyclability category. The APR anticipates and encourages technology development to improve the process of small package recovery but currently these items are not recovered.

- Items greater than two gallons in volume are detrimental to recycling. Recycling machinery, particularly automatic sorting equipment, is not large enough to accept items larger than two gallons. Because larger containers jam the systems, most MRFs employ manual sortation before the automatic line to remove the large items. These items are recovered in a stream of bulky rigid containers that are sold and processed as polyethylene since the vast majority of bulky rigid items are comprised of this polymer. Other polymers either negatively affect or are lost by the polyethylene processing.

CLOSURES & DISPENSERS

- Polypropylene and polyethylene closures are preferred. Since these polymers float, they are most easily separated from the bottle in conventional separation systems. Additionally, the PET recycling process captures floatable polyethylene and polypropylene to create an ancillary stream of marketable material. Care must be taken when modifying the polyethylene or polypropylene to ensure the modifier does not increase the overall density to the point it sinks.

- Closure systems without liners are preferred. Due to size and thickness, most liners are lost in the recycling process thereby slightly decreasing yield. Closures without liners do not experience this loss.

- EVA and TPE liners in plastic closures are preferred. Both EVA and TPE float in water and will be separated in the recycling process with the floatable polyethylene and polypropylene. Since EVA and TPE are compatible with these polymers, and in fact enhance their properties, they are preferred.

- Closures containing metal or metal foils require testing to determine the appropriate APR recyclability category. Metal is difficult to separate from PET compared to the preferred closure systems (polypropylene and polyethylene) and adds both capital and operating costs to conventional reclamation processes. Even a small amount of metal left in the RPET stream will block extruder screens in remanufacturing. Large metal items attached to PET packages may cause the package to be directed to the metal or waste stream in the recycling process, causing yield loss. Small metal components such as spray dispenser springs unravel in the recycling process and blind screens, adding significant cost for removal at the end of the process.

  Two test protocols are available:
  Screening Test: New Eddy Current and Magnetic Test for Attachments
  Definitive Test: Closure Test

- Closures made from polystyrene or thermoset plastics are undesirable for recycling. Both materials are heavier than water and sink in the float-sink tank with PET. They are extremely difficult to separate from RPET flake, requiring a costly and inexact polymer flake sorter currently not installed in many reclaiming operations.

- Closures containing silicone polymer are detrimental to recycling. Silicone sinks in the float-sink tank with the PET and is difficult to remove with other methods, thereby causing contamination in the final product.

The use of PVC closures or closure liners render the package non-recyclable per APR. PVC sinks and is extremely hard for the recycler to remove, particularly in small pieces. The recycled PET stream is very intolerable to even minute amounts of PVC.

➢ LABELS, INKS AND ADHESIVES

Removing adhesives is a significant component to the cost of recycling. The most recyclable packages use the lowest quantity of recycle-friendly adhesive. Lower adhesive usage reduces processing cost and potential contamination risk.

Polypropylene or polyethylene labels with a specific gravity less than 1.0 are preferred. These materials float in water so they are separated from the PET in the float-sink tank with the closures. Since they are the same general polymer as most of the closures they do not contaminate or devalue this stream. Care should be taken to ensure that any modifiers to the label material do not increase its density above 1.0.

Laminated labels require testing to determine the appropriate APR recyclability category. Labels that break into small, very thin pieces of material are more difficult to manage in the recycling process because they behave erratically in a float-sink tank. Therefore, labels that stay intact are preferred. Carry-over of delaminated labels into the RPET can result in contamination.

One test protocol is available:
Definitive Test: New Delamination Test

Full bottle sleeve labels require testing to determine the appropriate APR recyclability category. Full bottle sleeve labels cover a large amount of the bottle surface with a polymer that is not the same as the bottle body. Because of this, a sleeve label designed without considering recycling may cause a false reading on an automatic sorter and direct a PET bottle to another material stream where it is lost to the process. Furthermore, some sleeve label materials cannot be removed in the recycling process and contaminate the RPET produced. Sleeve labels that have been found compliant with the APR test protocols should be selected.

One test protocol is available:
Definitive Test: Sleeve Label Test

Pressure sensitive labels require testing to determine the appropriate APR recyclability category. Pressure sensitive labels generally require complete adhesive coverage which is greater than other typical label methods. This raises the importance of the compatibility of the type of adhesive with the recycling process. Adhesives resistant to washing in the recycling process allow labels to remain on the PET and become contaminants in the final product. Adhesives that have been found compliant with the APR test protocols should be selected.

Two test protocols are available:
Screening test: Thermoform Label Test
Definitive Test: Pressure Sensitive Label Test

- Polystyrene labels require testing to determine the appropriate APR recyclability category. While PS labels are tolerated by some PET reclaimers, PS has been identified as causing serious processing and end-use problems by others and should only be used if it can be easily and completely removed from the PET in conventional separation systems. PS inherently sinks in water due to its density so it travels with the PET in the recyclers' float-sink systems. However, expanded PS may float and in this case, it may be less of a problem to the recycler.

  One test protocol is available:
  Screening Test: Labels, Closures and Attachments Floatability Test

- Label structures that sink in water because of the choice of substrate, ink, decoration, coatings, and top layer require testing to determine the appropriate APR recyclability category. The reclaimers rely on float-sink systems to separate non-PET materials. Label components that sink with the PET end up in the RPET stream as contaminants.

  One test protocol is available:
  Definitive Test: PET Critical Guidance

- Paper labels are detrimental to recycling (for pressure sensitive paper labels reference the pressure sensitive label category). The PET reclamation process involves a hot caustic wash that removes glue and other label components to the levels required to render the RPET usable. Paper, when subjected to these conditions, becomes pulp which is very difficult to filter from the liquid, thereby adding significant load to the filtering and water treatment systems. Individual paper fibers making up pulp are very small and difficult to remove so some travel with the PET. Paper fibers remaining in the RPET carbonize when the material is heated and remelted, causing unacceptable quality degradation. Non-pulping paper labels that resist the caustic wash process sink in the float-sink tank, thereby causing RPET contamination.

- Metal foil labels are undesirable for recycling Sorting equipment in the recycling process is designed to detect and eliminate metal from PET. Even very thin metallized labels may be identified as metal by the sorting equipment and cause the entire bottle to be rejected as waste, thereby creating yield loss. If not detected, they pass through the process with the PET and cause contamination issues in the RPET.

- PVC and PLA labels render the package unrecyclable per APR. Both materials are extremely difficult to remove in the recycling process due to their similarity in density to PET. Both cause severe quality degradation in the final recycled PET stream even in very small amounts.

- Adhesives require testing to determine the appropriate APR recyclability category Adhesives that wash off cleanly from PET and remain adhered to the label are preferred. Label adhesive that is not removed from PET, or which re-deposits on the PET during the wash step is a source of contamination and discoloration when PET is recycled.

  The recycling process is designed to remove reasonably expected contamination from the surface of the PET to a degree necessary to render the RPET economically reusable in further applications. In practice, some adhesives are resistant to this process so are detrimental to recycling. In extreme cases, an adhesive and label cannot be separated from the PET and may render a package not recyclable.

Three test protocols are available:
Screening Tests: PET Flake Wash Test and Thermoform Label Test
Definitive Test: PET Critical Guidance

Label inks require testing to determine the appropriate APR recyclability category Some label inks bleed color in the reclamation process, discoloring the PET in contact with them and significantly diminishing its value for recycling. The APR and NAPCOR have developed a testing protocol to assist label manufacturers in evaluating whether a label ink will bleed in conventional PET reclaiming systems. Label inks must be chosen that do not bleed color when tested under this protocol.

Two test protocols are available:
Screening Tests: Bleeding Label Test and Flake to Plaque Bleeding Label Test
*See the definitive test for the appropriate label type

Direct printing other than date coding requires testing to determine its compatibility with the recycling system**.** Historically, inks used in direct printing tend to bleed or otherwise discolor the PET during the recycling process, or introduce incompatible contaminants. In either case, the value of the RPET is diminished. Some inks used in direct printing do not cause these problems. The specific ink must be tested to determine its effect.

Three test protocols are available:
Screening Tests: Bleeding Label Test and Flake to Plaque Bleeding Label Test
Definitive Test: Direct Print Label Test

- **ATTACHMENTS**

Clear PET attachments are preferred. Attachments made of the base polymer are recovered and recycled with the base polymer without causing contamination or yield loss, thereby generating the highest value.

Tamper evident sleeves and safety seals require testing to determine the appropriate APR recyclability category. If tamper resistance is required in specific product applications, it should be an integral design feature of the bottle. The use of tamper-resistant or tamper-evident sleeves or seals is discouraged as they can act as contaminants if they do not completely detach from the bottle, or are not easily removed in conventional separation systems. If sleeves or safety seals are used, they should be designed to completely detach from the bottle, leaving no remains on the bottle. The material used should float and separate from the PET in the float-sink system.

Two test protocols are available:
Screening Test: Labels, Closures and Attachments Floatability Test
Definitive Test: PET Critical Guidance

- Non-PET attachments such as handles require testing to determine the appropriate APR recyclability category. These should not be adhesively bonded to the package and should readily separate from the package when ground. They should be made from materials that float in water such as PP or HDPE. If adhesives are used to affix attachments, their selection should consider the adhesive criteria within this document.

  Two test protocols are available:
  Screening Test: Labels, Closures and Attachments Floatability Test
  Definitive Test: PET Critical Guidance

- Metal and metal containing attachments require testing to determine the appropriate APR recyclability category. Examples include metal foils and metalized substrates that sink in water as well as metal sprayer balls and springs. In the recycling process these items are either identified and removed along with their PET component in the early stages, thereby causing yield loss, or they pass into the recycling process causing a contamination issue. Since they are heavier than water they sink with the PET in the float-sink tank. Many of these items are too small to be removed with machinery designed to remove metal such as eddy current and optical separators. Springs in particular unravel and become entangled in filtering screens throughout the recycling process.

  One test protocol is available:
  Screening test: New Eddy Current and Magnetic Test for Attachments

- Paper attachments are detrimental to recycling. The PET reclamation process uses a hot caustic wash to remove glue and other contaminants to the levels required to render the RPET usable. Paper, when subjected to these conditions, becomes pulp which is very difficult to filter from the liquid, thereby adding significant load to the filtering and water treatment systems. Individual paper fibers making up pulp are very small and difficult to remove so some travel with the PET. Paper fibers remaining in the RPET carbonize when the material is reused causing unacceptable quality degradation.

- Welded attachments are detrimental to recycling. A certain amount of a welded attachment cannot be separated from the PET in the recycling process. These attachments, even when ground and made of floatable materials, cause RPET contamination and yield loss issues in both cases: when the PET they are attached to causes the ground section containing both polymers to sink, or when the ground section floats.

- RFID's (radio frequency identification devices) on packages, labels or closures are detrimental to recycling. Unless they are compatible with PET recycling and are demonstrated not to create any disposal issues based on their material content, the use of RFID's is discouraged as it limits PET yield, introduces potential contamination, and increases separation costs.

- PVC and PLA attachments of any kind render the package non-recyclable per APR definition**.** The use of PVC or PLA attachments of any kind on PET packaging is undesirable and should be scrupulously avoided. This includes thermoforms of PVC and/or PLA that may be visually confused with PET thermoforms. Very small amounts of PVC or PLA can severely contaminate and render large amounts of

PET useless for most recycling applications. In addition, PVC and PLA are very difficult to separate from PET in conventional water-based density separation systems due to similar densities (densities greater than 1.0) that cause both to sink in these systems.

- **BIO-BASED PET RESIN**

The use of bio-based PET resin, in which the MEG component is sourced from biological materials such as sugar cane residue or similar materials, are fully compatible with petroleum-based PET in the recycling process. Bio-based PET should not be confused with PET containing bio- or oxo-degradable additives.

- **POSTCONSUMER CONTENT**

The use of postconsumer PET in all packages is encouraged to the maximum amount technically and economically feasible.

- **RESIN IDENTIFICATION CODE, RIC**

Use the correct Resin Identification Code symbol of the proper size as detailed in ASTM D7611 is encouraged.

APR Design® Guide for Plastics Recyclability
for
High Density Polyethylene (HDPE, Resin Identification Code #2)

BACKGROUND: Due to its toughness, natural UV barrier properties and chemical resistance HDPE is one of the most widely used packaging resins. It is easily injection molded or blow molded into a bottle, pail, tub or closure. In its natural state, HDPE appears a milky white color. This is due to light reflection on the polymer structure rather than a colorant.

HDPE properties are commonly enhanced with colorants, additives and fillers, or it is placed alongside other polymers in a multi-layer package. Each modification and addition to the natural HDPE in a package must be considered for its effect on the recycling stream. Non-HDPE packaging features should either be economically removed from the HDPE in the typical recycling process or be compatible with HDPE in future uses. Of particular concern are mineral fillers or additives that cause the overall blend to sink in water. The density of HDPE is .94-.96 so it floats in water. Density is an important property as reclaimers typically rely on float-sink tanks to separate polymers and to remove contaminants.

Per the scope outlined in the Design Guide introduction, the following guidance is focused on postconsumer packaging items that are typically picked up in single stream curb side collection systems. Further the guidance considers the impact on sortation at a modern automated MRF or PRF, as well as the compatibility of a HDPE packaging item in common HDPE reclaiming processes. This guidance will also be applicable to other postconsumer household items such as toys.

HDPE is used in a wide number of industrial applications and postindustrial HDPE is an important source of HDPE that is collected and recycled. The APR Design® Guide can be a reference when designing industrial applications with HDPE, but not all guidance may be applicable when recyclability of such commercially used items is being considered.

The APR's Champions for Change® Program encourages consumer product, plastic package and bottle component manufacturers to work with the APR protocols to determine whether new modifications to a regularly recycled plastic package will negatively impact the recycling process prior to introducing the modification.

The Association of Plastic Recyclers

THE APR INTERACTIVE DESIGN GUIDE® CATEGORIES AT A GLANCE - HDPE

Scope Reminder: For Items processed through both an automated MRF and Plastics Reclaimer

FEATURE	RECYCLABILITY CATEGORIES Link to Definitions				LINK TO		
	APR DESIGN GUIDE™ PREFERRED	REQUIRES TESTING	DETRIMENTAL TO RECYCLING	RENDERS PACKAGE NON-RECYCLABLE PER APR DEFINITION	DETAILS	SCREENING/BENCHMARK TEST (indicative only - see definition of Screening and Benchmark tests)	DEFINITIVE TEST
BASE POLYMER:							
Post consumer Polyolefin content	x						
BARRIER LAYERS, COATINGS & ADDITIVES							
EVOH Layers	x						
Non-HDPE layers and coatings other than EVOH		x				HDPE Benchmark Test	
Degradable additives		x				HDPE/PP Degradeable additives Test	
Workhorse additives historically used without issue (see list in the guide)	x						
Additives not listed		x				HDPE Benchmark Test	
Total additive concentration causing material to sink				x		PO Float Test	
COLOR							
Unpigmented	x						
Optical brighteners			x				
translucent and opaque colors	x						
Black colorant				x			
DIMENSIONS							
More 2 dimensional than 3 dimensional (one dimension <=2")				x			
Three dimensions < 3"				x			
Greater than 2 gallons in volume			x				
CLOSURES AND DISPENSERS							
Polyethylene	x						
Polypropylene			x				
Closure systems without liners	x						
EVA and TPE liners in plastic closures	x						
Pumps and spray disensers containing metal parts			x				
Metal parts and foils			x				
Floating silicone polymer parts			x				
PVC			x				
PS or thermoset	x						
LABELS, INKS AND ADHESIVES							
Inks		x				PP/HDPE Bleeding Label Test - TBD	
Direct printing other than date coding		x				HDPE Benchmark Test	
In-mold labels of a compatible polymer	x						
Full bottle sleeve labelsdesigned for sorting	x						
Adhesives		x				PP/HDPE adhesive Test - TBD (3 outcomes: wash releasable, not wash releasable-compatible, not wash releasable-non compatible)	
Labels with Non Wash releasable, HDPE Compatible Adhesives							
PP, PE labels	x						
Paper labels			x				
Metal foil labels			x				
PVC or PLA labels				x			
PS labels			x				
Labels with Wash Releasable Adhesives							
PP, PE labels	x						
Paper labels			x				
Metal foil labels	x						
PVC labels			x				
PLA labels	x						
PS labels	x						
ATTACHMENTS							
PP - PE Tamper evident safety sleeves	x						
PETG Tamper evident safety sleeves	x						
PVC Tamper evident safety sleeves			x				
Non-PP attachments		x				HDPE Benchmark Test	
Metal and metal containing		x				Eddy current and magnetic test for attachments- TBD	
Plastic with a density > 1.0 except PVC	x						
Welded attachments		x				HDPE Benchmark test	
PP			x				
RFID's			x				
PLA	x						
PVC			x				

The information contained herein represents a snapshot in a point in time of the capabilities of a dynamic industry. The APR encourages and anticipates development in both package design features and the recycling infrastructures ability to process features, particularly in the areas of size and color.

This document is intended to be used as a summary and quick reference of some selected items within the Design Guide for Plastics Recyclability. In no manner is it intended or implied to be a replacement for the actual document.

➢ BASE POLYMER

- Postconsumer polyolefin content is preferred. The use of postconsumer HDPE in all packages is encouraged to the maximum amount technically and economically feasible.

➢ BARRIER LAYERS, COATINGS & ADDITIVES

The use of non-HDPE layers and coatings can be detrimental to recycling of HDPE if not implemented according to APR test protocols. When used, their content should be minimized to the greatest extent possible to maximize HDPE yield, limit potential contamination, and reduce separation costs.

- EVOH layers are preferred. EVOH is a common layer material used to increase the barrier properties of HDPE. It is not separable in the recycling process and therefore will become part of the recycled HDPE. Although EVOH blended with HDPE is not without issue (it may cause splay when extruded or molded and contribute to die lip build up) it is generally accepted. EVOH has performed successfully in previous critical guidance tests. Some recycled HDPE users have experienced molding problems at values approaching 3%. Its use should be minimized to maintain the best performance of recycled HDPE for future uses.

- Non-HDPE layers and coatings other than EVOH require testing to determine the appropriate APR recyclability category. Testing must show that layers and coatings will either separate and be removed from the HDPE in the recycling process or have no adverse effects on the recycled HDPE in future uses. When used, their content should be minimized to the greatest extent possible. Some layers and coatings have been found compatible with HDPE or are easily separated in conventional recycling systems.

  One test protocol is currently being developed:
  HDPE Benchmark Test

- Degradable additives (photo, oxo, or bio) require testing to determine the appropriate APR recyclability category. Recycled HDPE is intended to be reused into new products. The new products are engineered to meet particular quality and durability standards given properties of typical recycled HDPE. Additives designed to degrade the polymer by definition diminish the life of the material in the primary use. If not removed in the recycling process, these additives also shorten the useful life of the product made from the recycled HDPE, possibly compromising quality and durability.

  Degradable additives should not be used without testing to demonstrate that their inclusion will not materially impair the full-service life and properties of any product made from the recycled HDPE that includes the additive. Testing must show that these additives will either separate and be removed from the HDPE in the recycling process or have no adverse effects on the recycled HDPE in future uses. When used, their content should be minimized to the greatest extent possible.

  One test protocol is available:
  HDPE/PP Degradable Additives Test

- Workhorse additives historically used without issue are preferred. Most HDPE in a package contains some form of additives. The “workhorse” additives commonly used have not been shown to cause significant issues with the recycling process or further uses of the recycled HDPE. Commonly acceptable workhorse additives include:

- Thermal stabilizers - These additives typically enhance the further processing of the polymer and are therefore preferred for recycling.
- UV stabilizers – These additives typically enhance the further processing of the polymer and are therefore preferred for recycling
- Nucleating agents
- Antistatic agents
- Lubricants
- Fillers – note that many fillers are dense, so particular attention should be paid to the overall blend density
- Pigments
- Impact modifiers
- Chemical blowing agents

Additive usage should be minimized to maintain the best performance of recycled HDPE for future uses.

Additives not listed require testing to determine the appropriate APR recyclability category. The APR recognizes that other types of additives may be required for the performance of a particular package but are not addressed in this document. Of particular concern are additives which cause the recycled HDPE to discolor or change viscosity after remelting, or dense additives that increase the density of the blend making it sink, thus rendering the package unrecyclable per APR definition. The APR encourages users to test the additive according to the appropriate test protocol before implementing. Testing must show that additives will not cause unacceptable discoloration, viscosity changes, or density changes.

One test protocol is currently being developed:
HDPE Benchmark Test

Additive concentration causing the overall blend to sink renders the package non-recyclable per the APR definition. Many of the additives and fillers used with HDPE are very dense and when blended with the polymer increase the overall density of the blend. When their weight percentage reaches the point that the blend density is greater than 1.00, the blend sinks in water rather than floats. Density is an important property and float-sink tanks are critical separation tools used by reclaimers. Therefore, a sinking material will be considered waste by a polypropylene reclaimer and any HDPE in the blend will be lost. The APR test protocol should be consulted to determine if a blend sinks.

One test protocol is currently being developed:
PO Float Test

COLOR

Unpigmented HDPE is preferred. Natural material has the highest value as a recycled stream since it has the widest variety of end-use applications. It is the most cost effective to process through the recycling system.

- Optical brighteners are detrimental to recycling. Optical brighteners are not removed in the recycling process and can create an unacceptable fluorescence for next uses of recycled HDPE. It is difficult to identify material with this negative effect until extremely late in the recycling process where a great deal of added cost has been imparted into a material of low value due to the additive.

- Translucent and opaque colors are preferred. HDPE is commonly colored so volumes and markets exist for colored material and it is economical to process.

- Black color renders the package non-recyclable per APR. There is no mechanical property inherent in black HDPE that makes it unrecyclable. The problem lies in sorting and the physics behind polymer identification. NIR (near-infrared) sorting technology used in MRFs is not capable of identifying a polymer with a pure black color since black absorbs all light. There are shades of black that may be detected by NIR, and a HDPE label of a different color on a package might aid in detection by NIR. It is not feasible to use manual sorting to distinguish one black polymer from another since there are just too many items.

  Therefore, in a MRF or PRF facility, it is very difficult to sort most black colored HDPE materials and direct them into a HDPE bale for reclaiming. At the reclaimer, float-sink will not sort out black HDPE since many black polymers float with HDPE.

  Although the APR encourages and anticipates development in capturing black plastics at the MRF this technology does not exist today. It should be noted that black is a commonly used color in HDPE, particularly in oil bottles and industrial items. These items fall outside the scope of the design guide since they are not typically collected through curbside collection that is the focus of this guidance. Black HDPE, if collected in a source separated or postindustrial stream, can be reclaimed.

- **DIMENSIONS**

  Size and shape are critical parameters in MRF sorting, and this must be considered in designing packages for recycling. The MRF process separates items by size and shape first, then by material. Screens direct paper, and similar two-dimensional lightweight items, into one stream; containers and similar three-dimensional heavier items into another steam; while broken glass and smaller but heavy items are allowed to drop by gravity to yet another stream, which may or may not be further sorted. Large, bulky items are typically manually sorted on the front of the MRF process.

- Items more two-dimensional than three-dimensional render the package non-recyclable per APR definition. Aside from not being captured in the plastic stream, they cause contamination in the paper stream. Items should have a minimum depth of two inches in order to create a three-dimensional shape for proper sorting. This issue is unrelated to the polymer type. The APR encourages and anticipates developments in MRF design and technology to improve capture and recovery of thin plastics; however, at the current time this technology either does not exist or is uninstalled in the majority of MRFs.

- Items smaller than 3 inches in all dimensions render the package non-recyclable per APR definition. The industry standard screen size loses materials less than three inches to a non-plastics stream, causing contamination in that stream, or directly to waste. These small packages are lost to the plastic recycling stream. It is possible that some small containers travel with larger ones when either the screens wrap with film or they are operated above their design capacity. Film wrapping reduces the effective size of the screen and over-running provides a cushion of large items on which the smaller items travel. The design guidelines use clean screens operating at their design capacity for the determination of the recyclability category. The APR anticipates and encourages technology development to improve the process of small package recovery but currently these items are not recovered.

- Polyethylene or Polypropylene are preferred for items greater than two gallons in volume. Recycling machinery, particularly automatic sorting equipment, is not large enough to accept items larger than two gallons. Because larger containers jam the systems, most MRFs employ manual sortation before the automatic line to remove the large items. These items are recovered in a stream of bulky rigid containers that are sold and processed as polyethylene since the vast majority of bulky rigid items are comprised of this polymer. Other polymers either negatively affect or are lost by the polyethylene processing.

CLOSURES & DISPENSERS

- Polyethylene closures are preferred. Since polyethylene is the same polymer as the package body, closures and dispensers made of it will be captured and processed with HDPE. This increases the reclaimers yield and reduces possible waste.

- Polypropylene closures are detrimental to recycling. Since polypropylene floats in water like polyethylene it is not separated in the reclaimers float-sink tank. When blended with HDPE it negatively affects the impact properties and can render the material brittle. Although very small amounts of PP, such as that contributed by labels, are regularly accepted by HDPE reclaimers, closures and dispensers comprise a larger weight percentage of the package and therefore a greater negative affect. The APR recognizes that polypropylene is perhaps the most commonly used material for closures.

- Closure systems without liners are preferred. Due to size and thickness, most liners are lost in the recycling process thereby slightly decreasing yield. Closures without liners do not experience this loss.

- EVA and TPE liners in plastic closures are preferred. EVA and TPE float in water and will not be separated in the recycling process. However, they are compatible with HDPE and in fact enhance its properties so they are preferred.

- Pumps and spray dispensers containing metal parts are detrimental to recycling. Although metal is easily removed in the float-sink process, metal springs unravel during recycling and entwine themselves in screens designed to separate water from the material thereby ruining the screen. This adds significant cost and downtime to the recycling process. The APR encourages the use of polymer check valves and springs whenever technically possible. The body of the spray dispenser or pump should also be the same polymer as the body of the bottle whenever technical possible to increase yield and decrease contamination of the recycled HDPE.

- Closures containing metal or metal foils are detrimental to recycling. Although metal is easily removed in the float-sink process, most reclaimers have metal detection equipment designed to protect their cutting machinery. Therefore, the container never makes it to the float-sink tank. Large metal items attached to HDPE packages may cause the package to be directed to the metal or waste stream in the recycling process, causing yield loss.

- Closures containing floating silicone polymer are detrimental to recycling. This material passes through the float-sink tank along with the HDPE and is difficult to remove with other methods, thereby causing contamination in the final product. It should be noted that sinking silicone does not experience this issue.

- The use of PVC closures is detrimental to recycling**.** PVC is relatively easy to remove in the float-sink tank since it sinks while the HDPE floats. However, the float-sink tank is imperfect and even a very small amount of PVC with the recycled HDPE renders large amounts of it unusable as the PVC degrades at lower temperatures than those at which HDPE is processed.

- Closures made from polystyrene or thermoset plastics are preferred. Both materials are heavier than water and sink in the float-sink tank, thereby separating from the HDPE. They also do not damage or wear cutting machinery in the recycling process. Small amounts of these materials that make it through the float-sink process can be melt filtered from the recycled HDPE in the extrusion step. However, these materials are lost to the waste stream in the recycling process and are considered less preferable than an alternative floating attachment that is compatible with HDPE.

➢ LABELS, INKS AND ADHESIVES

- Label inks require testing to determine the appropriate APR recyclability category. Some label inks bleed color in the reclamation process, discoloring the HDPE in contact with them and possibly diminishing its value for recycling. Since most recycled HDPE is colored, the impact of bleeding inks may not be significant; however, since the end use is not known beforehand, label inks should be chosen that do not bleed color when recycled. The APR test protocol should be consulted to determine if an ink bleeds.

  One test is currently being developed:
  PP/HDPE Bleeding Label Test

- Direct printing other than date coding requires testing to determine its compatibility with the recycling system**.** Inks used in direct printing may bleed, otherwise discolor the HDPE during the recycling process, or introduce incompatible contaminants. In either case, the value of the recycled HDPE may be diminished. Some inks used in direct printing do not cause these problems. The specific ink must be tested to determine its effect.

  One test is currently being developed:
  HDPE Benchmark Test

- In-mold labels of a compatible polymer are preferred. In-mold labels are not removed in the recycling process since they are bonded with the wall of the package. They will flow though the recycling process with the HDPE and be blended with the recycled HDPE. The lack of adhesive is beneficial to recycling since it cannot affect color or other mechanical properties. The label polymer and ink should be compatible with HDPE so as not to negatively affect its properties.

Full bottle sleeve labels designed for sorting are preferred. A positive aspect of sleeve labels is the lack of adhesive requiring removal in the recycling process. However, full bottle sleeve labels cover a large amount of the bottle surface with a polymer that is not the same as the bottle body. Because of this, a sleeve label designed without considering sorting may cause an automatic sorter to direct a HDPE bottle to another material stream where it is lost to the process. Furthermore, some incompatible sleeve materials that cannot be separated from the HDPE in the float-sink tank can contaminate the recycled HDPE produced. Sleeve labels that are designed for automatic sorting and sink in water are preferred, with the exception of PVC, where even small residual amounts that make it through the float-sink process will destroy the recycled HDPE in the extrusion process. Polyolefin sleeve labels that are designed for automatic sorting are also preferred since the small levels of completely incompatible material expected from label residue has a very minimal negative impact.

Adhesives require testing to determine the appropriate APR recyclability category. Testing must show that adhesives will either wash off cleanly from the HDPE in the recycling process or be compatible with HDPE. However, typical HDPE recycling process conditions are not aggressive enough to remove all adhesive material, and a certain amount of residual adhesive is to be expected in recycled HDPE. Adhesive that is not removed from HDPE during the wash step is a source of contamination and discoloration when HDPE is recycled. For these reasons, minimal adhesive usage is encouraged.

The APR is developing a PP/HDPE adhesive test to classify adhesive as either wash friendly, non-wash friendly and compatible with HDPE, or non-wash friendly and incompatible with HDPE. Non-wash friendly, incompatible adhesive is detrimental to recycling.

One test is currently being developed:
PP/HDPE Adhesive Test

Label-Adhesive Combinations: The classification and recyclability of label substrates is dependent on the type of adhesive that is used with them. In general, a label substrate that sinks in water and is used with an adhesive that releases in the reclaimers wash system is preferred since the substrate will be removed in the float-sink tank. A label substrate that is compatible with HDPE is also preferred no matter what the adhesive. Therefore, label substrates are classified by the type of adhesive used with them.

Polypropylene or polyethylene labels are preferred. HDPE labels are the same polymer as the final product and PP at the very small levels expected from label residue has a very minimal negative impact. Therefore, these labels that remain with the HDPE throughout the recycling process, whether they detach or not, increase yield and have minimal negative quality impact for the reclaimer.

Paper labels are detrimental to recycling. The HDPE reclamation process involves water and agitation. The paper that detaches from the container when subjected to these conditions becomes pulp, which does not sink intact but remains suspended in the liquid, adding load to the filtering and water treatment systems. Paper remaining adhered to the HDPE travels with the HDPE to the extruder where the material carbonizes and causes color defects. Even after melt filtering, the burned smell and discoloration remain with the recycled HDPE thereby negatively affecting its potential reuse. Non-pulping paper labels used with non-releasing adhesives compound the problem since the entire label enters the extruder. Non-pulping labels, heavy enough to sink and durable enough to withstand the washing process that are used with releasing adhesives may alleviate this issue.

- Metal foil labels are detrimental to recycling when used with an adhesive that does not release in the wash and preferred when used with an adhesive that releases in the wash. In the MRF, even very thin metallized labels may be identified as metal by the sorting equipment and cause the entire bottle to be directed to the metal stream, thereby creating yield loss. Sorting equipment in the reclaiming process is designed to detect and eliminate metal from HDPE. If small, not detected, or allowed to pass, these labels, when used with an adhesive that does not release in the wash, either cause the attached HDPE to sink where it is lost in the float-sink tank or pass into the extruder and are removed with melt filtering. When used with an adhesive that releases in the wash, these labels quickly sink in the float sink tank where they are removed

- PVC labels render the package non-recyclable per APR when used with an adhesive that does not release in the wash and detrimental to recycling when used with an adhesive that releases in the wash. PVC, when used with an adhesive that does not release in the wash, enters the extruder with the HDPE where they are incompatible. PVC degrades at HDPE extrusion temperatures and renders large amounts of the recycled HDPE unusable. When used with an adhesive that releases in the wash, these labels sink in the float-sink tank where they are removed. But because the float-sink tank is imperfect, and even a very small amount of PVC entering the extruder causes severe quality and yield problems, this material is detrimental.

- PLA labels render the package non-recyclable per APR when used with an adhesive that does not release in the wash and preferred when used with an adhesive that releases in the wash. PLA label material, when used with an adhesive that does not release in the wash, enters the extruder with the HDPE where they are incompatible. When used with an adhesive that releases in the wash, the PLA detaches from the HDPE before the float-sink tank where it sinks and is removed. Even though the float-sink process is imperfect, the small amounts of PLA entering the extrusion process are not catastrophic

- Polystyrene labels are detrimental to recycling when used with an adhesive that does not release in the wash and preferred when used with an adhesive that releases in the wash. PS, when used with an adhesive that does not release in the wash, remains with the HDPE and enters the extruder where it is blended with the HDPE. PS is not compatible with HDPE and may cause splay or reduce impact toughness for the recycled HDPE user. PS label material, when used with an adhesive that releases in the wash, detaches from the HDPE before the float sink tank where it sinks and is removed.

➢ ATTACHMENTS

- Polypropylene or polyethylene tamper evident safety sleeves are preferred. HDPE safety sleeves are the same polymer as the final product, and PE at the very small levels expected from safety sleeve residue has a very minimal negative impact. Therefore, these attachments that remain with the HDPE throughout the recycling process increase yield and have minimal negative quality impact for the reclaimer.

- PETG tamper evident safety sleeves are preferred. PETG sinks in the float sink tank where it is removed from the HDPE. Unlike PVC, small amounts of PETG entering the extrusion process with the HDPE are not catastrophic since PETG can be melt filtered.

- PVC tamper evident safety seals are detrimental to recycling. PVC sinks in the float-sink tank where the majority of it is removed from the HDPE. Because the float sink tank is imperfect and even a very small amount of PVC entering the extruder causes sever quality and yield problems, this material is detrimental. PVC degrades at HDPE extrusion temperatures and renders large amounts of the recycled HDPE unusable.

- Non-HDPE attachments require testing to determine the appropriate APR recyclability category. Testing must show that these attachments are not adhesively bonded to the package and are made from materials that sink in water so they readily separate from the package when ground and put through a float-sink separation. If adhesives are used to affix attachments, their selection should consider the adhesive criteria within this document.

  One test is currently being developed:
  HDPE Benchmark Test

- Metal and metal-containing attachments require testing to determine the appropriate APR recyclability category. Metal or metal-containing attachments may cause NIR sorters in MRFs to misidentify a HDPE container as metal and direct it to a metal stream, from which it is then discarded. Sorting equipment in the reclaiming process is designed to detect and eliminate metal from HDPE in order to protect cutting machinery. Large items, or items adhesively bonded to the HDPE, can damage the machinery and render the entire package non-recyclable. If small, not detected, or allowed to pass, metals, when used with wash friendly or no adhesive quickly sink in the float sink tank where they are removed from the HDPE.

  APR is currently developing an eddy current and magnetic test protocol for metal and metal-containing attachments.

- Plastic attachments with a density > 1.00 except for PVC are preferred. These items sink in the sink-float tank where they are removed from the HDPE and small residual amounts do not severely affect the final product since many of them are melt filtered. PVC is detrimental as discussed elsewhere in this document.

- Welded attachments require testing to determine the appropriate APR recyclability category. A certain amount of a welded attachment cannot be separated from the HDPE in the recycling process. These attachments may cause recycled HDPE contamination and yield loss issues in both cases: when the ground section containing both polymers sinks and carries the HDPE with it, or when the ground section floats and carries an incompatible material with the HDPE into the extrusion process. Testing must show that the blend is of a density less than 1.0 so that it floats along with the HDPE in the float-sink tank, and that it is compatible with HDPE in the extrusion process.

- Polypropylene attachments are detrimental to recycling. Because polypropylene floats in water, it is not separated in the reclaimers float-sink tank. When blended with HDPE it negatively affects stiffness and impact properties. Although very small amounts of PE, such as that contributed by labels, are regularly accepted by HDPE reclaimers, some attachments comprise a larger weight percentage of the package and therefore a greater negative affect.

- RFID's (radio frequency identification devices) on packages, labels or closures are detrimental to recycling. RFID's are printed on silver metal, which may create costly waste disposal issues. While RFID's are small, they may affect HDPE recycling in the same ways as metal labels or other attachments. The use of RFID's is discouraged as may limit HDPE yield, introduce potential contamination, and increase separation and waste disposal costs.

- PLA attachments are preferred. As discussed in the sections on labels and closures, PLA sinks in the float-sink tank and can be therefore removed from the HDPE. Unlike PVC, small amounts of PLA entering the extrusion process are not catastrophic

- PVC attachments are detrimental to recycling. PVC sinks in the float sink tank where the majority of it is removed from the HDPE. Because the float sink tank is imperfect and even a very small amount of PVC entering the extruder causes sever quality and yield problems, this material is detrimental. PVC degrades at HDPE extrusion temperatures and renders large amounts of the recycled HDPE unusable

RESIN IDENTIFICATION CODE, RIC

Use the correct Resin Identification Code symbol of the proper size as detailed in ASTM D7611 is encouraged.

APR Design® Guide for Plastics Recyclability
for
PVC (Polyvinyl Chloride, Resin Identification Code #3)

BACKGROUND: Due to its price, clarity, chemical and UV resistance, natural barrier properties and low melting temperature, PVC is a good material for many applications. However, the low melting temperature and chemical composition of PVC makes it extremely incompatible with most other common polymers. When even minute amounts of PVC are processed with other polymers the PVC degrades into hydrochloric acid and chlorine rendering large amounts of the polymer useless. Since PVC sinks in water it is difficult to remove in conventional PET recycling systems. Currently, the number of PVC bottles in the post-consumer collected stream of plastic bottles is at such low levels that the bottles are not recycled and considered a contaminant. Because of this APR finds the use of PVC bottles undesirable if those bottles are included with bales of PET or HDPE bottles. PVC is currently best collected and recycled in a dedicated, source selected system outside the scope of the APR Design Guide for Plastics Recyclability such as a construction and demolition stream. If a bottle designer or specifier finds that PVC must be the resin of choice for a given application, APR recommends the following in hopes that PVC bottle recycling may someday be a commercial opportunity:

- **BASE POLYMER**

- **BARRIER LAYERS, COATINGS & ADDITIVES**

  - Non-PVC layers and coatings require testing to determine the appropriate APR recyclability category. The use of non-PVC layers and coatings can be detrimental to recycling of PVC if not implemented according to APR test protocols. Layers and coatings must either separate and be removed from the PVC in the recycling process or have no adverse effects on the RPVC in future uses. When used, their content should be minimized to the greatest extent possible to maximize PVC yield, limit potential contamination, and reduce separation costs.

    One test protocol is available:
    Screening Test: Quick Test for Color

  - Degradable additives (photo, oxo, or bio) require testing to determine the appropriate APR recyclability category. Recycled PVC is intended to be used in new products. The new products are engineered to meet particular quality and durability standards given properties of typical recycled PVC. Additives designed to degrade the polymer diminish the life of the material in the primary use. If not removed in the recycling process, these additives shorten the useful life of the product made from the RPVC as well, possibly compromising quality and durability.

    Degradable additives should not be used without testing to demonstrate that their inclusion will not materially impair the full-service life and properties of any product made from the RPVC that includes the additive. These additives must either separate and be removed from the PVC in the recycling process or have no adverse effects on the RPVC in future uses. When used, their content should be minimized to the greatest extent possible to maximize PVC yield, limit potential contamination, and reduce separation costs.

One test protocol is currently being developed.

- Additives require testing to determine the appropriate APR recyclability category. The APR recognizes that other types of additives may be required for the performance of a particular package but are not addressed in this document. Additives such as de-nesting, anti-static, anti-blocking, anti-fogging, anti-slip, UV barrier, stabilizer and heat receptor agents and lubricants should be tested to determine their compatibility with recycling. Of particular concern are additives which cause the RPVC to discolor or haze after remelting since RPVC with poor haze or discoloration is greatly devalued and has limited markets. This is particularly troublesome since it is difficult to identify material with this effect until extremely late in the recycling process where a great deal of added cost has been imparted into the material.

  One test protocol is available:
  Screening test: Quick Test for Color

- Optical brighteners are detrimental to recycling. Like many other additives, optical brighteners are not removed in the recycling process and can create an unacceptable fluorescence for next uses of RPVC containing the brighteners. It is difficult to identify material with this negative effect until extremely late in the recycling process where a great deal of added cost has been imparted into a material of low value due to the additive.

COLOR

- Clear unpigmented PVC is preferred. Clear material has the highest value as a recycled stream since it has the widest variety of end-use applications. It is the most cost effective to process through the recycling system.

- Black color renders the package non-recyclable. NIR sorting technology is not capable of identifying a black polymer and manual sorting cannot distinguish one black polymer from another. Oth**er** separation techniques such as float-sink cannot be employed since many black polymers sink with PVC. Therefore, black packaging is considered a contaminant for nearly all reclaimers.

DIMENSIONS

Size and shape are critical parameters in MRF sorting, and this must be considered in designing packages for recycling. The MRF process separates items by size and shape first, then by material. Screens direct paper, and similar two-dimensional lightweight items, into one stream; containers and similar three-dimensional heavier items into another steam; while broken glass and smaller but heavy items are allowed to drop by gravity to yet another stream, which may or may not be further sorted. Large, bulky items are typically manually sorted on the front of the MRF process.

- Items more two-dimensional than three-dimensional render the package non-recyclable per APR definition. Aside from not being captured in the plastic stream, they cause contamination in the paper stream. Items should have a minimum depth of two inches in order to create a three-dimensional shape for proper sorting. This issue is unrelated to the polymer type. The APR encourages and anticipates developments in MRF design and technology to improve capture and recovery of thin plastics; however, at the current time this technology either does not exist or is uninstalled in the majority of MRFs.

- Items smaller than 3 inches in all dimensions render the package non-recyclable per APR definition. The industry standard screen size loses materials less than three inches to a non-plastics stream, causing contamination in that stream, or directly to waste. These small packages are lost to the plastic recycling stream. It is possible that some small containers travel with larger ones when either the screens wrap with film or they are operated above their design capacity. Film wrapping reduces the effective size of the screen and over-running provides a cushion of large items on which the smaller items travel. The design guidelines use clean screens operating at their design capacity for the determination of the recyclability category. The APR anticipates and encourages technology development to improve the process of small package recovery but currently these items are not recovered.

- Items greater than two gallons in volume are detrimental to recycling. Recycling machinery, particularly automatic sorting equipment, is not large enough to accept items larger than two gallons. Because larger containers jam the systems, most MRFs employ manual sortation before the automatic line to remove the large items. These items are recovered in a stream of bulky rigid containers that are sold and processed as polyethylene since the vast majority of bulky rigid items are comprised of this polymer. Other polymers either negatively affect or are lost by the polyethylene processing.

➢ CLOSURES & DISPENSERS

- Polypropylene and polyethylene closures are preferred. Because these polymers float, they are most easily separated from the bottle in conventional separation systems. Additionally, the PVC recycling process captures floatable polyethylene and polypropylene to create an ancillary stream of marketable material. Care must be taken when modifying the polyethylene or polypropylene to ensure the modifier does not increase the overall density to the point it sinks.

- Closure systems without liners are preferred. Due to size and thickness, most liners are lost in the recycling process thereby slightly decreasing yield. Closures without liners do not experience this loss.

- EVA and TPE liners in plastic closures are preferred. Both EVA and TPE float in water and will be separated in the recycling process with the floatable polyethylene and polypropylene. Since EVA and TPE are compatible with these polymers, and in fact enhance their properties, they are preferred.

- Closures containing metal or metal foils require testing to determine the appropriate APR recyclability category. Metal is difficult to separate from PVC compared to the preferred closure systems (polypropylene and polyethylene) and adds both capital and operating costs to conventional reclamation processes. Even a small amount of metal left in the RPVC stream will block extruder screens in remanufacturing. Large metal items attached to PVC packages may cause the package to be directed to the metal or waste stream in the recycling process, causing yield loss. Small metal components such as spray dispenser springs unravel in the recycling process and blind screens, adding significant cost for removal at the end of the process.

Two test protocols are available:
Screening Test: New Eddy Current and Magnetic Test for Attachments
Definitive Test: Closure Test

Closures made from polystyrene or thermoset plastics are undesirable for recycling. Both materials are heavier than water and sink in the float-sink tank with PET. They are extremely difficult to separate from RPET flake, requiring a costly and inexact polymer flake sorter currently not installed in many reclaiming operations.

Closures containing silicone polymer are detrimental to recycling. Silicone sinks in the float-sink tank with the PVC and is difficult to remove with other methods, thereby causing contamination in the final product.

The use of PET closures or closure liners render the package non-recyclable per APR definition. PET sinks and is extremely hard for the recycler to remove.

- **LABELS, INKS AND ADHESIVES**

Removing adhesives is a significant component to the cost of recycling. The most recyclable packages use the lowest quantity of recycle-friendly adhesive. Lower adhesive usage reduces processing cost and potential contamination risk.

Polypropylene or polyethylene labels with a specific gravity less than 0.95 are preferred. These materials float in water so they are separated from the PVC in the float-sink tank with the closures. Since they are the same general polymer as most of the closures they do not contaminate or devalue this stream. Care should be taken to ensure that any modifiers to the label material do not increase its density above 0.95.

Laminated labels require testing to determine the appropriate APR recyclability category. Labels that break into small, very thin pieces of material are more difficult to manage in the recycling process because they behave erratically in a float-sink tank. Therefore, labels that stay intact are preferred. Carry-over of delaminated labels into the RPVC can result in contamination.

One test is currently available:
Definitive Test: New Delamination Test

Full bottle sleeve labels require testing to determine the appropriate APR recyclability category. Full bottle sleeve labels cover a large amount of the bottle surface with a polymer that is not the same as the bottle body. Because of this, a sleeve label designed without considering recycling may cause a false reading on an automatic sorter and direct a PVC bottle to another material stream where it is lost to the process. Furthermore, some sleeve label materials cannot be removed in the recycling process and contaminate the RPET produced. Sleeve labels that have been found compliant with the APR test protocols should be selected.

One test is currently available:
Definitive Test: Sleeve Label Test

Pressure sensitive labels require testing to determine the appropriate APR recyclability category. Pressure sensitive labels generally require complete adhesive coverage which is greater than other typical label methods. This raises the importance of the compatibility of the type of adhesive with the recycling process. Adhesives resistant to washing in the recycling process allow labels to remain on the PET and become contaminants in the final product. Adhesives that have been found compliant with the APR test protocols should be selected.

Two tests are available:
Screening test: Thermoform Label Test
Definitive Test: Pressure Sensitive Label Test

Polystyrene labels require testing to determine the appropriate APR recyclability category. PS inherently sinks in water due to its density so it travels with the PVC in the recyclers' float-sink systems. However, expanded PS may float and in this case, it may be less of a problem to the recycler.

One test is available:
Screening Test: Labels, Closures and Attachments Floatability Test

Label structures that sink in water because of the choice of substrate, ink, decoration, coatings, and top layer require testing to determine the appropriate APR recyclability category. The reclaimers rely on float-sink systems to separate non-PVC materials. Label components that sink with the PVC end up in the RPVC stream as contaminants.

Paper labels are detrimental to recycling (for pressure sensitive paper labels reference the pressure sensitive label category. The PVC reclamation process involves a hot caustic wash that removes glue and other label components to the levels required to render the RPVC usable. Paper, when subjected to these conditions, becomes pulp which is very difficult to filter from the liquid, thereby adding significant load to the filtering and water treatment systems. Individual paper fibers making up pulp are very small and difficult to remove so some travel with the PVC. Paper fibers remaining in the RPVC carbonize when the material is heated and remelted, causing unacceptable quality degradation. Non-pulping paper labels that resist the caustic wash process sink in the float-sink tank, thereby causing RPVC contamination.

Metal foil labels are detrimental to recycling. Sorting equipment in the recycling process is designed to detect and eliminate metal from PVC. Even very thin metallized labels may be identified as metal by the sorting equipment and cause the entire bottle to be rejected as waste, thereby creating yield loss. If not detected, they pass through the process with the PVC and cause contamination issues in the RPVC.

- PET and PETG labels render the package unrecyclable per APR. This material is extremely difficult to remove in the recycling process due to its similarity in density to PVC.

- Adhesives require testing to determine the appropriate APR recyclability category. Adhesives that wash off cleanly from PVC and remain adhered to the label are preferred. Label adhesive that is not removed from PET, or which re-deposits on the PVC during the wash step is a source of contamination and discoloration when PVC is recycled.

  The recycling process is designed to remove reasonably expected contamination from the surface of the PVC to a degree necessary to render the RPVC economically reusable in further applications. In practice, some adhesives are resistant to this process so are detrimental to recycling. In extreme cases, an adhesive and label cannot be separated from the PVC and may render a package not recyclable.

  Two tests are available that can be used for PVC:
  Screening Tests: PET Flake Wash Test and Thermoform Label Test

- Label inks require testing to determine the appropriate APR recyclability category. Some label inks bleed color in the reclamation process, discoloring the PVC in contact with them and significantly diminishing its value for recycling. Label inks must be chosen that do not bleed color when tested under this protocol.

  Two tests are available:
  Screening Tests: Bleeding Label Test and Flake to Plaque Bleeding Label Test
  *See the definitive test for the appropriate label type

- Direct printing other than date coding requires testing to determine its compatibility with the recycling system. Historically, inks used in direct printing tend to bleed or otherwise discolor the PET during the recycling process, or introduce incompatible contaminants. In either case, the value of the RPVC is diminished. Some inks used in direct printing do not cause these problems. The specific ink must be tested to determine its effect.

  Two PET test protocols are available that can be used for PVC:
  Screening Tests: Bleeding Label Test
  Definitive Test: Direct Print Label Test

➢ ATTACHMENTS

- Clear PVC attachments are preferred. Attachments made of the base polymer are recovered and recycled with the base polymer without causing contamination or yield loss, thereby generating the highest value.

- Tamper evident sleeves and safety seals require testing to determine the appropriate APR recyclability category. If tamper resistance is required in specific product applications, it should be an integral design feature of the bottle. The use of tamper-resistant or tamper-evident sleeves or seals is discouraged as they can act as contaminants if they do not completely detach from the bottle, or are not easily removed in conventional separation systems. If sleeves or safety seals are used, they should be designed to completely detach from the bottle, leaving no remains on the bottle. The material used should float and separate from the PVC in the float-sink system.

One PET test protocol is available that can be used for PVC:
Screening Test: Labels, Closures and Attachments Floatability Test

- Non-PVC attachments such as handles require testing to determine the appropriate APR recyclability category. These should not be adhesively bonded to the package and should readily separate from the package when ground. They should be made from materials that float in water such as PP or HDPE. If adhesives are used to affix attachments, their selection should consider the adhesive criteria within this document.

One PET test protocol is available that can be used for PVC:
Screening Test: Labels, Closures and Attachments Floatability Test

- Metal and metal containing attachments require testing to determine the appropriate APR recyclability category. Examples include metal foils and metalized substrates that sink in water as well as metal sprayer balls and springs. In the recycling process these items are either identified and removed along with their PVC component in the early stages, thereby causing yield loss, or they pass into the recycling process causing a contamination issue. Since they are heavier than water they sink with the PVC in the float-sink tank. Many of these items are too small to be removed with machinery designed to remove metal such as eddy current and optical separators. Springs in particular unravel and become entangled in filtering screens throughout the recycling process.

One PET test protocol is available that can be used for PVC:
Screening test: New Eddy Current and Magnetic Test for Attachments

- Paper attachments are detrimental to recycling. The PVC reclamation process uses a hot caustic wash to remove glue and other contaminants to the levels required to render the RPVC usable. Paper, when subjected to these conditions, becomes pulp which is very difficult to filter from the liquid, thereby adding significant load to the filtering and water treatment systems. Individual paper fibers making up pulp are very small and difficult to remove so some travel with the PVC. Paper fibers remaining in the RPVC carbonize when the material is reused causing unacceptable quality degradation.

- Welded attachments are detrimental to recycling. A certain amount of a welded attachment cannot be separated from the PVC in the recycling process. These attachments, even when ground and made of floatable materials, cause RPVC contamination and yield loss issues in both cases: when the PVC they are attached to causes the ground section containing both polymers to sink, or when the ground section floats.

- RFID's (radio frequency identification devices) on packages, labels or closures are detrimental to recycling. Unless they are compatible with PVC recycling and are demonstrated not to create any disposal issues based on their material content, the use of RFID's is discouraged as it limits PVC yield, introduces potential contamination, and increases separation costs.

PET and PLA attachments of any kind render the package non-recyclable per APR. The use of PET or PLA attachments of any kind on PVC packaging is undesirable and should be scrupulously avoided. This includes thermoforms of PET and/or PLA that may be visually confused with PVC thermoforms. Very small amounts of PET or PLA can severely contaminate and render large amounts of PVC useless for most recycling applications. In addition, PET and PLA are very difficult to separate from PVC in conventional water-based density separation systems due to similar densities (densities greater than 1.0) that cause both to sink in these systems.

- **POSTCONSUMER CONTENT**

The use of postconsumer PVC in all packages is encouraged to the maximum amount technically and economically feasible.

- **RESIN IDENTIFICATION CODE, RIC**

Use the correct Resin Identification Code symbol of the proper size as detailed in ASTM D7611 is encouraged.

APR Design® Guide for Plastics Recyclability
for
LDPE, LLDPE, HDPE Film

BACKGROUND: Film is used for many applications requiring a variety of properties. The vast majority of film is polyethylene and polypropylene but currently, only polyethylene is routinely collected and recycled postconsumer.

SCOPE: The following guidance provided for film plastics diverges from the scope outlined in the Design Guide introduction because it does not consider the single stream MRF the primary collection source. The film plastic guidance must address a different supply chain in which single stream curb side collection systems are a very minor part. Single-stream recovery of film, and film sortation in MRFs, does exist but the technology and logistics are in their infancy.

Collection and source selection of plastic film is an extremely important part of film recycling and is discussed at depth in the design guide resources section of the APR website.

Residential postconsumer film is primarily collected at retail locations, mostly grocery stores, and thus may include a mix of materials including LDPE, LLDPE, HDPE, PP and a growing number of multi-layer packaging. Depending on the contamination present and the desired application the recycler may use a wet or dry system to process this material. This guide considers both processes. Each modification and addition to a single clear base polyolefin polymer in a film or film package must be considered for its effect on the recycling stream.

Plastic film is used in a wide number of industrial applications and postindustrial film is an important source of film that is collected and recycled. The APR Design® Guide can be a reference when designing industrial applications with film, but not all guidance may be applicable when collection and recycling of such commercially used film is in a dedicated, closed loop system.

- **BASE POLYMER**

- Postconsumer polyethylene (PE) content is preferred. The use of postconsumer PE in all packages is encouraged to the maximum amount technically and economically feasible.

- **BARRIER LAYERS, COATINGS & ADDITIVES**
  The use of non-PE layers and coatings can be detrimental to recycling of PE film if not implemented according to APR test protocols. When used, their content should be minimized to the greatest extent possible to maximize yield, limit potential contamination, and reduce separation costs.

- Non-PE layers and coatings require testing to determine the appropriate APR recyclability category. Layers and coatings are not removed in the film recycling process. They enter the extrusion stage of the process with the base material where they are either melted and blended with the PE or remain solid and are filtered from the melted product. A filterable coating is rare due to its extremely thin profile. Testing must show that unfilterable layers and coatings have no adverse effect on the recycled PE in future uses. Some coatings such as EVOH may be acceptable at small weight percentages of the total film but only testing can determine this. Several compatibilizers are available on the market that may, if used correctly allow a non-compatible material to blend with the PE without negative effects. This can also be demonstrated by testing the specific formulation of the film.

The APR is developing a test protocol to determine a coating or layers compatibility with PE in film applications.

- PVC and PVDC layers and coatings render the package unrecyclable per APR definition. PVC and PVDC degrade at low temperatures rendering large portions of the recycled PE unusable.

- Metalized layers are detrimental to recycling. Metalized layers are extremely thin layers of metal deposited on the film as a vapor. They should not be confused with actual metal layers addressed as "foil" in this document. Metalized layers are not removed in the recycling process and are melted and blended with the PE. This causes material discoloring. In many cases a metalized film will be detected early in the recycling process by metal detectors designed to protect machinery from catastrophic damage. Metal detectors are unable to differentiate between a metalized film and a solid metal part so the entire package is normally discarded rather than accept the risk.

- Workhorse additives historically used without issue are preferred. Most PE films contain some form of additives. The "workhorse" additives commonly used have not been shown to cause significant issues with the recycling process or further uses of the recycled PE. Commonly acceptable workhorse additives include:
  - Thermal stabilizers - These additives typically enhance the further processing of the polymer and are therefore preferred for recycling.
  - UV stabilizers – These additives typically enhance the further processing of the polymer and are therefore preferred for recycling
  - Nucleating agents
  - Antistatic agents
  - Lubricants
  - Slip agents
  - Fillers – note that many fillers are dense, so particular attention should be paid to the overall blend density
  - Pigments
  - Impact modifiers
  - Chemical blowing agents
  - Tackifiers

Additive usage should be minimized to maintain the best performance of recycled PE for future uses.

- Degradable additives (photo, oxo, or bio) require testing to determine the appropriate APR recyclability category. Recycled film is intended to be reused into new products. The new products are engineered to meet particular quality and durability standards given properties of typical recycled film. Additives designed to degrade the polymer by definition diminish the life of the material in the primary use. If not removed in the recycling process, these additives also shorten the useful life of the product made from the recycled film, possibly compromising quality and durability.

Degradable additives should not be used without testing to demonstrate that their inclusion will not materially impair the full-service life and properties of any product made from the recycled film that includes the additive. Testing must show that these additives will either separate and be removed from the film in the recycling process or have no adverse effects on the recycled film in future uses. When used, their content should be minimized to the greatest extent possible.

One test protocol is available:
HDPE/PP Degradable Additives Test

- Additive concentration causing the overall blend to sink renders the package non-recyclable per the APR definition. Many of the additives and fillers used with PE are very dense and when blended with the polymer increase the overall density of the blend. When their weight percentage reaches the point that the blend density is greater than 1.00, the blend sinks in water rather than floats. Density is an important property and float-sink tanks are critical separation tools used by film reclaimers who use a wet wash process. Therefore, a sinking material will be considered waste by such a film reclaimer. Film reclaimers using a dry process are normally able to process this material but there is no way to determine if a particular film will be processed by a dry or wet system. The APR test protocol should be consulted to determine if a blend sinks.

One test is currently being developed:
PE Float Test

- Additives not listed require testing to determine the appropriate APR recyclability category. The APR recognizes that other types of additives may be required for the performance of a particular package but are not addressed in this document. Of particular concern are additives which cause the recycled PE to discolor, gel or change viscosity after remelting, or dense additives that increase the density of the blend making it sink, thus rendering the package unrecyclable per APR definition. The APR encourages users to test the additive according to the appropriate test protocol before implementing. Testing must show that additives have no adverse effect on the recycled PE in future uses.

The APR is developing a test protocol to determine an additives compatibility with PE in film applications.

COLOR

- Unpigmented PE is preferred. Natural material has the highest value as a recycled stream since it has the widest variety of end-use applications. It is the most cost effective to process through the recycling system.

- White, buff or lightly colored colors are preferred. It is not common for film to be sorted by color in the recycling process. Therefore, the resulting recycled material is a blend of all the colors present. Light colors blend well with little effect.

- Dark colors, particularly blues and greens are detrimental to recycling. It is not common for film to be sorted by color in the recycling process. Therefore, the resulting recycled material is a blend of all the colors present. Dark colors have a great effect on a lot of material. Since the standard material is a light blend and dark colors are relatively rare, the reclaimer normally hand selects dark colors and processes them separately. In some cases, the dark colors are discarded. The recyclers are adapting to this issue by building processes that are more accepting of dark colors, while at the same time, brand names are replacing dark colors with light colors for their packaging films.

LABELS, INKS AND ADHESIVES

- Direct printing is preferred: Of the available labeling methods direct printing adds the least amount of potential contamination. Small levels of the correct inks disperse in the final polymer without having much of an impact on quality. Heavily printed film of dark colors can be problematic since the dark colors affects a large amount of polymer, limiting its potential for reuse. The amount of printing should be limited since heavy levels of ink volatize in the extruder and may cause gels in the final product even if most recyclers use vented extruders. Large amounts of printing can overwhelm the capacity of these extruders to remove the volatile components.

- Polyethylene labels are preferred. Labels made of the same or compatible polymer as the film do not become contaminates and are recycled with the film

- Paper labels are detrimental to recycling. Paper labels pulp and become a water filtration and contamination problem if they are processed through a wet recycling process. Individual paper fibers are very difficult to remove and attach themselves to the film creating specks and irregularities in the products made from recycled film. Furthermore, in either a wet or dry process they degrade in the extruder creating an undesirable burnt smell that cannot be removed from the recycled plastic. This significantly limits its reuse.

- Metal foil labels and layers render the package unrecyclable per APR definition. These labels should not be confused with metalized film. Metal foil labels are extremely problematic in two areas. First, they alarm metal detectors that are employed at the beginning of the recycling process to protect machinery. When this occurs, the entire package containing the offending part is discarded and landfilled. Secondly, if they happen to pass through the process into the extruder they can quickly blind a melt filter causing a pressure upset which automatically shuts down the process for safety.

- **ATTACHMENTS**

Non-PE attachments require testing to determine the appropriate APR recyclability category. Attachments enter the film recycling process along with the film they are attached to. They enter the extrusion stage of the process with the base material where they are either melted and blended with the PE or remain solid and are filtered from the melted product. Testing must show that the material is removed from the PE stream or has no adverse effect on the recycled PE in future uses.

The APR is developing a test protocol to determine a coating or layers compatibility with PE in film applications.

Metal and metal-containing attachments render the package unrecyclable per APR. Metal parts are extremely problematic in two areas. First, they alarm metal detectors that are employed at the beginning of the recycling process to protect machinery. When this occurs, the entire package containing the offending part is discarded and landfilled. Secondly, if they happen to pass through the process into the extruder they can damage the extruder or quickly blind a melt filter causing a pressure upset which automatically shuts down the process for safety.

- **RESIN IDENTIFICATION CODE, RIC**

Use the correct Resin Identification Code symbol of the proper size as detailed in ASTM D7611

The Association of Plastic Recyclers

APR Design® Guide for Plastics Recyclability for Polypropylene (PP, Resin Identification Code #5)

BACKGROUND: Due to its balance of impact, heat and chemical resistance, along with stiffness and close dimensional tolerance, PP is one of the most widely used packaging resins. It is easily injection molded, blow molded or thermoformed into a bottle, pail, tray, tub or closure. Unlike some other polymers, the versatility of PP allows all components (label, body and closure) of many PP packages to be made of PP. This practice is beneficial to recycling.

PP properties are commonly enhanced with colorants, additives and fillers, or it is placed alongside other polymers in a multi-layer package. Each modification and addition to the natural PP in a package must be considered for its effect on the recycling stream. Non-PP packaging features should either be economically removed from the PP in the typical recycling process or be compatible with PP in future uses. Of particular concern are mineral fillers or additives that cause the overall density of the blend to be greater than 1.00. The density of PP is .90-.92 so it floats in water. Density is an important property as reclaimers typically rely on float-sink tanks to separate polymers and to remove contaminants.

Per the scope outlined in the Design Guide introduction, the following guidance is focused on postconsumer packaging items that are typically picked up in single stream curb side collection systems. Further the guidance considers the impact on sortation at a modern automated MRF or PRF, as well as the compatibility of a PP packaging item in common PP reclaiming processes. This guidance will also be applicable to other postconsumer household items such as toys.

PP is used in a wide number of industrial applications and postindustrial PP is an important source of PP that is collected and recycled. The APR Design® Guide can be a reference when designing industrial applications with PP, but not all guidance may be applicable when recyclability of such commercially used items is being considered.

The APR's Champions for Change® Program encourages consumer product, plastic package and bottle component manufacturers to work with the APR protocols to determine whether new modifications to a regularly recycled plastic package will negatively impact the recycling process prior to introducing the modification.

The Association of Plastic Recyclers

THE APR INTERACTIVE DESIGN GUIDE® CATEGORIES AT A GLANCE - PP

Scope Reminder: For Items processed through both an automated MRF and Plastics Reclaimer

FEATURE	RECYCLABILITY CATEGORIES (Link to Definitions): APR DESIGN GUIDE™ PREFERRED	REQUIRES TESTING	DETRIMENTAL TO RECYCLING	RENDERS PACKAGE NON-RECYCLABLE PER APR DEFINITION	LINK TO: DETAILS	SCREENING/BENCHMARK TEST (indicative only - see definition of Screening and Benchmark tests)	DEFINITIVE TEST
BASE POLYMER:							
Post consumer Polyolefin content	X						
BARRIER LAYERS, COATINGS & ADDITIVES							
EVOH Layers	X						
Non-PP layers and coatings otherr than EVOH		X				PP Benchmark Test	
Degradable additives		X				HDPE/PP Degradeable additives Test	
Workhorse additives historically used without issue (see list in the guide)	X						
Additives not listed		X				PP Benchmark Test	
Total additive concentration causing material to sink				X		PO Float Test	
COLOR							
Unpigmented	X						
Optical brighteners			X				
translucent and opaque colors	X						
Black colorant				X			
DIMENSIONS							
More 2 dimensional than 3 dimensional (one dimension <=2")				X			
Three dimensions < 3"				X			
Greater than 2 gallons in volume			X				
CLOSURES AND DISPENSERS							
Polypropylene	X						
Polyethylene			X				
Closure systems without liners	X						
EVA and TPE liners in plastic closures	X						
Pumps and spray disensers containing metal parts			X				
Metal parts and foils			X				
Floating silicone polymer parts			X				
PVC			X				
Metal lidding			X				
PS or thermoset	X						
LABELS INKS AND ADHESIVES							
Inks		X				PP/HDPE Bleeding Label Test - TBD	
Direct printing other than date coding		X				PP Benchmark Test	
In-mold labels of a compatible polymer	X						
Full bottle sleeve labels designed for sorting	X						
Adhesives		X				PP/HDPE adhesive Test - TBD (3 outcomes: wash releasable, not wash releasable-compatible, not wash releasable-non compatible)	
With Non Wash Releasable, PP Compatible Adhesives: PP, PE labels	X						
With Non Wash Releasable, PP Compatible Adhesives: Paper labels			X				
With Non Wash Releasable, PP Compatible Adhesives: Metal foil labels			X				
With Non Wash Releasable, PP Compatible Adhesives: PVC or PLA labels				X			
With Non Wash Releasable, PP Compatible Adhesives: PS labels			X				
With Wash Releasable Adhesives: PP, PE labels	X						
With Wash Releasable Adhesives: Paper labels			X				
With Wash Releasable Adhesives: Metal foil labels	X						
With Wash Releasable Adhesives: PVC labels			X				
With Wash Releasable Adhesives: PLA labels	X						
With Wash Releasable Adhesives: PS labels	X						
ATTACHMENTS							
PP - PE Tamper evident safety sleeves	X						
PETG Tamper evident safety sleeves	X						
PVC Tamper evident safety sleeves			X				
Non-PP attachments		X				PP Benchmark Test	
Metal and metal containing		X				Eddy current and magnetic test for attachments- TBD	
Plastic with a density > 1.0 except PVC	X						
Welded attachments		X				PP Benchmark test	
PE			X				
RFID's			X				
PLA	X						
PVC			X				

The information contained herein represents a snapshot in a point in time of the capabilities of a dynamic industry. The APR encourages and anticipates development in both package design features and the recycling infrastructures ability to process features, particularly in the areas of size and color.

This document is intended to be used as a summary and quick reference of some selected items within the Design Guide for Plastics Recyclability. In no manner is it intended or implied to be a replacement for the actual document.

- **BASE POLYMER**

- Postconsumer polyolefin content is preferred. The use of postconsumer PP in all packages is encouraged to the maximum amount technically and economically feasible.

- **BARRIER LAYERS, COATINGS & ADDITIVES**

The use of non-PP layers and coatings can be detrimental to recycling of PP if not implemented according to APR test protocols. When used, their content should be minimized to the greatest extent possible to maximize PP yield, limit potential contamination, and reduce separation costs.

- EVOH layers are preferred. EVOH is a common layer material used to increase the barrier properties of PP. It is not separable in the recycling process and therefore will become part of the recycled PP. Although EVOH blended with PP is not without issue (it may cause splay when extruded or molded and contribute to die lip build up) it is generally accepted. EVOH has performed successfully in previous critical guidance tests. Some recycled PP users have experienced molding problems at values approaching 3%. Its use should be minimized to maintain the best performance of recycled PP for future uses.

- Non-PP layers and coatings other than EVOH require testing to determine the appropriate APR recyclability category. Testing must show that layers and coatings will either separate and be removed from the PP in the recycling process or have no adverse effects on the recycled PP in future uses. When used, their content should be minimized to the greatest extent possible. Some layers and coatings have been found compatible with PP or are easily separated in conventional recycling systems.

  One test protocol is available:
  PP Benchmark Test

- Degradable additives (photo, oxo, or bio) require testing to determine the appropriate APR recyclability category. Recycled PP is intended to be used in new products. The new products are engineered to meet particular quality and durability standards given properties of typical recycled PP. Additives designed to degrade the polymer by definition diminish the life of the material in the primary use. If not removed in the recycling process, these additives also shorten the useful life of the product made from the recycled PP, possibly compromising quality and durability.

  Degradable additives should not be used without testing to demonstrate that their inclusion will not materially impair the full-service life and properties of any product made from the recycled PP that includes the additive. Testing must show that these additives will either separate and be removed from the PP in the recycling process or have no adverse effects on the recycled PP in future uses. When used, their content should be minimized to the greatest extent possible.

  One test protocol is available:
  HDPE/PP Degradable Additives Test

- Workhorse additives historically used without issue are preferred. Most PP in a package contains some form of additives. The "workhorse" additives commonly used have not been shown to cause significant issues with the recycling process or further uses of the recycled PP. Commonly acceptable workhorse additives include:

- Thermal stabilizers - These additives typically enhance the further processing of the polymer and are therefore preferred for recycling.
- UV stabilizers – These additives typically enhance the further processing of the polymer and are therefore preferred for recycling
- Nucleating agents
- Clarifying agents
- Antistatic agents
- Lubricants
- Fillers – note that many fillers are dense, so particular attention should be paid to the overall blend density
- Pigments
- Impact improvers
- Chemical blowing agents

Additive usage should be minimized to maintain the best performance of recycled PP for future uses.

Additives not listed require testing to determine the appropriate APR recyclability category. The APR recognizes that other types of additives may be required for the performance of a particular package but are not addressed in this document. Of particular concern are additives which cause the recycled PP to discolor or change viscosity after remelting, or dense additives that will increase the density of the blend over 1.0, thus rendering the package unrecyclable per APR definition. The APR encourages users to test the additive according to the appropriate test protocol before implementing. Testing must show that additives will not cause unacceptable discoloration, viscosity changes, or density changes.

One test protocol is available:
PP Benchmark Test

Additive concentration causing the overall blend to sink renders the package non-recyclable per the APR definition. Many of the additives and fillers used with PP are very dense and when blended with the polymer increase the overall density of the blend. When their weight percentage reaches the point that the blend density is greater than 1.00, the blend sinks in water rather than floats. Density is an important property and float-sink tanks are critical separation tools used by reclaimers. Therefore, a sinking material will be considered waste by a polypropylene reclaimer and any PP in the blend will be lost. The APR test protocol should be consulted to determine if a blend sinks.

One test protocol is available:
PO Float Test

➢ **COLOR**

- Unpigmented PP is preferred. Natural material has the highest value as a recycled stream since it has the widest variety of end-use applications. It is the most cost effective to process through the recycling system.

- Optical brighteners are detrimental to recycling. Optical brighteners are not removed in the recycling process and can create an unacceptable fluorescence for next uses of recycled PP. It is difficult to identify material with this negative effect until extremely late in the recycling process where a great deal of added cost has been imparted into a material of low value due to the additive.

- Translucent and opaque colors are preferred. PP is commonly colored so volumes and markets exist for colored material and it is economical to process.

- Black color renders the package non-recyclable per APR definition. There is no mechanical property inherent in black PP that makes it unrecyclable. The problem lies in sorting and the physics behind polymer identification. NIR (near-infrared) sorting technology used in MRFs is not capable of identifying a polymer with a pure black color since black absorbs all light. There are shades of black that may be detected by NIR, and a PP label of a different color on a package might aid in detection by NIR. It is not feasible to use manual sorting to distinguish one black polymer from another since there are just too many items.

  Therefore, in a MRF or PRF facility, it is very difficult to sort most black colored PP materials and direct them into a PP bale for reclaiming. At the reclaimer, float-sink will not sort out black PP since many black polymers float with PP.

  Although the APR encourages and anticipates development in capturing black plastics at the MRF this technology does not exist today. It should be noted that black is a commonly used color in PP, particularly in automotive batteries and similar industrial items. These items fall outside the scope of the design guide since they are not typically collected through curbside collection that is the focus of this guidance. Black PP, if collected in a source separated or postindustrial stream, can be reclaimed.

➢ **DIMENSIONS**

Size and shape are critical parameters in MRF sorting, and this must be considered in designing packages for recycling. The MRF process separates items by size and shape first, then by material. Screens direct paper, and similar two-dimensional lightweight items, into one stream; containers and similar three-dimensional heavier items into another steam; while broken glass and smaller but heavy items are allowed to drop by gravity to yet another stream, which may or may not be further sorted. Large, bulky items are typically manually sorted on the front of the MRF process.

- Items more two-dimensional than three-dimensional render the package non-recyclable per APR definition. Aside from not being captured in the plastic stream, they cause contamination in the paper stream. Items should have a minimum depth of two inches in order to create a three-dimensional shape for proper sorting. This issue is unrelated to the polymer type. The APR encourages and anticipates developments in MRF design and technology to improve capture and recovery of thin plastics; however, at the current time this technology either does not exist or is uninstalled in the majority of MRFs.

- Items smaller than 3 inches in all dimensions render the package non-recyclable per APR definition. The industry standard screen size loses materials less than three inches to a non-plastics stream, causing contamination in that stream, or directly to waste. These small packages are lost to the plastic recycling stream. It is possible that some small containers travel with larger ones when either the screens wrap with film or they are operated above their design capacity. Film wrapping reduces the effective size of the screen and over-running provides a cushion of large items on which the smaller items travel. The design guidelines use clean screens operating at their design capacity for the determination of the recyclability category. The APR anticipates and encourages technology development to improve the process of small package recovery but currently these items are not recovered.

- Polyethylene or Polypropylene are preferred for items greater than two gallons in volume. Recycling machinery, particularly automatic sorting equipment, is not large enough to accept items larger than two gallons. Because larger containers jam the systems, most MRFs employ manual sortation before the automatic line to remove the large items. These items are recovered in a stream of bulky rigid containers that are sold and processed as polyethylene since the vast majority of bulky rigid items are comprised of this polymer. Other polymers either negatively affect or are lost by the polyethylene processing.

➢ CLOSURES & DISPENSERS

- Polypropylene closures are preferred. Bacause polypropylene is the same polymer as the package body, closures and dispensers made of it will be captured and processed with PP. This increases the reclaimers yield and reduces possible waste.

- Polyethylene closures are detrimental to recycling. Because polyethylene floats in water like polypropylene, it is not separated in the reclaimers float-sink tank. When blended with PP it negatively affects stiffness and impact properties. Although very small amounts of PE, such as that contributed by labels, are regularly accepted by PP reclaimers, closures and dispensers comprise a larger weight percentage of the package and therefore a greater negative affect.

- Closure systems without liners are preferred. Due to size and thickness, most liners are lost in the recycling process thereby slightly decreasing yield. Closures without liners do not experience this loss.

- EVA and TPE liners in plastic closures are preferred. EVA and TPE float in water and will not be separated in the recycling process. However, they are compatible with PP and in fact enhance its properties so they are preferred.

- Pumps and spray dispensers containing metal parts are detrimental to recycling. Although metal is easily removed in the float-sink process, metal springs unravel during recycling and entwine themselves in screens designed to separate water from the material thereby ruining the screen. This adds significant cost and downtime to the recycling process. The APR encourages the use of polymer check valves and springs whenever technically possible. The body of the spray dispenser or pump should also be the same polymer as the body of the bottle whenever technical possible to increase yield and decrease contamination of the recycled PP.

- Closures containing metal or metal foils are detrimental to recycling. Although metal is easily removed in the float-sink process, most reclaimers have metal detection equipment designed to protect their cutting machinery. Therefore, the container never makes it to the float-sink tank. Large metal items attached to PP packages may cause the package to be directed to the metal or waste stream in the recycling process, causing yield loss.

- Closures containing floating silicone polymer are detrimental to recycling. This material passes through the float-sink tank along with the PP and is difficult to remove with other methods, thereby causing contamination in the final product. It should be noted that sinking silicone does not experience this issue.

- The use of PVC closures is detrimental to recycling**.** PVC is relatively easy to remove in the float-sink tank since it sinks while the PP floats. However, the float-sink tank is imperfect and even a very small amount of PVC with the recycled PP renders large amounts of it unusable as the PVC degrades at lower temperatures than those at which PP is processed.

- Closures made from polystyrene or thermoset plastics are preferred. Both materials are heavier than water and sink in the float-sink tank, thereby separating from the PP. They also do not damage or wear cutting machinery in the recycling process. Small amounts of these materials that make it through the float-sink process can be melt filtered from the recycled PP in the extrusion step. However, these materials are lost to the waste stream in the recycling process and are considered less preferable than an alternative floating attachment that is compatible with PP.

➢ LABELS, INKS AND ADHESIVES

- Label inks require testing to determine the appropriate APR recyclability category. Some label inks bleed color in the reclamation process, discoloring the PP in contact with them and possibly diminishing its value for recycling. Since most recycled PP is colored, the impact of bleeding inks may not be significant; however, since the end use is not known beforehand, label inks should be chosen that do not bleed color when recycled. The APR test protocol should be consulted to determine if an ink bleeds.

  The APR is in the process of developing a test protocol for inks:
  PP/HDPE Bleeding Label Test

- Direct printing other than date coding requires testing to determine its compatibility with the recycling system**.** Inks used in direct printing may bleed, otherwise discolor the PP during the recycling process, or introduce incompatible contaminants. In either case, the value of the recycled PP may be diminished. Some inks used in direct printing do not cause these problems. The specific ink must be tested to determine its effect.

One test protocol is available:
PP Benchmark Test

- In-mold labels of a compatible polymer are preferred. In-mold labels are not removed in the recycling process since they are bonded with the wall of the package. They will flow though the recycling process with the PP and be blended with the recycled PP. The lack of adhesive is beneficial to recycling since it cannot affect color or other mechanical properties. The label polymer and ink should be compatible with PP so as not to negatively affect its properties.

- Full bottle sleeve labels designed for sorting are preferred. A positive aspect of sleeve labels is the lack of adhesive requiring removal in the recycling process. However, full bottle sleeve labels cover a large amount of the bottle surface with a polymer that is not the same as the bottle body. Because of this, a sleeve label designed without considering sorting may cause an automatic sorter to direct a PP bottle to another material stream where it is lost to the process. Furthermore, some incompatible sleeve materials that cannot be separated from the PP in the float-sink tank can contaminate the recycled PP produced. Sleeve labels that are designed for automatic sorting and sink in water are preferred, with the exception of PVC, where even small residual amounts that make it through the float-sink process will destroy the recycled PP in the extrusion process. Polyolefin sleeve labels that are designed for automatic sorting are also preferred since the small levels of completely incompatible material expected from label residue has a very minimal negative impact.

- Adhesives require testing to determine the appropriate APR recyclability category. Testing must show that adhesives will either wash off cleanly from the PP in the recycling process or be compatible with PP. However, typical PP recycling process conditions are not aggressive enough to remove all adhesive material, and a certain amount of residual adhesive is to be expected in recycled PP. Adhesive that is not removed from PP during the wash step is a source of contamination and discoloration when PP is recycled. For these reasons, minimal adhesive usage is encouraged.

The APR is developing a PP/HDPE adhesive test to classify adhesive as either wash friendly, non-wash friendly and compatible with PP, or non-wash friendly and incompatible with PP. Non-wash friendly, incompatible adhesive is detrimental to recycling.

One test protocol is under development:
PP/HDPE Adhesive Test

Label-Adhesive Combinations: The classification and recyclability of label substrates is dependent on the type of adhesive that is used with them. In general, a label substrate that sinks in water and is used with an adhesive that releases in the reclaimers wash system is preferred since the substrate will be removed in the float-sink tank. A label substrate that is compatible with PP is also preferred no matter what the adhesive. Therefore, label substrates are classified by the type of adhesive used with them.

- Polypropylene or polyethylene labels are preferred. PP labels are the same polymer as the final product and PE at the very small levels expected from label residue has a very minimal negative impact. Therefore, these labels that remain with the PP throughout the recycling process, whether they detach or not, increase yield and have minimal negative quality impact for the reclaimer.

- Paper labels are detrimental to recycling. The PP reclamation process involves water and agitation. The paper that detaches from the container when subjected to these conditions becomes pulp, which does not sink intact but remains suspended in the liquid, adding load to the filtering and water treatment systems. Paper remaining adhered to the PP travels with the PP to the extruder where the material carbonizes and causes color defects. Even after melt filtering, the burned smell and discoloration remain with the recycled PP thereby negatively affecting its potential reuse. Non-pulping paper labels used with non-releasing adhesives compound the problem since the entire label enters the extruder. Non-pulping labels, heavy enough to sink and durable enough to withstand the washing process that are used with releasing adhesives may alleviate this issue.

- Metal foil labels are detrimental to recycling when used with an adhesive that does not release in the wash and preferred when used with an adhesive that releases in the wash. In the MRF, even very thin metallized labels may be identified as metal by the sorting equipment and cause the entire bottle to be directed to the metal stream, thereby creating yield loss. Sorting equipment in the reclaiming process is designed to detect and eliminate metal from PP. If small, not detected, or allowed to pass, these labels, when used with an adhesive that does not release in the wash, either cause the attached PP to sink where it is lost in the float-sink tank or pass into the extruder and are removed with melt filtering. When used with an adhesive that releases in the wash, these labels quickly sink in the float sink tank where they are removed

- PVC labels render the package non-recyclable per APR when used with an adhesive that does not release in the wash and detrimental to recycling when used with an adhesive that releases in the wash. PVC, when used with an adhesive that does not release in the wash, enters the extruder with the PP where they are incompatible. PVC degrades at PP extrusion temperatures and renders large amounts of the recycled PP unusable. When used with an adhesive that releases in the wash, these labels sink in the float-sink tank where they are removed. But because the float-sink tank is imperfect, and even a very small amount of PVC entering the extruder causes severe quality and yield problems, this material is detrimental.

- PLA labels render the package non-recyclable per APR when used with an adhesive that does not release in the wash and preferred when used with an adhesive that releases in the wash. PLA label material, when used with an adhesive that does not release in the wash, enters the extruder with the PP where they are incompatible. When used with an adhesive that releases in the wash, the PLA detaches from the PP before the float-sink tank where it sinks and is removed. Even though the float-sink process is imperfect, the small amounts of PLA entering the extrusion process are not catastrophic

- Polystyrene labels are detrimental to recycling when used with an adhesive that does not release in the wash and preferred when used with an adhesive that releases in the wash. PS, when used with an adhesive that does not release in the wash, remains with the PP and enters the extruder where it is blended with the PP. PS is not compatible with PP and may cause splay or reduce impact toughness for the recycled PP user. PS label material, when used with an adhesive that releases in the wash, detaches from the PP before the float sink tank where it sinks and is removed.

➢ ATTACHMENTS

- Polypropylene or polyethylene tamper evident safety sleeves are preferred. PP safety sleeves are the same polymer as the final product, and PE at the very small levels expected from safety sleeve residue has a very minimal negative impact. Therefore, these attachments that remain with the PP throughout the recycling process increase yield and have minimal negative quality impact for the reclaimer.

- PETG tamper evident safety sleeves are preferred. PETG sinks in the float sink tank where it is removed from the PP. Unlike PVC, small amounts of PETG entering the extrusion process with the PP are not catastrophic since PETG can be melt filtered.

- PVC tamper evident safety seals are detrimental to recycling. PVC sinks in the float-sink tank where the majority of it is removed from the PP. Because the float sink tank is imperfect and even a very small amount of PVC entering the extruder causes sever quality and yield problems, this material is detrimental. PVC degrades at PP extrusion temperatures and renders large amounts of the recycled PP unusable.

- Non-PP attachments require testing to determine the appropriate APR recyclability category. Testing must show that these attachments are not adhesively bonded to the package and are made from materials that sink in water so they readily separate from the package when ground and put through a float-sink separation. If adhesives are used to affix attachments, their selection should consider the adhesive criteria within this document.

  One test protocol is available:
  PP Benchmark Test

- Metal and metal-containing attachments require testing to determine the appropriate APR recyclability category. Metal or metal-containing attachments may cause NIR sorters in MRFs to misidentify a PP container as metal and direct it to a metal stream, from which it is then discarded. Sorting equipment in the reclaiming process is designed to detect and eliminate metal from PP in order to protect cutting machinery. Large items, or items adhesively bonded to the PP, can damage the machinery and render the entire package non-recyclable. If small, not detected, or allowed to pass, metals, when used with wash friendly or no adhesive quickly sink in the float sink tank where they are removed from the PP.

  APR is currently developing an eddy current and magnetic test protocol for metal and metal-containing attachments.

- Plastic attachments with a density > 1.00 except for PVC are preferred. These items sink in the sink-float tank where they are removed from the PP and small residual amounts do not severely affect the final product since many of them are melt filtered. PVC is detrimental as discussed elsewhere in this document.

- Welded attachments require testing to determine the appropriate APR recyclability category. A certain amount of a welded attachment cannot be separated from the PP in the recycling process. These attachments may cause recycled PP contamination and yield loss issues in both cases: when the ground section containing both polymers sinks and carries the PP with it, or when the ground section floats and carries an incompatible material with the PP into the extrusion process. Testing must show that the blend is of a density less than 1.0 so that it floats along with the PP in the float-sink tank, and that it is compatible with PP in the extrusion process.

- Polyethylene attachments are detrimental to recycling. Because polyethylene floats in water like polypropylene, it is not separated in the reclaimers float-sink tank. When blended with PP it negatively affects stiffness and impact properties. Although very small amounts of PE, such as that contributed by labels, are regularly accepted by PP reclaimers, some attachments comprise a larger weight percentage of the package and therefore a greater negative affect.

- RFID's (radio frequency identification devices) on packages, labels or closures are detrimental to recycling. RFID's are printed on silver metal, which may create costly waste disposal issues. While RFID's are small, they may affect PP recycling in the same ways as metal labels or other attachments. The use of RFID's is discouraged as may limit PP yield, introduce potential contamination, and increase separation and waste disposal costs.

- PLA attachments are preferred. As discussed in the sections on labels and closures, PLA sinks in the float-sink tank and can be therefore removed from the PP. Unlike PVC, small amounts of PLA entering the extrusion process are not catastrophic

- PVC attachments are detrimental to recycling. PVC sinks in the float sink tank where the majority of it is removed from the PP. Because the float sink tank is imperfect and even a very small amount of PVC entering the extruder causes sever quality and yield problems, this material is detrimental. PVC degrades at PP extrusion temperatures and renders large amounts of the recycled PP unusable

RESIN IDENTIFICATION CODE, RIC

Use the correct Resin Identification Code symbol of the proper size as detailed in ASTM D7611 is encouraged.

APR Design® Guide for Plastics Recyclability
for
EPS (Expanded Polystyrene, Resin Identification Code #6)

BACKGROUND: The light bulk density of expanded polystyrene (EPS) provides outstanding insulation and cushioning and is frequently used in applications requiring these properties. EPS is most often collected and recycled in a dedicated, source selected system outside the scope of the APR Design Guide for Plastics Recyclability such as a distribution center stream.

EPS is a very recyclable material once the product arrives at the reclaimer. Collection and transportation challenges should not be confused with processibility and reusability of this material.
A limited number of curbside EPS collection systems exist in North America so this material does not currently meet the collection accessibility criteria established in "APR's definition of recyclable" or by the FTC https://www.ftc.gov/sites/default/files/attachments/press-releases/ftc-issues-revised-green-guides/greenguides.pdf Anticipating the development and growth of future EPS recycling programs, the APR recommends the following guidelines:

- **BASE POLYMER:**
  - The use of postconsumer PS in all packages is encouraged to the maximum amount technically and economically feasible.

- **BARRIER LAYERS, COATINGS & ADDITIVES**
  - Degradable additives (photo, oxo, or bio) require testing to determine the appropriate APR recyclability category. Recycled EPS is intended to be used in new products. The new products are engineered to meet particular quality and durability standards given properties of typical recycled EPS. Additives designed to degrade the polymer diminish the life of the material in the primary use. If not removed in the recycling process, these additives shorten the useful life of the product made from the RPS as well, possibly compromising quality and durability.

    Degradable additives should not be used without testing to demonstrate that their inclusion will not materially impair the full-service life and properties of any product made from the EPS that includes the additive. These additives must either separate and be removed from the EPS in the recycling process or have no adverse effects on future uses. When used, their content should be minimized to the greatest extent possible to maximize yield, limit potential contamination, and reduce separation costs.

    One test protocol will be developed.

- **COLOR**

- Unpigmented or white polymer is preferred. This material has the highest value as a recycled stream since it has the widest variety of end-use applications.

- Light pink or light blue color is preferred. These colors are common and dilute enough that they don't significantly affect the color of the recycled product.

- Black color renders the package non-recyclable per APR definition. NIR sorting is critical to establishing an EPS stream in a MRF. This technology is not capable of identifying a black polymer and manual sorting cannot distinguish one black polymer from another. Therefore, black packaging is considered a contaminant for nearly all reclaimers.

- **DIMENSIONS**

Size and shape are critical parameters in MRF sorting, and this must be considered in designing packages for recycling. The MRF process separates items by size and shape first, then by material. Screens direct paper, and similar two-dimensional lightweight items, into one stream; containers and similar three-dimensional heavier items into another steam; while broken glass and smaller but heavy items are allowed to drop by gravity to yet another stream, which may or may not be further sorted. Large, bulky items are typically manually sorted on the front of the MRF process.

- Items more two-dimensional than three-dimensional render the package non-recyclable per APR definition. Aside from not being captured in the plastic stream, they cause contamination in the paper stream. Items should have a minimum depth of two inches in order to create a three-dimensional shape for proper sorting. This issue is unrelated to the polymer type. The APR encourages and anticipates developments in MRF design and technology to improve capture and recovery of thin plastics; however, at the current time this technology either does not exist or is uninstalled in the majority of MRFs.

- Items smaller than 3 inches in all dimensions render the package non-recyclable per APR definition. The industry standard screen size loses materials less than three inches to a non-plastics stream, causing contamination in that stream, or directly to waste. These small packages are lost to the plastic recycling stream. It is possible that some small containers travel with larger ones when either the screens wrap with film or they are operated above their design capacity. Film wrapping reduces the effective size of the screen and over-running provides a cushion of large items on which the smaller items travel. The design guidelines use clean screens operating at their design capacity for the determination of the recyclability category. The APR anticipates and encourages technology development to improve the process of small package recovery but currently these items are not recovered.

- Items greater than two gallons in volume are detrimental to recycling. Recycling machinery, particularly automatic sorting equipment, is not large enough to accept items larger than two gallons. Because larger containers jam the systems, most MRFs employ manual sortation before the automatic line to remove the large items. These items are recovered in a stream of bulky rigid containers that are sold and processed as polyethylene since the vast majority of bulky rigid items are comprised of this polymer. Other polymers either negatively affect or are lost by the polyethylene processing.

CLOSURES & DISPENSERS

- Polypropylene and polyethylene closures are detrimental to recycling. Although the polymer is heavier than water, EPS floats in water due to the air entrapped in the structure. PE and PP float as well so they are not separated by conventional density separation methods. PE and PP therefore, remain with the EPS until the extrusion process. Contaminates that remain until the extrusion process are filtered from the PS if they remain solid at PS processing temperatures. PE and PP are liquid at these temperatures and are not removed.

- The use of PVC closures renders the package non-recyclable per APR. Float sink tanks are not perfect machines. Even though PVC sinks and the EPS floats small amounts of PVC travel with the EPS. The recycled EPS stream is very intolerable to even minute amounts of PVC since it degrades quickly at EPS processing temperatures, erodes machinery and creates a safety risk. Small pieces of PVC render large amounts of the finished product unusable.

LABELS, INKS AND ADHESIVES

Some EPS recycling processes do not remove adhesive. The adhesive travels through the process with the PS and is blended in the final product. The most recyclable packages use the lowest quantity of adhesive that is compatible with PS. Lower adhesive usage reduces processing cost and potential contamination risk.

- Polystyrene labels are preferred. PS is the same material as the package so the label will behave like the package and be recycled along with it creating no added contamination or yield loss.

- Direct printing on EPS is preferred.Most direct print inks withstand the standard EPS recycling process and remain on the package. Since no adhesive is used and the weight percent of label is extremely low compared to alternative labeling, they add little contamination to the final product.

- High melting temperature plastic labels such as PET are preferred. These labels sink in the float sink tank if one is employed and remain solid in the PS extruder so they can be removed through filtering.

- Metal foil labels are detrimental to recycling. Metal detectors are employed in the recycling process to protect machinery. Even thin metal foil labels may be identified by detectors and cause the entire package to be rejected as waste, thereby creating yield loss. If not detected, they pass through the process with the PS and cause contamination in the extrusion process. Since they remain solid in the extrusion process they can be filtered from the melted polymer which is advantageous over other materials that melt.

- Paper labels are detrimental to recycling. Most paper labels remain on the package during the washing phase of the recycling process and enter the extruder with the PS. Paper degrades in the extruder emitting a burnt smell into the plastic that cannot be removed. Most of the paper can be filtered from melted PS but the smell and small individual fibers remain.

- Polypropylene or polyethylene labels are detrimental to recycling. Like most labels, PP and PE labels remain on the package during the washing phase of the recycling process and enter the extruder with the PS. Both PE and PP are liquid at the operating temperatures of the PS extruder and cannot be removed by a filter. They contaminate the final PS.

- PVC labels render the package unrecyclable per APR. This material is extremely difficult to remove in the recycling process due to its similarity in density to PS. Furthermore, it degrades in the extruder rendering large sections of PS unusable.

- Adhesives require testing to determine the appropriate APR recyclability category. Most adhesives will remain on the package during the EPS washing process and enter the extruder with the PS. Adhesives should either remain solid so they can be melt filtered from the PS or be compatible with PS.

ATTACHMENTS

- Clear PS attachments affixed to EPS containers are preferred. Attachments made of the base polymer cause no contamination.

- Non-PS attachments such as handles require testing to determine the appropriate APR recyclability category. These should not be adhesively bonded to the package and should readily separate from the package when ground. They should be made from materials that sink in water such as filled PP/HDPE, or PET. If adhesives are used to affix attachments, their selection should consider the adhesive criteria within this document.

  One test protocol for PP is available that can be used for EPS:
  Screening Test: Float test

- Metal and metal containing attachments are detrimental to recycling. Metal attachments to EPS are either detected by metal detectors at the beginning of the recycling process and cause the entire section to be rejected or they enter the process with the EPS where they wear and damage machinery before being separated in the float-sink tank. If they stay attached to the material, they can be floated into downstream equipment with the EPS and damage the machinery.

- Welded attachments are detrimental to recycling. A certain amount of a welded attachment cannot be separated from the main polymer in the recycling process. These attachments, even when ground and made of floatable materials, cause contamination and yield loss issues in both cases: when the EPS they are attached to causes the ground section containing both polymers to float, or when the ground section floats.

- RFID's (radio frequency identification devices) on packages, labels or closures are detrimental to recycling. Unless they are compatible with EPS recycling and are demonstrated not to create any disposal issues based on their material content, the use of RFID's is discouraged as it limits yield, introduces potential contamination, and increases separation costs.

- PVC attachments of any kind render the package non-recyclable per APR definition. The use of PVC attachments of any kind on EPS packaging is undesirable and should be avoided. Even though PVC sinks, the recycled EPS stream is very intolerable to even minute amounts of PVC since it degrades quite easily and renders large sections of the finished product unusable.

- **RESIN IDENTIFICATION CODE, RIC**
  Use of the correct Resin Identification Code symbol of the proper size as detailed in ASTM D7611 is encouraged.

APR Design® Guide for Plastics Recyclability
for
PS (Polystyrene, Resin Identification Code #6)

BACKGROUND: Polystyrene is typically used in applications requiring its stiffness, resistance to cracking, and ease of modification. This section of the design® guide applies to rigid PS. Expanded PS (EPS) is addressed in its own dedicated section.

A limited number of curbside PS collection systems exist in North America so this material does not currently meet the collection accessibility criteria established in "APR's definition of recyclable" or by the FTC https://www.ftc.gov/sites/default/files/attachments/press-releases/ftc-issues-revised-green-guides/greenguides.pdf Anticipating the development and growth of future PS recycling programs, the APR recommends the following guidelines:

- **BASE POLYMER:**
  - The use of postconsumer PS in all packages is encouraged to the maximum amount technically and economically feasible.

- **BARRIER LAYERS, COATINGS & ADDITIVES**

- Non-PS layers and coatings require testing to determine the appropriate APR recyclability category. The use of non-PS layers and coatings can be detrimental to recycling of PS if not implemented according to APR test protocols. Layers and coatings must either separate and be removed from the container wall in the recycling process or have no adverse effects on the polymer in future uses. When used, their content should be minimized to the greatest extent possible to maximize yield, limit potential contamination, and reduce separation costs.

  Test protocol: TBD

- Degradable additives (photo, oxo, or bio) require testing to determine the appropriate APR recyclability category. Recycled PS is intended to be used in new products. The new products are engineered to meet particular quality and durability standards given properties of typical recycled PS. Additives designed to degrade the polymer diminish the life of the material in the primary use. If not removed in the recycling process, these additives shorten the useful life of the product made from the RPS as well, possibly compromising quality and durability.

  Degradable additives should not be used without testing to demonstrate that their inclusion will not materially impair the full-service life and properties of any product made from the RPS that includes the additive. These additives must either separate and be removed from the PS in the recycling process or have no adverse effects on future uses. When used, their content should be minimized to the greatest extent possible to maximize yield, limit potential contamination, and reduce separation costs.

Test protocol TBD

- Additives require testing to determine the appropriate APR recyclability category. The APR recognizes that other types of additives may be required for the performance of a particular package but are not addressed in this document. Additives such as de-nesting, anti-static, anti-blocking, anti-fogging, anti-slip, UV barrier, stabilizer and heat receptor agents and lubricants should be tested to determine their compatibility with recycling. Of particular concern are additives which cause the polymer to discolor or haze after remelting since recycled material with poor haze or discoloration is greatly devalued and has limited markets. This is particularly troublesome since it is difficult to identify material with this effect until extremely late in the recycling process where a great deal of added cost has been imparted into the material.
  Test protocol: TBD

- Optical brighteners are detrimental to recycling. Like many other additives, optical brighteners are not removed in the recycling process and can create an unacceptable fluorescence for next uses of the recycled polymer containing the brighteners. It is difficult to identify material with this negative effect until extremely late in the recycling process where a great deal of added cost has been imparted into a material of low value due to the additive.

COLOR

- Clear unpigmented polymer is preferred. Clear material has the highest value as a recycled stream since it has the widest variety of end-use applications. It is the most cost effective to process through the recycling system.

- Black color renders the package non-recyclable. NIR sorting technology is not capable of identifying a black polymer and manual sorting cannot distinguish one black polymer from another. Other separation techniques such as float-sink cannot be employed since many black polymers sink with PS/PLA. Therefore, black packaging is considered a contaminant for nearly all reclaimers.

DIMENSIONS

Size and shape are critical parameters in MRF sorting, and this must be considered in designing packages for recycling. The MRF process separates items by size and shape first, then by material. Screens direct paper, and similar two-dimensional lightweight items, into one stream; containers and similar three-dimensional heavier items into another steam; while broken glass and smaller but heavy items are allowed to drop by gravity to yet another stream, which may or may not be further sorted. Large, bulky items are typically manually sorted on the front of the MRF process.

- Items more two-dimensional than three-dimensional render the package non-recyclable per APR definition. Aside from not being captured in the plastic stream, they cause contamination in the paper stream. Items should have a minimum depth of two inches in order to create a three-dimensional shape for proper sorting. This issue is unrelated to the polymer type. The APR encourages and anticipates developments in MRF design and technology to improve capture and recovery of thin plastics; however, at the current time this technology either does not exist or is uninstalled in the majority of MRFs.

- Items smaller than 3 inches in all dimensions render the package non-recyclable per APR definition. The industry standard screen size loses materials less than three inches to a non-plastics stream, causing contamination in that stream, or directly to waste. These small packages are lost to the plastic recycling stream. It is possible that some small containers travel with larger ones when either the screens wrap with film or they are operated above their design capacity. Film wrapping reduces the effective size of the screen and over-running provides a cushion of large items on which the smaller items travel. The design guidelines use clean screens operating at their design capacity for the determination of the recyclability category. The APR anticipates and encourages technology development to improve the process of small package recovery but currently these items are not recovered.

- Items greater than two gallons in volume are detrimental to recycling. Recycling machinery, particularly automatic sorting equipment, is not large enough to accept items larger than two gallons. Larger containers jam the systems. Most MRFs employ manual sortation before the automatic line to remove the large items. These items are recovered, but most likely baled with a mixed stream of bulky rigid containers and are not normally sorted by polymer at the MRF. Some MRFs may not recover items picked in the pre-sort.

CLOSURES & DISPENSERS

- Polypropylene and polyethylene closures are preferred. Since these polymers float, they are most easily separated from the bottle in conventional separation systems. Additionally, the PS recycling process captures floatable polyethylene and polypropylene to create an ancillary stream of marketable material. Care must be taken when modifying the polyethylene or polypropylene to ensure the modifier does not increase the overall density to the point it sinks. Note that these are not removed in the combined recycling process but, instead become a contaminate. Minimizing closure size is advantageous to both processes.

- Closure systems without liners are preferred. Due to size and thickness, most liners are lost in the recycling process thereby slightly decreasing yield. Closures without liners do not experience this loss.

- EVA and TPE liners in plastic closures are preferred. Both EVA and TPE float in water and will be separated in the recycling process with the floatable polyethylene and polypropylene. Since EVA and TPE are compatible with these polymers, and in fact enhance their properties, they are preferred.

- Closures containing metal or metal foils require testing to determine the appropriate APR recyclability category. Metal is difficult to separate from PS compared to the preferred closure systems (polypropylene and polyethylene) and adds both capital and operating costs to conventional reclamation processes. Even a small amount of metal left in the recycled polymer stream will block extruder screens in remanufacturing. Large metal items attached to PS packages may cause the package to be directed to the metal or waste stream in the recycling process, causing yield loss. Small metal components such as spray dispenser springs unravel in the recycling process and blind screens, adding significant cost for removal at the end of the process.

  Two PET test protocols are available that can be used for PS/PLA:
  Screening Test: New Eddy Current and Magnetic Test for Attachments
  Definitive Test: Closure Test

- Closures made from thermoset plastics are detrimental to recycling. These materials are heavier than water and sink in the float-sink tank with PS/PLA. They are extremely difficult to separate from the recycled polymer flake, requiring a costly and inexact polymer flake sorter currently not installed in many reclaiming operations.

- Closures containing silicone polymer are detrimental to recycling. Silicone generally sinks in the float-sink tank with the PS/PLA and is difficult to remove with other methods, thereby causing contamination in the final product.

- The use of PVC closures or closure liners render the package non-recyclable per APR definition. PVC sinks and is extremely hard for the recycler to remove. The recycled PS stream is very intolerable to even minute amounts of PVC since it degrades quite easily.

LABELS, INKS AND ADHESIVES

Removing adhesives is a significant component to the cost of recycling. The most recyclable packages use the lowest quantity of recycle-friendly adhesive. Lower adhesive usage reduces processing cost and potential contamination risk.

- Polypropylene or polyethylene labels with a specific gravity less than 0.95 are preferred. These materials float in water so they are separated from the PS in the float-sink tank with the closures. Since they are the same general polymer as most of the closures they do not contaminate or devalue this stream. Care should be taken to ensure that any modifiers to the label material do not increase its density above 0.95. Note that these are not removed in the combined recycling process but, instead become a contaminate. Minimizing label size is advantageous to both processes.

- Laminated labels require testing to determine the appropriate APR recyclability category. Labels that break into small, very thin pieces of material are more difficult to manage in the recycling process because they behave erratically in a float-sink tank. Therefore, labels that stay intact are preferred. Carry-over of delaminated labels into the RPS can result in contamination.

One PET test protocol is available that can be used for PS:
Definitive Test: New Delamination Test

- Full bottle sleeve labels require testing to determine the appropriate APR recyclability category. Full bottle sleeve labels cover a large amount of the bottle surface with a polymer that is not the same as the bottle body. Because of this, a sleeve label designed without considering recycling may cause a false reading on an automatic sorter and direct a PS bottle to another material stream where it is lost to the process. Furthermore, some sleeve label materials cannot be removed in the recycling process and contaminate the RPS produced. Sleeve labels that have been found compliant with the APR test protocols should be selected.

  One PET test protocol is available that can be used for PS:
  Definitive Test: Sleeve Label Test

- Pressure sensitive labels require testing to determine the appropriate APR recyclability category. Pressure sensitive labels generally require complete adhesive coverage which is greater than other typical label methods. This raises the importance of the compatibility of the type of adhesive with the recycling process. Adhesives resistant to washing in the recycling process allow labels to remain on the container and become contaminants in the final product. Adhesives that have been found compliant with the APR test protocols should be selected.

  Two PET test protocols are available that can be used for PS:
  Screening test: Thermoform Label Test
  Definitive Test: Pressure Sensitive Label Test

- Polystyrene labels are preferred for PS Containers. PS is the same material as the bottle body, so the label will behave like the bottle, and be recycled along with it.

- Label structures that sink in water because of the choice of substrate, ink, decoration, coatings, and top layer require testing to determine the appropriate APR recyclability category. The reclaimers rely on float-sink systems to separate non-PS materials. Label components that sink with the PS end up in the recycled polymer stream as contaminants.

- High melting temperature plastic labels such as PET are preferred. These labels sink in the float sink tank if one is employed and remain solid in the PS extruder so they can be removed through filtering.

- Paper labels are detrimental to recycling (for pressure sensitive paper labels reference the pressure sensitive label category. The PS reclamation process involves a hot caustic wash that removes glue and other label components to the levels required to render the RPS usable. Paper, when subjected to these conditions, becomes pulp which is very difficult to filter from the liquid, thereby adding significant load to the filtering and water treatment systems. Individual paper fibers making up pulp are very small and difficult to remove so some travel with the PS. Paper fibers remaining in the RPS carbonize when the material is heated and re-melted, causing quality degradation and a burnt smell to the polymer. Non-pulping paper labels that resist the caustic wash process sink in the float-sink tank, thereby causing RPS contamination. These, although removed when the polymer is melt filtered, carbonize causing the same effect.

- Metal foil labels are detrimental to recycling. Sorting equipment in the recycling process is designed to detect and eliminate metal from PS. Even very thin metal foil labels may be identified as metal by the sorting equipment and cause the entire bottle to be rejected as waste, thereby creating yield loss. If not detected, they pass through the process with the PS and cause contamination issues in the final product.

- PVC labels render the package unrecyclable per APR. This material is extremely difficult to remove in the recycling process due to its similarity in density to PS

- PLA labels affixed to PS containers render the package unrecyclable per APR. This material is extremely difficult to remove in the recycling process due to its similarity in density to PS and cause quality problems for the end product.

- Adhesives require testing to determine the appropriate APR recyclability category. Adhesives that wash off cleanly from PS and remain adhered to the label are preferred. Label adhesive that is not removed from PS, or which re-deposits on the PS during the wash step is a source of contamination and discoloration when PS is recycled.

  The recycling process is designed to remove reasonably expected contamination from the surface of the container to a degree necessary to render the polymer economically reusable in further applications. In practice, some adhesives are resistant to this process so are detrimental to recycling. In extreme cases, an adhesive and label cannot be separated from the PS/PLA and may render a package not recyclable.

  Two PET test protocols are available that can be used for PS:
  Screening Tests: PET Flake Wash Test and Thermoform Label Test

- Label inks require testing to determine the appropriate APR recyclability category . Some label inks bleed color in the reclamation process, discoloring the polymer in contact with them and significantly diminishing its value for recycling. Label inks must be chosen that do not bleed color when tested under this protocol.

  Two PET test protocols are available that can be used for PS:
  Screening Tests: Bleeding Label Test and Flake to Plaque Bleeding Label Test
  *See the definitive test for the appropriate label type

- Direct printing other than date coding requires testing to determine its compatibility with the recycling system. Historically, inks used in direct printing tend to bleed or otherwise discolor the polymer during the recycling process, or introduce incompatible contaminants. In either case, the value of the recycled polymer is diminished. Some inks used in direct printing do not cause these problems. The specific ink must be tested to determine its effect.

  Two PET test protocols are available that can be used for PS:

Screening Tests: Bleeding Label Test
Definitive Test: Direct Print Label Test

- **ATTACHMENTS**

- Clear PS attachments affixed to PS containers are preferredAttachments made of the base polymer are recovered and recycled with the base polymer without causing contamination or yield loss, thereby generating the highest value.

- Tamper evident sleeves and safety seals require testing to determine the appropriate APR recyclability category. If tamper resistance is required in specific product applications, it should be an integral design feature of the bottle. The use of tamper-resistant or tamper-evident sleeves or seals is discouraged as they can act as contaminants if they do not completely detach from the bottle, or are not easily removed in conventional separation systems. If sleeves or safety seals are used, they should be designed to completely detach from the bottle, leaving no remains on the bottle. The material used should float and separate from the PS in the float-sink system.

  One PET test protocol is available that can be used for PS:
  Screening Test: Labels, Closures and Attachments Floatability Test

- Non-PS attachments such as handles require testing to determine the appropriate APR recyclability category. These should not be adhesively bonded to the package and should readily separate from the package when ground. They should be made from materials that float in water such as PP or HDPE. If adhesives are used to affix attachments, their selection should consider the adhesive criteria within this document.

  One PET test protocol is available that can be used for PS.
  Screening Test: Labels, Closures and Attachments Floatability Test

- Metal and metal containing attachments require testing to determine the appropriate APR recyclability category. Examples include metal foils and metalized substrates that sink in water as well as metal sprayer balls and springs. In the recycling process these items are either identified and removed along with their PS component in the early stages, thereby causing yield loss, or they pass into the recycling process causing a contamination issue. Since they are heavier than water they sink with the PS in the float-sink tank. Many of these items are too small to be removed with machinery designed to remove metal such as eddy current and optical separators. Springs in particular unravel and become entangled in filtering screens throughout the recycling process.

  One PET test protocol is available that can be used for PS:
  Screening test: New Eddy Current and Magnetic Test for Attachments

- Paper attachments are detrimental to recycling. The PS reclamation process uses a hot caustic wash to remove glue and other contaminants to the levels required to render the RPS usable. Paper, when subjected to these conditions, becomes pulp which is very difficult to filter from the liquid, thereby adding significant load to the filtering and water treatment systems. Individual paper fibers making up pulp are very small and difficult to remove so some travel with the final polymer. Paper fibers remaining in the RPS carbonize when the material is reused causing quality degradation.

- Welded attachments are detrimental to recycling. A certain amount of a welded attachment cannot be separated from the main polymer in the recycling process. These attachments, even when ground and made of floatable materials, cause contamination and yield loss issues in both cases: when the PS/PLA they are attached to causes the ground section containing both polymers to sink, or when the ground section floats.

- RFID's (radio frequency identification devices) on packages, labels or closures are detrimental to recycling. Unless they are compatible with PS/PLA recycling and are demonstrated not to create any disposal issues based on their material content, the use of RFID's is discouraged as it limits yield, introduces potential contamination, and increases separation costs.

- PVC attachments of any kind render the package non-recyclable per APR definition**.** The use of PVC attachments of any kind on PS packaging is undesirable and should be scrupulously avoided. This includes thermoforms of PVC that may be visually confused with PS thermoforms. Very small amounts of PVC can severely contaminate and render large amounts of PS useless for most recycling applications. In addition, PVC is very difficult to separate from PS in conventional water-based density separation systems due to similar densities (densities greater than 1.0) that cause both to sink in these systems.

- PLA attachments of any kind affixed to a PS container render the package non-recyclable per APR definition. The use of PLA attachments of any kind on PS packaging is undesirable and should be scrupulously avoided.. Very small amounts of PLA can severely contaminate and render large amounts of PS useless for most recycling applications. In addition, PLA is very difficult to separate from PS in conventional water-based density separation systems due to similar densities (densities greater than 1.0) that cause both to sink in these systems.

➢ POSTCONSUMER CONTENT

The use of postconsumer PS in all packages is encouraged to the maximum amount technically and economically feasible.

➢ RESIN IDENTIFICATION CODE, RIC

Use the correct Resin Identification Code symbol of the proper size as detailed in ASTM D7611 is encouraged.