Introduction – Scope, significance and use

This is a comprehensive laboratory scale evaluation, or protocol, that can be used to assess the compatibility of HDPE rigid container packaging innovations with reclamation systems sourcing post-consumer material.

HDPE rigid containers are typically sorted into one of two streams listed as natural or colored stream. These streams can be processed differently in the commercial world and this protocol will reflect those differences in terms of paths. This test can be used to evaluate the impact of HDPE rigid container packaging innovations and components, examples including but not limited to: Additives, Barriers, Layers, Copolymers, Caps, Closures and Labels. This test may be utilized to potentially gain recognition for the natural stream, the colored stream or both if results meet certain criteria.

In APR Processing Practices and Test Protocols, the term “article” is used to mean the package submitted for testing (except in the special case where a resin pellet is tested and is referred to simply as “resin pellet”). The article incorporates the innovation or design feature which requires test data.

Data developed by an independent third-party laboratory following this protocol can be used in petitions for APR’s Critical Guidance Recognition. Petitions require data for an innovative article compared to a control.

In certain cases, before Critical Guidance Protocol test results can be submitted to APR for consideration of guidance recognition, all pre-requisite tests, including sortation potential protocols and degradable additives testing, must be passed and such evidence must be presented with any guidance applications. In addition, the Program Administrator may ask for additional exposure testing and performance testing as are pertinent to the innovation. To determine when pre-requisite testing is needed, please refer to the APR Design® Guide text and tables (Link) and the following test protocols and resources.

For products or innovations that employ metal decoration or which contain metal components:
- **APR RES-SORT-1 Metal Sorting Resource**
- **APR SORT-B-03 Metal Sortation Protocol**

For items less than 5 cm in 2 dimensions:
- **APR RES-SORT-3 Size Sortation Resource**
- **APR SORT-B-02 Size Sortation Protocol**
- **APR SORT-PR-01 Compression Practices**

For dark colors and label coverage (see definition in Design® Guide):
- **APR RES-SORT-2 NIR Sorting Resource**
- **APR SORT-B-01 NIR Sortation Protocol**
- **APR-SORT-B-04 Color Sortation Protocol**
For materials that might be employed or marketed as degradable additives for plastics and which might be expected to display time dependent behavior or change with environmental exposure where appearance or physical properties can change over time:

- APR O-S-03 HDPE/PP Degradable Additives Test

This list is not inclusive. The Critical Guidance Protocol is not appropriate for package constructions that are not in alignment with the APR Design® Guide for Plastics Recycling text in cases where additional conditions are specified in the relevant Design® Guide section.

**Disclaimer:** This document has been prepared by the Association of Plastic Recyclers as a service to the plastic industry to promote the most efficient use of the nation’s plastic recycling infrastructure and to enhance the quality and quantity of recycled postconsumer plastic. The information in this document 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. Participation in the Recognition Program is purely voluntary and does not guarantee compliance with any U.S. law or regulation or that a package or plastic article incorporating the innovation is recyclable or will be recycled.

**Method Summary**

This Critical Guidance protocol provides two pathways for testing HDPE resins and articles with flow diagrams found on pages 10-13 for articles that employ multi-layer constructions, coatings, additives, new HDPE resin controls, new innovative HDPE resins, multi-material compositions, lids, dispensers and closures as innovation samples. Controls are comprised of similar articles made solely with a control PE resin without the innovation. Reference document APR Polyolefin Standard Laboratory Processing Practices, O-P-00 through O-P-07 for complete details.

**Path 1** – Paths 1-A, Path 1-B and Path 1-C are utilized for complete HDPE rigid packages that include the innovation being tested.

- Path 1-A is followed when evaluating against a HDPE Colored Stream
- Path 1-B is followed when evaluating against a HDPE Natural Stream
- Path 1-C is followed when evaluating for both of the above streams

A flow diagram for Path 1-A, Path 1-B and Path 1-C on pages 10-12 illustrates that these articles are separately processed through these steps:

- Granulation
- Wash against the correct path (Based on O-P-04 – Wash Selection)
- Additional part production and natural color testing required only for Path 1-C
- Drying
• Elutriation
• Blends created from the processed materials. APR Critical Guidance protocols require blends of 50% control and 50% innovation to be compared with 100% control material. Optional blends can be used if desired by the investigator at 75% control and 25% innovation blend.
• Blends dried, extruded and pelletized
• Pellets subjected to testing and evaluation
• Injection molding or compression molding (ASTM D4703 Procedure C) of test bars for required ASTM tests of each blend. Injection molding is recommended for materials above a 1 MI. Compression molding is recommended for materials below a 1 MI. This determination is to be made based upon the Control MI and held consistent for all sample preparation with a project for comparison consistency.

Path 2 - Path 2 is utilized for testing resins and resin blends that incorporate the innovation being tested but have not been converted into package form for both Natural and Colored HDPE stream. A flow diagram for Path 2, on page 13, illustrates that these articles are separately processed through these steps:
• Control and test dry blends processed for a single melt history to represent the initial production.
• Blends created from the processed materials. APR Critical Guidance protocols require blends of 50% control and 50% innovation to be compared with 100% control material. Optional blends can be used if desired by the investigator at 75% control and 25% innovation blend.
• Blends dried, extruded and pelletized
• Pellets subjected to testing and evaluation
• Injection molding or compression molding (ASTM D4703 Procedure C) of test bars for required ASTM tests of each blend. Injection molding is recommended for materials above a 1 Melt Index (MI). Compression molding is recommended for materials below a 1 MI. This determination is to be made based upon the Control MI and held consistent for all sample preparation with a project for comparison consistency.
Reference Documents

The following documents are referenced in this Critical Guidance Protocol:

**APR Polyolefin Standard Laboratory Processing Practices**, O-P-01 through O-P-07

**APR Screening Test Methods:**
- *Polyolefin Packaging Article Sink or Float Evaluation*, O-S-01

**ASTM Pellet Test Methods:**
- ASTM D3418 Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
- ASTM D1238 Melt Flow Rates of Thermoplastics by Extrusion Plastometer
- ASTM D5630 Ash Content in Plastics
- ASTM D6980 Determination of Moisture in Plastics by Loss in Weight
- ASTM D7399 Determination of the Amount of Polypropylene in Polypropylene/Low Density Polyethylene Mixtures Using Infrared Spectrophotometry
- ASTM D6290 Color Determination of Plastic Pellets

**ASTM Part Test Methods:**
- ASTM D638 Tensile Properties of Plastics
- ASTM D256 Determining the Izod Pendulum Impact Resistance of Plastics
- ASTM D790 Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Material
- ASTM D4976 Polyethylene Plastics Molding and Extrusion Materials
- ASTM D792 Density and Specific Gravity (Relative Density) of Plastics by Displacement
- ASTM D4703 Compression Molding Thermoplastic Materials into Test Specimens, Plaques, or Sheets
Method Steps for Extrusion Blends and Evaluation

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Path 1 Method Steps

The following steps are taken to prepare samples for evaluation; these steps are illustrated in the flow diagram labeled Path 1, and details of each step are presented in the APR Polyolefin Standard Laboratory Processing Practices, O-P-01 through O-P-07 (included in document O-P-00). The amount of material will depend upon the equipment and scale used in each laboratory.

1. Obtain control and test article to use in the evaluation for Path 1. For a list of acceptable control resins, refer to Practice O-P-01.
2. For each of the test and control articles for Path 1, separately:
   a. Granulate articles
   b. Sink-float the control and test articles per the Screening Test O-S-01
   c. Wash using the correct method (Based on O-P-04 – Wash Selection)
   d. If following Path 1-C, wash material to move forward with Critical Guidance Testing utilizing the Commercial wash process. Additionally, wash materials against the Caustic wash process to proceed with the part production and natural color testing.
   e. Elutriation of granulated and washed material
3. Prepare the following required blends:
   a. 100% processed control - Sample A
   b. 50/50 processed control and innovation – Sample B
   c. Any optional blends chosen by the investigator, for example: 75/25 processed control and innovation – Sample C
4. Step 4 only required for Path 1-C. If following Path 1-A or Path 1-B, skip to Step 5.
   a. Injection/Compression mold ASTM samples from caustic wash + elutriated flake to be evaluated for natural color testing. Injection Molding recommended for this step for better mixing of materials resulting in more uniform color properties.
   b. Evaluate color properties of produced parts.
5. Extrude blends and melt filter to create the samples: A pellets, B pellets and C pellets.
   a. Extruded pellets to be evaluated for DSC, melt index, ash content(if applicable), moisture content, FTIR, and color tests.
6. Injection molding or compression molding (ASTM D4703 Procedure C) of test bars for required ASTM tests of each blend. Injection molding is recommended for materials above a 1 MI. Compression molding is recommended for materials below a 1 MI. This determination is to be made based upon the Control MI and held consistent for all sample preparation with a project for comparison consistency.
   a. Produced parts to be evaluated for melt index, density, tensile strength at yield, elongation at break, notched izod, flexural modulus and color properties.
Path 2 Method Steps

If the form submitted for testing is resin instead of containers, Path 1 method steps 1 and 2 are unnecessary. Steps 3, 5, and 6 for resin samples are illustrated in the flow diagram labeled Path 2.

Details of each step are presented in the *APR Polyolefin Standard Laboratory Processing Practices*, O-P-01 through O-P-07 (included in document O-P-00).

The amount of material will depend upon the equipment and scale used in each laboratory.

### Measurements, Report and Guidance Values

#### Path 1 - Incoming Flake Analysis

<table>
<thead>
<tr>
<th>Property</th>
<th>Method</th>
<th>APR Guidance Preferred values</th>
<th>Additional Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sink-float</td>
<td>O-S-01</td>
<td>100% Floatability for Olefin material</td>
<td>Any non-PO labels, closures, layers, attachments, or other materials must either sink in water and be removed or must be compatible with PE. It is unacceptable for a non-PE material to stick to or otherwise not separate from the PE substrate and cause the PE to sink, resulting in yield loss, or stay with the PE and contaminate the PE.</td>
</tr>
</tbody>
</table>

#### Path 2 - 1st Melt History Extruded Pellet

<table>
<thead>
<tr>
<th>Property</th>
<th>Method</th>
<th>APR Guidance Preferred values</th>
<th>Additional Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Pack Pressure Build</td>
<td>Practice O-P-06</td>
<td>Record and Report</td>
<td>No guidance; first step only for melt history</td>
</tr>
</tbody>
</table>
### Path 1 and 2 - Extruded Pellet Sample Evaluation

<table>
<thead>
<tr>
<th>Property</th>
<th>Method</th>
<th>APR Guidance Preferred values</th>
<th>Additional Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Pack Pressure Build</td>
<td>Practice O-P-06</td>
<td>End pressure no greater than 25% over starting pressure value</td>
<td></td>
</tr>
<tr>
<td>Melt Index</td>
<td>ASTM – D1238</td>
<td>&lt; 0.75 g/10minutes delta to the control</td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>ASTM – D5630</td>
<td></td>
<td>Perform only if density &gt;0.98. Record and Report</td>
</tr>
<tr>
<td>Volatiles/Moisture</td>
<td>ASTM – D6980</td>
<td>&lt; 0.5%</td>
<td></td>
</tr>
<tr>
<td>DSC</td>
<td>ASTM – D3418</td>
<td>Primary Melting Peak on 2\textsuperscript{nd} Heat not to exceed 140 C</td>
<td>Record primary and secondary melting peaks temperature and J/g. Calculate the J/g delta from primary peak to secondary peak if present.</td>
</tr>
<tr>
<td>FTIR</td>
<td>ASTM – D7399</td>
<td>&lt; 5% PP Content in test sample B (up to 10% allowable in innovation)</td>
<td>Report as &lt; 5% or &gt; 5%</td>
</tr>
<tr>
<td>Pellet Irregularity</td>
<td>Porosity, roughness, grainy, gloss etc.</td>
<td></td>
<td>Record, Report, and Photograph</td>
</tr>
<tr>
<td>Extrusion Process Irregularity</td>
<td>Unusual sticking, fumes, odor or build-up occurring at the feed throat or die exit of the extruder</td>
<td></td>
<td>Record and Report</td>
</tr>
<tr>
<td>Pellet Color Variations or Inconsistencies (Only for Path 1-B, and Path 2)</td>
<td>ASTM – D6290</td>
<td>Guidelines established for Natural Claims: $\Delta E &lt; 3.5$ between control and test</td>
<td>Not meeting color guidelines renders material ineligible for Natural Stream, but still eligible for Color Stream</td>
</tr>
</tbody>
</table>
### Path 1 and 2 – ASTM Part Evaluation

<table>
<thead>
<tr>
<th>Property</th>
<th>Method</th>
<th>APR Guidance Preferred values</th>
<th>Additional Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required values</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melt Index</td>
<td>ASTM – D1238</td>
<td>&lt; 0.75 g/10 minutes delta to the control</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>ASTM – D792</td>
<td>Lower limit of test material with 50% innovation shall be no less than 0.941 g/cm³</td>
<td>Control no less than 0.941 g/cm³</td>
</tr>
<tr>
<td>Tensile Strength at Yield</td>
<td>ASTM – D638</td>
<td>No more than a 25% decrease, control to test samples.</td>
<td></td>
</tr>
<tr>
<td>Elongation at Break</td>
<td>ASTM – D638</td>
<td>No more than a 50% delta decrease, control to test sample</td>
<td></td>
</tr>
<tr>
<td>Notched Izod</td>
<td>ASTM – D256</td>
<td>Control and test samples should have the same break type or show greater ductility for test sample.</td>
<td>Record and report break type (no break, partial, hinge, complete) and values for the control and test.</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>ASTM – D790</td>
<td>No more than a 25% decrease, control to test samples.</td>
<td></td>
</tr>
<tr>
<td>Part Colors</td>
<td>Modified ASTM – D290</td>
<td>Guidelines established for Natural Claims: ΔE &lt; 3.5 between control and test</td>
<td>Not meeting color guidelines renders material ineligible for Natural Stream, but still eligible for Color Stream</td>
</tr>
</tbody>
</table>

(Only for Path 1-B, 1-C and Path 2)
Path 1-A(Colored): Flow Diagram for HDPE Rigid Containers with Commercial Wash

Start

Obtain HDPE Control Container

Obtain HDPE Innovation Container

Granulation O-P-03

Granulation O-P-03

Commercial Basic Wash O-P-04

Commercial Basic Wash O-P-04

Air Separation O-P-05

Air Separation O-P-05

Create Blends

<table>
<thead>
<tr>
<th>Required A 100% Control Sample</th>
<th>Optional C 75% Control Sample 25% Innovation Sample</th>
<th>Required B 50% Control Sample 50% Innovation Sample</th>
</tr>
</thead>
</table>

Required Evaluations: Screen pack pressure build

Extrude and Pelletize each Blend O-P-06

Injection Mold or Compression Mold ASTM Test Parts of each Blend

End

Required Evaluations:
- Melt Index
- Tensile Strength
- Elongation at Yield
- Notched Izod
- Flexural Modulus
- Density
- Melt Index
- Ash (if density > 0.98)
- Moisture
- %PP (FTIR)
- Pellet discoloration
- Screen pack pressure build
- Pellet Appearance
- Pellet Production
- Performance

Required Evaluation: Sink/Float
Path 1-B(Natural): Flow Diagram for HDPE Rigid Containers with Caustic Wash

Start

Obtain HDPE Control Container

Obtain HDPE Innovation Container

Granulation O-P-03

Granulation O-P-03

Caustic Wash O-P-04

Caustic Wash O-P-04

Air Separation 0-P-05

Air Separation 0-P-05

Create Blends

Required A
100% Control Sample

Optional C
75% Control Sample
25% Innovation Sample

Required B
50% Control Sample
50% Innovation Sample

Extrude and Pelletize each Blend O-P-06

Injection Mold or Compression Mold ASTM Test Parts of each Blend

End

Required Evaluations:
Melt Index
Tensile Strength
Elongation at Yield
Notched Izod
Flexural Modulus
Density
Part Color

Required Evaluations:
Melt Index
Ash (if density >0.98)
Moisture
%PP (FTIR)
Pellet discoloration
Screen pack pressure build
Pellet Appearance
Pellet Production
Performance

Required Evaluation:
Sink/Float

Required Evaluation:
Screen pack pressure build

Start

Caustic Wash O-P-04

Air Separation 0-P-05
Path 1-C(Colored & Natural): Flow Diagram for HDPE Rigid Containers with Both Caustic and Commercial Washes

Start

Obtain HDPE Control Container
- Caustic Wash O-P-04
  - Air Separation O-P-05
  - Injection Mold or Compression Mold ASTM Test Parts of each Blend

Obtain HDPE Innovation Container
- Granulation O-P-03
  - Commercial Basic Wash O-P-04
  - Air Separation O-P-05

Sink/Float Required Evaluation

Create Blends
- Required A
  100% Control Sample
- Optional C
  75% Control Sample
- 25% Innovation Sample
- Required B
  50% Control Sample
  50% Innovation Sample

Extrude and Pelletize each Blend O-P-06
- Required Evaluations:
  Screen pack pressure build

Injection Mold or Compression Mold ASTM Test Parts of each Blend
- Required Evaluations:
  Part Colors
  Melt Index
  Tensile Strength
  Elongation at Yield
  Notched Izod
  Flexural Modulus
  Density

End

Caustic Wash O-P-04
- Air Separation O-P-05
- Injection Mold or Compression Mold ASTM Test Parts of each Blend

Commercial Wash O-P-04

Air Separation O-P-05

Granulation O-P-03

Granulation O-P-03
Path 2 (Colored & Natural): Flow Diagram for HDPE Rigid Resin incorporating innovations

Start

Obtain HDPE Resin Control

Obtain HDPE Resin with Innovation

Extrude O-P-06

Extrude O-P-06

Create Blends

Optional Evaluation: Screen pack pressure build

Required A
100% Control Sample

Optional C
75% Control Sample
25% Innovation Sample

Required B
50% Control Sample
50% Innovation Sample

Extrude and Pelletize each Blend O-P-06

Required Evaluation:
Screen pack pressure build

Required Evaluations:
Melt Index
Tensile Strength
Elongation at Yield
Notched Izod
Flexural Modulus
Density
Part Colors

Injection Mold or Compression Mold ASTM Test Parts of each Blend

Required Evaluations:
Melt Index
Density
Ash (if density > 0.98)
Moisture
%PP (FTIR)
Pellet discoloration
Screen pack pressure build
Pellet Appearance
Pellet Production
Performance

End
## DOCUMENT VERSION HISTORY

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<tr>
<th>Version</th>
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<tr>
<td>1</td>
<td>12-5-2019</td>
<td>Made minor clarifying changes, approved by OTC on 10/2/19</td>
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<td>2</td>
<td>7/24/2020</td>
<td>Test and specification changes, Approved by OTC on 6/4/2020</td>
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<td>3</td>
<td>June 3, 2021</td>
<td>Added language clarifying need for pre-requisite testing</td>
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<tr>
<td>4</td>
<td>August 16, 2021</td>
<td>Added expanded disclaimer language</td>
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<tr>
<td>5</td>
<td>February 7, 2022</td>
<td>Added changes approved by OTC including additional pathway and change to density guidance; combined all 3 HDPE CG tests into one</td>
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<td>6</td>
<td>March 21, 2022</td>
<td>Edits per OTC; new copyright date</td>
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