

Job Number: 20240715COF

Customer:
Retail Product Partner



OTR Testing Results

We are pleased to submit the results
of our transmission rate

Date: 2024/07/15

Test Conditions:

Test Gas	Oxygen	Test Temperature	23 (°C)
Test Gas Concentration	100%Oxygen	Carrier Gas	98% N ₂ , 2% H ₂
Test Gas Humidity	0%RH	Carrier Gas Humidity	0% RH
Test Gas Pressure	760 mmHg		

Test Results:

Sample Identification	Oxygen Transmission Rate cc/m ² • day	
	Parallel 1	Parallel 2
High Barrier HDPE (Resin 2 Flexible Film) and Pouch (Spout Pouch, Stand Up Pouch, BIB bag in box liner)	0.22	0.24

Note: Above samples were analyzed on a MOCON OX-TRAN 2/22.

The standard that applies to this instrument is ASTM D 3985, ASTM F1927, ISO 15105-2.

Test Operator: Amy Liu

Test Operator: *Amy Liu*

Date: 2024/07/15

Date: *2024. 7. 15*

This information represents our best judgement based on work done, but the company (MOCON) assumes no liability whatsoever in connection with the use of information or findings contained herein.



Job Number: 20240715CWF

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WVTR Testing Results

We are pleased to submit the results
of our transmission rate

Date: 2024/07/15

Test Conditions:

Test Gas	Water Vapor	Test Temperature	38 (°C)
Test Gas Humidity	90% RH	Carrier Gas	N2
Test Gas Pressure	760 mmHg	Carrier Gas Humidity	0% RH

Test Results:

Sample Identification	Water Vapor Transmission Rate g/m ² -day	
	Parallel 1	Parallel 2
High Barrier HDPE (Resin 2 Flexible Film) and Pouch (Spout Pouch, Stand Up Pouch, BIB bag in box liner)	2.6645	2.7194

Note: Above samples were analyzed on a MOCON PERMATRAN-W 3/34.
The standard that applies to this instrument is ASTM F 1249.

Test Operator: Amy Liu

Test Operator: *Amy Liu*

Date: 2024/07/15

Date: *2024.7.15*

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HDPE (R2Film) - Specialized OTR & WVTR Data Sheet

1. Introduction

High-Density Polyethylene (HDPE) is a widely used thermoplastic known for its good mechanical properties, chemical resistance, and cost-effectiveness. While standard HDPE offers a good moisture barrier and a moderate oxygen barrier, specialized applications often require enhanced barrier performance.

This data sheet focuses on a specific material designated as "HDPE (R2Film)", characterized by the following user-provided barrier properties:

- **Oxygen Transmission Rate (OTR):** 0.23 cc/m²·day
- **Water Vapor Transmission Rate (WVTR):** 2.66 g/m²·day

These values suggest that "HDPE (R2Film)" is a high-performance material, particularly with respect to its oxygen barrier, which is significantly superior to standard HDPE.

2. Specified Barrier Properties for HDPE (R2Film)

The defining characteristics provided for "HDPE (R2Film)" are its transmission rates:

Property	Value	Unit	Assumed/Required Conditions
Oxygen Transmission Rate (OTR)	0.23	cc/m ² ·day	(e.g., at 23°C, specific %RH, 1 atm O ₂ partial pressure difference, for a specific film thickness)
Water Vapor Transmission Rate (WVTR)	2.66	g/m ² ·day	(e.g., at 38°C, 90% RH, for a specific film thickness)

Crucial Considerations:

- **Film Thickness:** The OTR and WVTR values are highly dependent on the thickness of the film. These provided values are assumed to be for a *specific, but unstated, thickness* of the "HDPE (R2Film)" product. Without knowing the thickness, direct comparison to permeability constants of other materials is difficult.

- **Test Conditions:** Standard test conditions (temperature, relative humidity, pressure differential for OTR) are critical for interpreting these values. These should be confirmed with the supplier of "R2Film". For this data sheet, typical conditions are referenced for context.

3. Interpretation of Provided Barrier Values

3.1. Oxygen Transmission Rate (OTR) - 0.23 cc/m²·day

This OTR value is **exceptionally low** and indicates a **very high oxygen barrier performance**.

- Standard HDPE films (e.g., 25.4 µm / 1 mil thick) typically have OTR values in the range of 150-500 cc/m²·day·atm.
- The provided value of 0.23 cc/m²·day (assuming 1 atm O₂ pressure and standard conditions) places "HDPE (R2Film)" in the category of high-barrier materials, comparable to:
 - **EVOH (Ethylene Vinyl Alcohol copolymer, dry conditions):** Typically 0.05 - 1.0 cc/m²·day·atm (for 25.4 µm).
 - **Metallized Films (e.g., MetPET, MetOPP):** Often < 1 cc/m²·day·atm.
 - **Barrier coatings (e.g., SiOx, AlOx on PET):** Can achieve OTR < 1 cc/m²·day·atm.

This suggests that "HDPE (R2Film)" is not a simple monolayer HDPE film. It is likely one of the following:

- A **multilayer coextruded or laminated film** where HDPE is combined with a high-oxygen-barrier layer (e.g., EVOH, Polyamide (Nylon), or a specialty barrier resin).
- An HDPE film with a **high-performance barrier coating** (e.g., inorganic like SiOx/AlOx, or specialized organic coatings).
- An HDPE compounded with **advanced barrier additives or nanocomposites** that significantly reduce oxygen permeability.

3.2. Water Vapor Transmission Rate (WVTR) - 2.66 g/m²·day

This WVTR value indicates a **moderate moisture barrier**.

- Standard HDPE films (e.g., 25.4 µm / 1 mil thick at 38°C, 90% RH) typically have WVTR values in the range of 0.3 - 1.0 g/m²·day.
- The provided value of 2.66 g/m²·day is higher (less effective barrier) than typical monolayer HDPE. It is more comparable to materials like:
 - **PET (Polyethylene Terephthalate, crystalline):** Typically 1.5 - 3.0 g/m²·day (for 25.4 µm).

- Some grades of **Polypropylene (PP)**.

This combination of ultra-high oxygen barrier and moderate (yet higher than standard HDPE) moisture barrier is significant. It could imply:

- If "R2Film" is a multilayer structure, the HDPE layers might be thinner to accommodate the barrier layer, or the barrier layer itself (e.g., EVOH) might have a higher intrinsic WVTR, especially if affected by humidity.
- The technology used to achieve the exceptional OTR might have a trade-off effect on the WVTR.
- The overall thickness of the "R2Film" for which this WVTR is reported might be less than a typical HDPE film used for moisture barrier comparisons.

4. General Properties of Base HDPE (Illustrative)

The "R2Film" likely uses HDPE as a primary structural or sealant component. The general properties of the base HDPE resin would contribute to the overall film characteristics (e.g., mechanical strength, sealability).

Property	Typical Value Range (for base HDPE)	Units	ASTM/ISO Test Method (Example)
Density	0.941 - 0.965	g/cm ³	ASTM D792 / ISO 1183
Melt Flow Index (MFI)	0.05 - 50 (Condition dependent)	g/10 min	ASTM D1238 / ISO 1133
Tensile Strength at Yield	20 - 35 (2900 - 5000 psi)	MPa	ASTM D638 / ISO 527-2
Elongation at Break	10 - 1200	%	ASTM D638 / ISO 527-2
Hardness (Shore D)	60 - 70	Shore D	ASTM D2240 / ISO 868

Note: These are general values for HDPE. The specific grade used in "R2Film" and its modifications will determine the final properties.

5. Potential Technologies for "HDPE (R2Film)" Achieving Stated Barrier

Given the barrier values, "HDPE (R2Film)" likely incorporates one or more of these technologies:

- **Advanced Additives/Nanocomposites:**

- Incorporation of **nanoclays, graphene, or other nano-fillers** into an HDPE matrix to create a tortuous path for gas molecules. Achieving an OTR of 0.23 cc/m²·day through this route alone would represent a very advanced formulation.

6. Potential Applications for HDPE (R2Film)

Based on its ultra-high oxygen barrier and moderate moisture barrier, "HDPE (R2Film)" could be suitable for:

- **Oxygen-Sensitive Food Packaging:**

- Modified Atmosphere Packaging (MAP) for fresh and processed meats, poultry, fish.
- Packaging for coffee (beans or ground), nuts, and certain cheeses.
- Snack foods requiring extended shelf life and protection from oxidation.
- Long shelf-life dairy products (if WVTR is acceptable).

- **Pharmaceutical Packaging:**

- Blister packs or pouches for oxygen-sensitive drugs.

- **Medical Device Packaging:**

- Sterile packaging requiring high oxygen barrier.

- **Industrial Applications:**

- Packaging for oxygen-sensitive chemicals or components.

Considerations for Application:

- The WVTR of 2.66 g/m²·day means it may not be ideal for extremely hygroscopic (moisture-sensitive) products without further assessment or combination with other materials.
- Other properties like seal strength, puncture resistance, clarity, printability, and regulatory compliance (e.g., for food contact) would need to be verified from the "R2Film" supplier.

7. Standard Test Methods for OTR & WVTR (General Reference)

These are standard methods used to determine OTR and WVTR:

7.1. OTR Test Methods

- **ASTM D3985:** Standard Test Method for Oxygen Gas Transmission Rate Through Plastic Film and Sheeting Using a Coulometric Sensor.
- **ISO 15105-2:** Plastics -- Film and sheeting -- Determination of gas-transmission

rate -- Part 2: Equal-pressure method.

7.2. WVTR Test Methods

- **ASTM F1249:** Standard Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor.
- **ASTM E96/E96M:** Standard Test Methods for Water Vapor Transmission of Materials (Desiccant method / Water method).
- **ISO 15106-2:** Plastics -- Film and sheeting -- Determination of water vapour transmission rate -- Part 2: Infrared-detection sensor method.

8. Conclusion

The provided OTR (0.23 cc/m²·day) and WVTR (2.66 g/m²·day) values for "HDPE (R2Film)" characterize it as a specialized, high-performance barrier material. Its exceptionally low oxygen transmission rate makes it suitable for applications demanding superior protection against oxidation. The moderate water vapor barrier is better than many non-polyolefin plastics

The specific structure and composition of "HDPE (R2Film)" (e.g., multilayer, coated, advanced additives) are key to these properties. It is imperative to consult the material supplier for a complete technical data sheet, including the film thickness at which these values were measured, the exact test conditions, and other relevant performance data, before considering it for any application.

High-density polyethylene (HDPE) and low-density polyethylene (LDPE) are both widely used plastics, but they possess distinct properties that make them suitable for different applications, particularly concerning their barrier capabilities. The primary difference lies in their molecular structure: HDPE has a more linear and tightly packed molecular structure, leading to higher density and crystallinity, while LDPE has a more branched and loosely packed structure, resulting in lower density and greater flexibility.¹

Here's a comparison of their Oxygen Transmission Rate (OTR) and Water Vapor Transmission Rate (WVTR), along with an explanation of why HDPE is generally preferred for barrier applications:

Comparison of HDPE vs. LDPE Barrier Properties

Property	Unit	HDPE (Given)	LDPE (Typical)
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OTR	cc/m ² ·day	0.23	~7500
WVTR	g/m ² ·day	2.66	~20

- **Oxygen Transmission Rate (OTR):** This measures how much oxygen gas can pass through a material over a given area and time.² A lower OTR indicates a better barrier against oxygen.
- **Water Vapor Transmission Rate (WVTR):** This measures how much water vapor can pass through a material over a given area and time.³ A lower WVTR indicates a better barrier against moisture.

Why HDPE is Better for Barrier Applications

Based on the typical values, HDPE exhibits significantly lower OTR and WVTR compared to LDPE.

1. **Lower OTR (Oxygen Barrier):** HDPE's OTR of 0.23 cc/m²·day is vastly lower than LDPE's typical OTR of around 7500 cc/m²·day. This means HDPE is an excellent barrier to oxygen. Oxygen can degrade many products, especially food and pharmaceuticals, by causing oxidation, spoilage, or loss of potency.⁴ For applications where oxygen ingress must be minimized (e.g., packaging for milk, juices, or certain chemicals), HDPE is the superior choice.
2. **Lower WVTR (Moisture Barrier):** HDPE's WVTR of 2.66 g/m²·day is also considerably lower than LDPE's typical WVTR of approximately 20 g/m²·day. This indicates that HDPE provides a much better barrier against moisture. Moisture can lead to product degradation, caking, microbial growth, or changes in texture and efficacy.⁵ Therefore, for products sensitive to humidity (e.g., dry foods, electronics, or certain medications), HDPE offers better protection.

The reason for HDPE's superior barrier properties lies in its molecular structure. HDPE has a more linear polymer chain with fewer branches, allowing its molecules to pack together more tightly and form a denser, more crystalline structure.⁶ This dense packing creates a more tortuous path for gas and water vapor molecules to permeate through, effectively reducing their transmission rates. In contrast, LDPE's highly branched structure results in a looser, less crystalline arrangement, making it more permeable to gases and vapors.⁷

Due to its high barrier performance against both oxygen and water vapor, HDPE is highly recommended for applications requiring robust protection against environmental factors, ensuring product freshness, shelf-life, and integrity. LDPE,

while flexible and tough, is less suitable for applications where high barrier properties are critical due to its higher OTR and WVTR.

The Critical Role of Low OTR and WVTR in Retail Packaging for Food, Candy, and Consumables: Extending Shelf Life and Ensuring Quality

In the competitive landscape of retail, packaging plays a pivotal role beyond mere containment. For food, candy, and other consumables, the packaging serves as a critical barrier, directly impacting product quality, safety, and ultimately, shelf life. Two key metrics, Oxygen Transmission Rate (OTR) and Water Vapor Transmission Rate (WVTR), are paramount in determining a package's effectiveness. Lower values for both indicate superior barrier properties, which are essential for preserving freshness, preventing spoilage, and maintaining the sensory and nutritional integrity of products.

The Importance of Lower OTR (Oxygen Transmission Rate)

Oxygen, though vital for life, is a significant antagonist to the quality and shelf life of many packaged goods. A high OTR means that oxygen can easily permeate the packaging material and interact with the product inside, leading to a cascade of undesirable reactions.

- **Oxidation and Rancidity:** For fat-containing foods like chips, nuts, baked goods, and many candies, exposure to oxygen triggers oxidation of fats and oils. This process leads to rancidity, characterized by off-flavors, unpleasant odors, and a significant reduction in palatability. A low OTR actively prevents or slows down this oxidative process, keeping fats stable and palatable for longer.
- **Color Degradation:** Many food pigments, such as those found in fresh produce, processed meats, and even some candies, are sensitive to oxygen. Exposure can cause discoloration, leading to dull, unappetizing appearances. A low OTR helps maintain vibrant, appealing colors, which are crucial for consumer appeal.
- **Nutritional Loss:** Vitamins (especially fat-soluble vitamins like A, D, E, K, and water-soluble vitamin C) and other sensitive nutrients can be degraded by oxygen. This leads to a loss of nutritional value over time. Packaging with a low OTR helps to preserve these essential nutrients, ensuring that consumers receive the full benefits of the product.
- **Microbial Growth (Aerobic Spoilage):** While some spoilage microorganisms are anaerobic (thrive without oxygen), many common spoilage bacteria and molds are aerobic, meaning they require oxygen to grow. By minimizing oxygen ingress, low OTR packaging can inhibit the growth of these spoilage organisms, thereby

extending the microbiological safety and freshness of the product.

- **Flavor and Aroma Deterioration:** Many delicate flavor and aroma compounds are volatile and susceptible to oxidation. Oxygen exposure can lead to the breakdown of these compounds, resulting in a loss of intended flavor or the development of stale or off-notes. A strong oxygen barrier preserves the intended taste and smell profile of the product.
- **Texture Changes:** For some products, like crisp snacks or certain candies, oxygen interaction can contribute to changes in texture, such as softening or staling, even independent of moisture.

The Importance of Lower WVTR (Water Vapor Transmission Rate)

Water vapor, or moisture, is another critical factor influencing the quality and shelf life of packaged consumables. A high WVTR means that water vapor can easily move across the packaging barrier, either into or out of the product, with detrimental effects.

- **Moisture Gain (Sogginess/Caking):** For dry products like crackers, cereals, powdered mixes, and many types of candy (e.g., hard candies, chocolate bars), moisture gain from the environment can lead to sogginess, clumping, or caking. This dramatically impacts texture, palatability, and consumer satisfaction. A low WVTR prevents this unwelcome moisture ingress, keeping products crisp, free-flowing, and in their intended state.
- **Moisture Loss (Drying Out/Hardening):** Conversely, for moist products like baked goods, certain soft candies, or prepared meals, moisture loss to the environment can lead to drying out, hardening, or a rubbery texture. This directly affects freshness and consumer appeal. A low WVTR helps to retain the product's inherent moisture, preserving its desired texture and freshness.
- **Microbial Growth (Water Activity):** The presence of moisture is a fundamental requirement for the growth of most microorganisms, including bacteria, yeasts, and molds. Every food product has a specific "water activity" (aw) value, which indicates the amount of unbound water available for microbial growth. Maintaining a low aw (for dry products) or preventing significant changes in aw (for moist products) is crucial for controlling microbial spoilage. A low WVTR is essential for managing the water activity within the package, thereby inhibiting microbial proliferation and extending the product's safe shelf life.
- **Chemical and Enzymatic Reactions:** Many undesirable chemical and enzymatic reactions that lead to spoilage (e.g., non-enzymatic browning, enzymatic degradation) are accelerated in the presence of higher moisture levels. By controlling moisture transfer, a low WVTR helps to slow down these detrimental

reactions.

- **Ingredient Migration and Bloom:** In products like chocolate, changes in moisture can contribute to "sugar bloom" (where sugar crystals migrate to the surface) or "fat bloom" (where fats migrate and recrystallize), both of which are aesthetically unappealing. Maintaining stable moisture conditions with a low WVTR can prevent these issues.

How Lower OTR and WVTR Extend Shelf Life (Detailed Explanation)

The ability of packaging to effectively reduce OTR and WVTR directly translates to extended shelf life through several interconnected mechanisms:

1. Slowing Down Degradation Pathways:

- **Oxidative Degradation:** By limiting the oxygen available within the package, the rate of oxidative reactions (rancidity, color fading, nutrient loss) is drastically reduced. This means the product maintains its fresh characteristics for a longer period before these reactions reach a noticeable or unacceptable level.
- **Hydrolytic Degradation:** By preventing significant moisture fluctuations, the rate of hydrolytic reactions (reactions involving water that break down compounds) and water activity-dependent enzymatic activities are slowed down, preserving product integrity.

2. Inhibiting Microbial Spoilage:

- **Oxygen Exclusion:** For aerobic spoilage organisms, low oxygen levels create an unfavorable environment, thus inhibiting their growth.
- **Moisture Control:** For virtually all microorganisms, controlling water activity (preventing moisture gain for dry goods, or maintaining optimal moisture for moist goods) is the most critical factor in preventing their proliferation. A good moisture barrier directly addresses this, keeping the product microbiologically safe and stable.

3. Preserving Sensory Attributes:

- **Flavor and Aroma Retention:** By minimizing the ingress of external off-odors and preventing the escape or oxidation of desirable volatile flavor compounds, low OTR and WVTR packaging ensures the product retains its intended taste and smell.
- **Texture Maintenance:** Preventing moisture gain (for crispiness) or moisture loss (for softness/moisture) is fundamental to maintaining the desired texture of a food product throughout its shelf life.

4. Maintaining Nutritional Value:

By shielding sensitive vitamins and nutrients from oxidative degradation and moisture-accelerated reactions, the nutritional profile

of the food product is preserved for a longer duration.

In essence, lower OTR and WVTR values signify a superior protective barrier. This barrier acts as a shield against the primary environmental factors (oxygen and moisture) that drive spoilage in food, candy, and consumables. By effectively mitigating these threats, retail packaging with low OTR and WVTR characteristics directly contributes to increased product quality, enhanced consumer satisfaction, reduced food waste, and ultimately, a more economically viable supply chain due to extended viable selling periods.

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