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Plastic Squeeze Tubes Design Resource Document
HDPE and PP Based Tube Packaging

Introduction

Plastic squeeze tubes are typically defined as having a semi-flexible body, pinched off at one end, and closed on the other end by a rigid shoulder and cap. This resource document was developed to provide those engaged with plastic squeeze tube packaging detailed understanding of steps that can be taken to design or employ a squeeze tube that is technically compatible with either the HDPE bottle or PP rigid curbside residential collection recycling stream.

This document is written to complement the APR Design® Guide for Plastics Recyclability by consolidating key APR Design® Guidance directed to HDPE and PP squeeze tubes: https://plasticsrecycling.org/apr-design-guide/apr-design-guide-home

*Important note: This APR Resource Document is intended to provide guidance on how to design plastic squeeze tube packaging that is technically compatible with the current HDPE bottle and PP rigid recycling streams. Design alone is not sufficient to make marketing claims of recyclability for a specific tube design, if the packaging format is not yet considered accepted for recycling. Work is currently underway by a multi-stakeholder initiative to address the necessary elements to achieve recyclability for plastic squeeze tubes as a packaging format, beyond design. Please reference this **site** for additional information.*

This document will provide:

- Background on the construction and recycling of tubes.
- Design guidance and a model specification for HDPE based tubes.
- Design guidance and a model specification for PP based tubes.

Background

Common applications for tube packaging

Tube packaging is often used for personal care products such as lotion, shampoo, conditioner, toothpaste, or cosmetics for example. Tubes can also be used for food products.

Tubes are employed in a range of sizes from less than an ounce in volume up to 12 ounces.

Components of a tube

HDPE tubes can be extruded or assembled with a laminated sheet or film. PP tubes are typically extruded, injection molded or assembled with a laminated sheet or film. These are the common components of any tube:

- The tube body or sleeve
- A shoulder
- A closure

Further,

- The tube body might employ a gas or flavor barrier layer. Aluminum foils have been widely used in the past. EVOH barrier layers are also used.
- Pigments and fillers are often used to color the tube and provide opacity to protect the product inside the tube.
- Typical squeeze tube wall thicknesses are 160 micron (.006 in) to 600 micron (.020 in).
- The tube will have labeling and decoration. Surface printing is common for extrusion and laminated tubes. It is common for injection molded PP tubes to employ in-mold labels.
- It is not common, but there might be a tube design that includes an insert or an attachment that is part of the package design.

Recycling of tubes in curbside single stream collection

Curbside single stream collection is the most common method for collection of rigid postconsumer plastic packaging for recycling. Currently, tubes are not considered an accepted packaging format for recycling in curbside collection. Tubes need to be compatible with an existing commodity consolidated for recycling at the material recovery facility (MRF) because as a packaging type they do not generate enough material by weight to be consolidated alone. Design guidance to ensure compatibility and sortability with the appropriate bale commodities purchased by reclaimers is a key initial step for tubes on the journey to being accepted for recycling.

Stakeholders engaged in the use of tubes are interested in developing the capability for tubes to be routinely included in the curbside collection one day. The information below presents the technical features that are required for tubes to be compatible with today's reclamation and sortation processes.

APR Design Guidance for HDPE tubes

An HDPE tube that meets preferred Design Guidance is presented in the model specification below. This model specification anticipates that the target bale for a HDPE

tube will be the mixed color HDPE bottle bale. This model is not intended to replace detailed specifications agreed to between individual buyers and sellers of plastic squeeze tubes, and which may include requirements that extend beyond the guidance provided in this model.

The HDPE Tubes Model Specifications Present:

1. A guidance table for materials selection and reclamation performance
2. A guidance table for sorting performance.

With today's emphasis on developing the circular economy for plastics, packages that are compatible with widely used recycling processes and have negligible impact, if any, on the quality and productivity of HDPE recycling are considered APR Preferred. The tube body for an HDPE tube is produced from a low melt flow rate (MFR) HDPE resin; the low MFR HDPE is similar in viscosity to HDPE resins used in some blow molded bottles thus making them more compatible during recycling. LLDPE and LDPE resins are also used in tube manufacturing and can be compatible with the HDPE recycled bottle stream. The shoulder and closures are made by injection molding. APR Guidance for HDPE tubes is that it is preferred when all components are made of the same resin, including the sleeve, shoulder, cap and insert, at density and melt flow blends that allow the package to meet the below noted density and melt flow ranges. Additionally, efforts toward improved evacuation of the product through design and the use of PCR in the package, are also highly encouraged.

1. **Model Specification: HDPE Tube Materials Selection and Reclamation Performance**

Tube Material/Feature	Preferred Material	APR Guidance	Test Method
Body, shoulder and cap as a package Body/sleeve can be extruded or laminated.	HDPE and/or (L)LDPE, EVOH, tie layer	Melt Flow Rate (MFR) between >0.2 g/10 min, but < 4.00 g/10 min 190C/2.16kg (based on the HDPE-CG-01 MFR requirement of the 50:50 blend delta to the control) Density in range of 0.941-0.970 g/cm3 for the package is preferred, if greater than .98 g/cm3, testing is required. 5% or less EVOH (with minimum 32mol%	ASTM D1238 (190/2.16) MFI can be measured in the laboratory or calculated with the equations provided below under Melt Index Blend. ASTM D792 for specific gravity (result .943-.972)[1] Alternative: ASTM D1505 for density

[1] When using the ASTM D792 for specific gravity to determine density, subtract .002 g/cc from D792 value.

Tube Material/Feature	Preferred Material	APR Guidance	Test Method
		ethylene) of the package is preferred	APR Critical Guidance Test HDPE-CG-01 - Testing is performed on the package. Cap is also included, if HDPE.
Wall Thickness		Experience indicates a wall section of less than 200 microns should be tested. Elutriation loss maximum pending review.	Elutriation of Polyolefin Flake, O-P-05, as referenced in O-P-00 Polyolefin Standard Laboratory Processing Practices
Any inserts or attachments	Made with HDPE and so compatible with HDPE, or is made with a polymer that can be liberated and separated from the tube.	100 % of the HDPE based material with any pigments, fillers and label decoration floats in water.	Polyolefin Sink/float Screening Test O-S-01 No impact on melt filtration test in HDPE-CG-01

Density
Squeeze tubes can use different densities of PE as long as the blend of the package meets the overall density requirement.

Melt Index Blend
Explanation note on melt index of the blend of the body, shoulder and cap to achieve the melt flow rate above. The weight percentage of the closure and shoulder can be a substantial percent of the total weight of the tube. APR Guidance is to select the melt index of the shoulder, tube, and closure to have the least impact on the over-all melt index of the blended material. Please see examples below.

One method to know the melt index of the blend is to follow the practices employed in the HDPE-CG-01 where parts are granulated and melt extruded. The melt index of the melt blended material can be measured.

The following calculation is offered and can be employed as an alternative to laboratory testing:

$$log(MI_{blend}) = \sum \quad w_i log(MI_i)$$

So, to meet current requirements in the Critical Guidance given in HDPE-CG-01 where a 50:50 blend of an innovation must have an MFI of less than 0.75 g/10 min delta to the control. Using a common control value of 0.35 MFI and targeting 1.10 as the MFI blend maximum. Then you solve to determine the MFI for the Innovation:

$$log(MFI_{blend}) = 0.5\ log\ log\ (Innovation\ MFR)\ \ + 0.5\ log\ log\ (Control\ MFR)$$

The maximum MFR of the Innovation is 3.42 dg/min.

A MFI value of the 50:50 blend of up to 4.00 g/10 was calculated for maximum melt flow index of the tube construction (sleeve, tube and closure) follows from the Critical Guidance given in HDPE-CG-01 where a 50/50 blend of a test package with a 0.25 MFR control resin.

Below are examples of how the varying MFI based on % components in different tube constructions:

$log(MFI_{tube\ construction}) = \%\ log\ log\ (MFI)\ (Cap)\ \ + \%\ log\ log\ (MFI)\ (Shoulder) + \%\ log\ log\ (MFI)(Sleeve)$ = <4.00

Cap%	MFI	Shoulder %	MFI	Sleeve %	MFI	MFB	Final tube construction blend MFI (<4.00 g/10 min)
0.3373	16	0.1332	35	0.5295	0.437	0.421	2.639
0.3373	16	0.1332	16	0.5295	0.437	0.376	2.378
0.3373	6	0.1332	8	0.5295	0.437	0.192	1.557

Selection of a barrier material if the EVOH content is greater than 5%

The tube will be recyclable, but with a detrimental feature. Its use should be minimized to maintain the best performance of recycled HDPE for future uses. Tube developers may employ the HDPE-CG-01 test to demonstrate that higher levels of EVOH can be preferred for tubes.

Other Barriers, Coatings and Additives

Please see the HDPE Design Guide for guidance on other barriers, coatings and additives.

Wall Thickness

Wall thickness determines compatibility with the rigid recycling process because thin films can be lost to the elutriation step, an air separation process. Experience has shown that a wall thickness less than 200 micron (.008 in) may affect the recycling of the primary package and needs to be tested. It is important to ensure package flake is not lost in the elutriation process; it also aids in flake cleaning by allowing the rigidity of the flakes to scrape against each other.

Printing and Labels

Please see the HDPE Design Guide for guidance on printing and labeling, including inks and adhesives.

Inserts

Although a non-HDPE insert that can be liberated and separated from the tube is acceptable, it does increase yield loss and should be avoided when technically possible.

Closure

The intention is to recycle the caps/closure with the tubes, which is aligned with APR's caps on message. Tube caps can make up a significant part of the package and preferred design increases the value of the tube as a recyclable package.

PP is a contaminate to the HDPE stream but is marginally compatible with HDPE after melt blending and so HDPE based tubes that employ a PP closure are considered recyclable, but with a detrimental feature. If using a PP closure, every effort should be made to reduce the percent of the package represented by the cap as it negatively impacts the properties of the material. Use of HDPE caps able to meet melt flow requirements (as noted above for the whole package) is preferred and greatly improves the compatibility of the tube for recycling in the HDPE stream.

2. Model Specification: HDPE Tube Sorting Performance

Performance element	APR Guidance	Test	Impact
Size and size sortation	Tube with 2 dimensions greater that 50 mm is preferred Or if tested: Greater than 90% retained to be preferred. 50% to 90% is considered recyclable with a detrimental feature	Sort-B-02	This test confirms that tubes are not lost on sizing screens.
2D-3D sortation		In development	

NIR sortation	Dark colors with L value of 40 or greater is preferred, less than 40 should be tested. Less than 5% variance from reference materials.	Sort-B-01	Confirms that an NIR optical sorter makes a positive detection of the base plastic and successfully directs the package into the correct stream.
Metals sortation	Any packaging with metalized films or foil layers should be tested.	Sort-B-03	Confirms that any metal or metalized decoration does not cause the package to be ejected by a metal detector.

APR Design Guidance for PP Tubes

A PP tube that meets preferred Design Guidance is presented in the model specification below. This model specification anticipates that the target bale for a PP tube will be the PP Small Rigid Plastics, Tubs and Lids, or 3-7 Bottles and Small Rigid bales along with rigid tubs and lids, bottles and other injection molded PP. This model is not intended to replace detailed specifications agreed to between individual buyers and sellers of plastic squeeze tubes, and which may include requirements that extend beyond the guidance provided in this model.

The PP Tubes Model Specifications Present:

1. A guidance table for materials selection and reclamation performance
2. A guidance table for sorting performance.

With today's emphasis on developing the circular economy for plastics, packages that are compatible with widely used recycling processes and have negligible impact, if any, on the quality and productivity of PP recycling are considered APR Preferred. The body and shoulder sections of PP tubes are most commonly extruded, injection molded or assembled with a laminated sheet or film. An in-mold label or surface printing are also commonly employed. It is also common to employ a PP closure on a PP tube. The model specification below anticipates this method of manufacture for PP tubes. APR Guidance for PP tubes is that it is preferred when all components are made of the same resin, including the sleeve, shoulder, cap and insert, at density and melt flow blends that allow the package to meet the below noted density and melt flow ranges. Additionally, efforts toward improved evacuation of the product through design and the use of PCR in the package, are also highly encouraged.

3. **Model Specification: PP Tube Materials Selection and Reclamation Performance**

Tube Material/Feature	Preferred Material	APR Guidance	Test Method
Body, shoulder and cap as a package	PP	Melt flow rate (MFR) between 2 and 40 g/10 min 230C/2.16kg Density <1.0 g/cm3 is preferred for sink/float reasons 5% or less EVOH of the package is preferred	ASTM D1238 (230/2.16) ASTM D792 for specific gravity[2] Alternative: ASTM D1505 for density APR Critical Guidance Test PP-CG-01 - Testing is performed on the package.
Wall Thickness		Experience indicates a wall section of less than 200 microns should be tested. Elutriation loss maximum pending review.	Elutriation of Polyolefin Flake, O-P-05, as referenced in O-P-00 Polyolefin Standard Laboratory Processing Practices
Any inserts or attachments	Made with PP and so compatible with PP, or is made with a polymer that can be liberated and separated from the tube.	100 % of the PP based material with any pigments, fillers and label decoration floats in water.	Polyolefin Sink/float Screening Test O-S-01 No impact on melt filtration test in PP-CG-01

Density and Melt Flow Rates

Squeeze tubes can use different densities and melt flow rates of PP as long as the blend of the package meets the overall density and MFR requirement noted above.

Wall Thickness

[2] When using the ASTM D792 for specific gravity to determine density, subtract .002 g/cc from D792 value.

Wall thickness determines compatibility with the rigid recycling process because thin films can be lost to the elutriation step, an air separation process. Experience has shown that a wall thickness less than 200 micron (.008 in) may affect the recycling of the primary package and needs to be tested. It is important to ensure package flake is not lost in the elutriation process; it also aids in flake cleaning by allowing the rigidity of the flakes to scrape against each other.

Selection of a barrier material if the EVOH content is greater than 5%
The tube will be recyclable, but with a detrimental feature. Its use should be minimized to maintain the best performance of recycled PP for future uses. Tube developers may employ the PP-CG-01 test to demonstrate that higher levels of EVOH can be preferred for tubes.

Other Barriers, Coatings and Additives
Please see the PP Design Guide for guidance on other barriers, coatings and additives.

Printing and Labels
Please see the PP Design Guide for guidance on printing and labeling, including inks and adhesives.

Inserts
Although a non-PP insert that can be liberated and separated from the tube is acceptable, it does increase yield loss and should be avoided when technically possible.

Closure
PP caps are preferred. The intention is to recycle the caps/closure with the tubes, which is aligned with APR's caps on message. Tube caps can make up a significant part of the package, and the preferred design increases the value of the tube as a recyclable package.

4. **Model Specification: PP Tube Sorting Performance**

Performance element	APR Guidance	Test	Impact
Size and size sortation	Tube with 2 dimensions greater that 50 mm is preferred Or if tested: Greater than 90% retained to be preferred. 50% to 90% is considered recyclable with a detrimental feature	Sort-B-02	This test confirms that tubes are not lost on sizing screens.
2D-3D sortation		In development	
NIR sortation	Dark colors with L value of 40 or greater is preferred,	Sort-B-01	Confirms that an NIR optical sorter makes a positive detection of the

	less than 40 should be tested. Less than 5% variance from reference materials.		base plastic and successfully directs the package into the correct stream.
Metals sortation	Any packaging with metalized films or foil layers should be tested.	Sort-B-03	Confirms that any metal or metalized decoration does not cause the package to be ejected by a metal detector.

DOCUMENT VERSION HISTORY

Version	Publication Date	Revision Note
1	August 20, 2020	
2	September 29, 2021	Editorial corrections, new test references, technical clarity
3	**September 9, 2022**	**Corrections to MFI and calculations**