

## 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
<b>Body/sleeve - extruded or laminated</b>	Mono-layer HDPE, or  Multi-layer construction: HDPE and/or (L)LDPE, EVOH	Melt flow rate (MFR) between >0.2g/10 min, but < 0.75g/10 min 190C/2.16kg  Density range of 0.941-.965 g/cm <sup>3</sup> . HDPE percentage in the body/sleeve should be greater than 55% by weight.	ASTM D1238 (190/2.16)  ASTM D792 for specific gravity (result .943-.967) <sup>1</sup> Alternative: ASTM D1505 for density
<b>Shoulder</b>	HDPE	Lowest possible melt index	
<b>Cap</b>	HDPE	Lowest possible melt index	
<b>Body, shoulder and cap as a package</b>	HDPE and/or (L)LDPE, EVOH	MFR between >0.2g/10 min, but < 1.61 g/10 min 190C/2.16kg  Density in range of 0.941-0.965 g/cm <sup>3</sup> for the package is preferred, if greater than .98 g/cm <sup>3</sup> , testing is required.  5% or less EVOH of the package is preferred	See tests noted above  MFR can be measured in the laboratory or calculated with the equations provided below under Melt Index Blend.  APR Critical Guidance Test HDPE-CG-02 - Testing is performed on the package. Cap is also included, if HDPE.
<b>Wall Thickness</b>		Wall section of the tube is at least 200 microns  Or if tested, no loss greater than guidance values	HDPE-CG-02 elutriation practice
<b>Any inserts or attachments</b>	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.	Sink/float separation O-S-01  No impact on melt filtration test in HDPE-CG-02

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

### 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: 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 and tube to have the least impact on the over-all melt index of the blended material. For example, the shoulder could have a MFI of up to 5g/10min 190C/2.16kg, as long as the blended melt flow for the package meets the above noted range.

One method to know the melt index of the blend is to follow the practices employed in the HDPE-CG-02 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:

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

So, say you have 40% of a 30 MI resin and 60% of a 0.3 one. Then:

$$\log(MI_{blend}) = 0.4 \log(30) + 0.6 \log(0.3) = 0.277$$
$$MI_{blend} = 1.89$$

The reason that a value of 1.61 is allowed for melt index of the blend follows from the Critical Guidance given in HDPE-CG-02 where a 50/50 blend of a test package with a control resin must have a melt index of 0.75 or less. When a 50/50 blend of a 0.35 MI control resin is made with a tube having a blend of 1.61, the melt index of the 50/50 blend is calculated to be 0.75.

### 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-02 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. A wall thickness less than 200 micron (.008 in) may be detrimental to 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
<b>Size and size sortation</b>	<p>Tube with 2 dimensions greater than 50 mm is preferred</p> <p>Or if tested: Greater than 90% retained to be preferred. 50% to 90% is considered recyclable with a detrimental feature</p>	Sort-B-02	This test confirms that tubes are not lost on sizing screens.
<b>2D-3D sortation</b>		In development	
<b>NIR sortation</b>	<p>Dark colors with L value of 40 or greater is preferred, less than 40 should be tested.</p> <p>Less than 5% variance from reference materials.</p>	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.
<b>Metals sortation</b>	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
<b>Body, shoulder and cap</b>	PP	Melt flow rate (MFR) between 2 and 40 g/10 min 230C/2.16kg  Density <1.0 g/cm <sup>3</sup> 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 <sup>2</sup> Alternative: ASTM D1505 for density  APR Critical Guidance Test PP-CG-01 - Testing is performed on the package.
<b>Wall Thickness</b>		Wall section of the tube is at least 200 microns  Or if tested, no loss greater than guidance values	HDPE-CG-02 elutriation practice
<b>Any inserts or attachments</b>	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.	Sink/float separation 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 requirement noted above.

#### 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. A wall thickness less than 200 micron (.008 in) may be detrimental to 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.

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

### 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
<b>Size and size sortation</b>	Tube with 2 dimensions greater than 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.
<b>2D-3D sortation</b>		In development	
<b>NIR sortation</b>	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.
<b>Metals sortation</b>	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 7, 2020	