

Aligned Test Methods and Sampling Plans for DuPont™ Tyvek® Medical and Pharmaceutical Packaging Styles

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Aligned Test Methods

The Medical Packaging Transition Project demonstrated functional equivalence and interchangeability of legacy and transition Tyvek® 1073B and Tyvek® 1059B manufactured in both Richmond, VA, and in Luxembourg. Part of this project has been alignment of work practices in both QC laboratories to support interchangeability. The aligned test methods and sampling plans are provided in this document and apply to all medical and pharmaceutical packaging styles unless noted otherwise.

Basis Weight

The measure of the weight per unit of area of the sheet. This is typically expressed in oz/yd² or g/m². For example, DuPont™ Tyvek® 1073B has a basis weight of 2.20 oz/yd², 74.7 g/m².

Reference standard: ASTM D3776 (modified sample size) or EN ISO 536 depending on style.

Delamination

The measure of the internal bonding level of a given substrate. For Tyvek®, it is the weakest point of the substrate, which is near the middle. To perform the measurement, a split is initiated in a 1-in. (25.4-mm) wide sample. This split is the starting point to peel the layers apart. The average force to continue the peel is measured using a tensile tester. The results are given as lb_f or Newtons.

Reference standard: ASTM D2724 (modified for speed and sample width).

Elongation

The measure of the extent to which a substrate will stretch before reaching maximum force. The units are percentage (%) of sample length. Thus, a 10-in. (25-cm) sample of a substrate that has 20% elongation will stretch 2 in. (5 cm) before reaching maximum force. Elongation is measured by taking a 1-in. (25.4-mm) strip of product, clamping it so that 5 in. (127 mm) are between the jaws of a tensile tester, and then applying force to the ends until reaching the maximum force.

Reference standard: EN ISO 1924-2 (modified for speed, sample width and gauge length).

Hydrostatic Head

The measure of the pressure required to force three drops of water through a substrate. It is converted to the height of a column of water, which corresponds to the pressure. The units are typically inches (in.) or centimeters (cm). This property is impacted by the substrate's affinity for water. For Tyvek® medical and

pharmaceutical packaging styles, the surface energy is 32 dynes/cm to 25 dynes/cm. Reference standard: AATCC TM 127 (rate of use: 60 cm H₂O/min.).

Microbial Barrier

According to ISO 11607:2019, microbial barrier is defined as the "property of a sterile barrier system to minimize the risk of ingress of microorganisms". DuPont applies two different microbial barrier test methods and publishes typical values for all medical and pharmaceutical packaging styles to allow to assess the risk of ingress of microorganisms. Risks should be evaluated based on the specific packaging application and the applicable regulatory requirements. Both test methods are listed in annex B of ISO 11607-1:2019.

One standard test method, ASTM F1608, measures the "filtration" efficiency of a substrate to remove spores from an aerosol being forced through the substrate in an air stream.

A completely impermeable control sample (microbial penetration is zero) is challenged with one million or 10⁶ colony forming units (cfu). The number of cfu 10⁶ has a log₁₀ value of 6. If a sample challenged in the same way as the control allows 10 cfu (log₁₀ (10) = 1) to penetrate, then its log reduction value (LRV) is 5 (6 - 1 = 5). Therefore, the higher the LRV, the more resistant the packaging is to microorganisms. ASTM F1608 has been originally approved in 1995 and is used in the industry over the full range of medical packaging applications and various packaging materials with a minimum acceptance criterion of LRV 1.5, a value considered an absolute minimum for a microbial barrier material.

There are two disadvantages associated with ASTM F1608. The first is that the test method's air flow rate significantly exceeds the air flow rate seen during typical distribution of a medical device. The second disadvantage is that it takes a long time to incubate the spores to get a count of how many spores penetrated the test material.

ASTM F2638 eliminates both of these problems. It's a real-time test, eliminating the need to incubate spores. It functions by counting inert particles as they penetrate the barrier material. More importantly, the air flow rates are close to those experienced during transportation, eliminating another disadvantage. This test method varies the flow rate and thereby generates a penetration curve. On this penetration curve, most substrates tested have a maximum if the equipment can cover the required flow rates. In this case, it is possible to report a % pMax, which is the maximum penetration for the given substrate. The flow rate at which the maximum occurs depends on the mass, fiber diameter and density of the substrate.

The lower the %pMax, the better the microbial barrier performance. The use of ASTM F2638, a physical test method, is based on research by Alan Tallentire and Colin Sinclair. The research concluded that the filtration of microorganisms follows the same mechanisms as particle filtration¹. DuPont included this method in the functional equivalence testing protocol for the Medical Packaging Transition Project. The method was accepted by regulatory authorities around the world. DuPont applies an internal maximum acceptance criterion for this method for non-sterilized materials.

Moisture Vapor Transmission Rate (MVTR)

The measure of the rate at which moisture vapor is transmitted through a sample. The test is conducted by putting the sample, which is mounted over a cup of distilled water, in a controlled humidity chamber and measuring the change in weight over a period of time. It is measured in g/m²/24 hr. There are several different manufacturers of MVTR equipment. It is important to note that MVTR results are highly dependent on the test method used and the material type. Important variables between test methods include: pressure gradient; volume of air space between liquid and sheet sample; temperature; air flow speed over the sample; and test procedure. Therefore, the results are not comparable from one company to another, nor between different pieces of equipment.

Reference standard: TAPPI T523 (test conditions: 73°F [23°C], 85% relative humidity).

Mullen Burst

The measure of the ability of a substrate to resist forces applied uniformly throughout the substrate. It is measured by clamping a sample in a ring stand and expanding a diaphragm under the sample until the sample ruptures in the weakest spot. The pressure in the diaphragm (psi or kPa) is recorded. Because DuPont™ Tyvek® is roughly isotropic (exhibits the same value when measured along axes in all directions), it has a very high Mullen burst for a low weight material. Mullen burst is proportional to the basis weight of the material, the bonding level, and to some extent, the elongation. The Mullen burst value increases as these three property values increase. This property indicates how a package may perform in environments where pressure changes take place and the package balloons or where a force is applied over

a relatively large area, such as when a heavy object is placed on top of a lidded tray.

Reference standard: ISO 2758.

Opacity

The measure of non-transparency of a substrate. It is a ratio of the reflected light through a sample with a white and a black background. If the reflected light is the same from both backgrounds, then the opacity is 100%. A white background without any sample reflects 100% of light. A black background has zero reflectance. Opacity depends on the basis weight and bonding level of Tyvek®.

Reference standard: ISO 2471 (modified for different backing standards, area and illumination).

Porosity

The measure of the ability of a substrate to permit flow of air at a given pressure differential. Two methods are used: Gurley Hill porosity and Bendtsen air permeability. The Gurley Hill method measures the time to pass 100 cc of air through 1 in² (6.45 cm²) of sample at a pressure differential of 1.22 kPa (approximately 5 in. of water). The Bendtsen method measures the actual flow rate of air in mL/min through a 10 cm² sample at a pressure differential of 1.5 kPa (6 in. of water).

DuPont measures the air permeance, which is defined as the mean flow of air through a unit area under unit pressure difference in unit time (expressed in micrometers per pascal second). The values are then converted to calculate the respective Gurley Hill and Bendtsen values.

Porosity is important for gas sterilization processes to ensure that a sufficient amount of sterilant saturates the package in a short time and that the subsequent flushing and aeration of any residuals of the sterilant are efficient. Porosity also allows the packages to equilibrate rapidly from the pressure changes

that occur in gaseous sterilization, shipping and storage environments. If any material in the device develops an odor after gamma radiation, the porous material allows the odor to vent so that none is evident when the package is opened.

Reference standards: Gurley Hill Porosity: TAPPI T460; Bendtsen Air Permeability: ISO 5636-3.

¹ Sinclair, C.S. and A. Tallentire, Definition of a Correlation Between Microbiological and Physical Particulate Barrier Performances for Porous Medical Packaging Materials. PDA Journal of Pharmaceutical Science and Technology, 2002. 56(1): p. 11-19.

Spencer Puncture

The method for determining the impact resistance of plastic films and packaging materials under conditions that closely approximate the strain rate that these materials are subject to in the healthcare industry. This property indicates how a package will perform if an object falls on the package or if an object in the package strikes the lid. DuPont uses procedure B of ASTM D3420, modified with a $\frac{9}{16}$ -in. (14.28-mm) diameter hemispheric-shaped probe tip with a 6,400-gram pendulum. A modified probe is necessary because Tyvek® resists puncture by the standard probe. Results are reported in J/m² to highlight the use of the modified probe. Values may not be compared to other materials unless tested in the exact same manner.

Reference standard: ASTM D3420 (modified for $\frac{9}{16}$ -in. [14.28-mm] probe).

Tear

The measure of the ability of a substrate to resist tearing when a highly localized force is applied. Elmendorf tear measures the force required to propagate an initiated tear for a unit distance. The units are lb_f or Newtons. This property is important because nicks and cuts may occur at the edge of a lid and could affect its clean peel. The tear strength of Tyvek® is significantly higher than that of medical-grade paper. Reference standard: ASTM D1424.

Tensile Strength

The measure of the ability of a substrate to resist loads in the plane of the sheet. The units are lb_f or Newtons.

Along with elongation, tensile determines the ability of a material to absorb energy before failure. Tensile is measured by taking a 1-in. (25.4-mm) strip of product, clamping it so that 5 in. (127 mm) are between the jaws of a tensile tester, and then applying force to the ends until reaching the maximum force.

Reference standard: EN ISO 1924-2 (modified for speed, sample width and gauge length).

Thickness

The measure of the distance between the upper and lower surfaces of a substrate. The units of measure are usually mils, μm or mm. Thickness is measured by placing the material on a hard, flat surface and then determining the distance from the base by using a presser foot that is parallel to the base and applied to the top surface of the material. The presser foot is normally circular and the pressure applied to the foot depends on the material measured. For Tyvek®, the pressure is 50 kPa and the foot surface is 2 cm². The measurement corresponds to the highest spot in the area covered by the presser foot. The larger the cross-sectional area of the presser foot, the greater the chance to pick the highest spots on the sheet. For this reason, the average thickness value measured for a sheet is lower as the area of the presser foot decreases. The standard deviation for thickness is approximately 1 mil (25 μm).

Reference standard: EN ISO 534 (surface 2 cm², pressure 14.5 psi [50 kPa]).

Test methods used in DuPont quality labs for measuring material physical properties

Property	Comparable standard methods used in Richmond, VA and Luxembourg	Deviations from standard test methods
Basis Weight	ASTM D3776 or EN ISO 536 depending on style	Modified sample size.
Delamination	ASTM D2724	Modified for speed and sample width.
Gurley-Hill Porosity	TAPPI T460	—
Opacity	ISO 2471	Modified for different backing standards, area and illumination.
Thickness (individual)	EN ISO 534	Surface 2 cm ² , pressure 14.5 psi (50 kPa).
Tensile and Elongation	EN ISO 1924-2	Modified for speed, sample width and gauge length.
Elmendorf Tear	ASTM D1424	—
Hydrostatic Head	AATCC TM 127	Rate of use: 60 cm H ₂ O/min.
Mullen Burst	ISO 2758	—
Bendtsen Air Permeability	ISO 5636-3	—
Spencer Puncture	ASTM D3420	Modified for $\frac{9}{16}$ -in. (14.28-mm) probe.
Moisture Vapor Transmission Rate	TAPPI T523	Test conditions: 73 °F (23 °C), 85% relative humidity.

Aligned Sampling Plans

Specification Properties

The process of manufacturing DuPont™ Tyvek® requires strict adherence to good manufacturing practices, ISO 9001 quality processes and quality control measures. DuPont manufactures Tyvek® medical and pharmaceutical packaging styles using statistical process control methodology to control specification properties as established in the respective product specification sheets. These properties are controlled to a nominal value to produce material within specification ranges.

Specification properties are reported as a nominal value, a low value (minimum) and a high value (maximum), the latter two values representing the specification range within which product is released. Specification properties are reviewed periodically (and/or on an as-needed basis) and are based on process capability, market requirements and product performance history. Specification properties are based on roll averages with samples taken uniformly across the sheet. Routine sampling plans for specification properties are described here below. Start-up, transitions between styles of Tyvek® or abnormal situations may require additional sampling.

Sampling Plans for Specification Properties

Specification property measurements are made off-line in the laboratory.

Laboratory samples are taken from full-width rolls (~10 ft = ~3 m) typically once or twice per 8-hour shift. Laboratory measurements for specification properties are made at 12 approximately equally spaced locations across the roll; numbers are averaged to give “roll averages”—which are compared to specifications. Note that laboratory basis weight measurements may be made at frequencies less than once or twice per 8-hour shift when the process is stable—but not less than once per day.

Good laboratory practices, such as timely instrument calibration and measurement control testing, are used to generate laboratory data. The lab data is kept for up to 10 years.

Miscellaneous Properties

DuPont reports miscellaneous physical, mechanical and barrier properties to demonstrate the outstanding balance of properties that Tyvek® features. These miscellaneous properties provide useful information when comparing Tyvek® to other packaging materials.

Sampling Plans for Miscellaneous Properties

Miscellaneous properties represent typical values based on roll averages, with samples taken at locations and frequencies comparable to specification properties (unless otherwise noted). Miscellaneous properties are not controlled in the process and, therefore, are subject to slight changes from “normal” process drift.

Miscellaneous properties are measured in the laboratory from samples taken from full width rolls (~10 ft = ~3 m). Laboratory measurements are made at 6 to 12 approximately equally spaced locations across the roll and averaged to give “roll averages,” except for thickness, where approximately 112 individual data points are taken at 1-in. (2.54-cm) intervals. These data points are pooled with individual data points from other rolls and averaged to give an individual (average) thickness.

Microbial barrier is measured approximately once per month or per manufacturing campaign with at least one of the test methods specified above. Bioburden and Moisture Vapor Transmission Rates (MVTR) are checked approximately once per year.

Laboratory data is generated following established procedures and guidelines, which include good laboratory practices, such as timely instrument calibrations. The lab data on physical properties is kept for up to 10 years.

DuPont reserves the right to modify testing per our change control procedures as needed to meet customer needs or to improve production control and efficiency.

For more information about the DuPont-Tyvek Medical Packaging Transition Project (MPTP), visit transition.tyvek.com and transitiondata.tyvek.com.

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