DuPont™
Tyvek®
Medical
Packaging
Transition
Project

5-Year Real-Time
Aging Industry
Summary Report

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Robert H. Gowell
Global Safety Technical Director

Thierry Wagner
Global Director – Regulations & Standards

Jennifer H. Van Mullekom, PhD
Senior Consulting Statistician
EXECUTIVE SUMMARY

5-Year Real-Time Aging package testing results for the 78 cells in the Medical Packaging Transition Project ("MPTP") by third-party Nelson Laboratories indicate Functional Equivalence between Legacy Tyvek® styles 1073B and 1059B and Transition Protocol material styles 1073B and 1059B. Specific test data to support this conclusion includes:

- Seal Strength (ASTM F88): 78 out of 79 instances of Functional Equivalence
- Microbial Barrier (ASTM F2638): 78 out of 78 instances of Non-Inferiority
- Package Integrity (ASTM F1929): 1,404 out of 1,404 instances of No Dye Penetration

Additional details are provided in the Tables and Figures that follow, including those in Appendix A, where results are presented by category.

MEDICAL PACKAGING TRANSITION PROJECT ("MPTP") OVERVIEW SUMMARY

The Pre-Sterilization and Post-Sterilization Industry Summary Report (November 2014; Corrected April 2015) provides an extensive overview of MPTP. It can be found in the “Medical Packaging Transition Project Industry Reports” section of the transitiondata.tyvek.com website. Important points to re-emphasize include:

- **Functional Equivalence** means that attributes of Transition Protocol material meet functional and performance requirements.
- The **U.S. FDA Transition Protocol** is a study plan based on sound principles of experimental design and statistical analysis for generating data to prove Functional Equivalence by comparing Transition Protocol material and Legacy Tyvek® using 60 different device/package combinations ("cells") with a validated design and a validated forming, sealing and assembly process. Table 1 summarizes all 60 U.S. FDA Transition Protocol cells.
Table 1. Sixty Cell U.S. FDA Transition Protocol Matrix

<table>
<thead>
<tr>
<th>Style</th>
<th>Pouches and Bags</th>
<th>Form-Fill-Seal</th>
<th>Rigid Trays</th>
</tr>
</thead>
<tbody>
<tr>
<td>EO Coated</td>
<td>1073B 1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>EO Uncoated</td>
<td>1073B 22</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>Gamma Coated</td>
<td>1073B 28</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Gamma Uncoated</td>
<td>1073B 40</td>
<td>41</td>
<td>42</td>
</tr>
<tr>
<td>Electron-beam Coated</td>
<td>1073B 43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electron-beam Uncoated</td>
<td>1073B 46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO Coated</td>
<td>1059B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO Uncoated</td>
<td>1059B 52</td>
<td>53</td>
<td>54</td>
</tr>
</tbody>
</table>

- The **Phantom Protocol** involves the creation and testing of 18 additional sterilized medical device/package combinations (“cells”) that are outside the scope of the U.S. FDA Transition Protocol but have been requested by the industry to support risk assessments. Table 2 summarizes all 18 Phantom Protocol cells.

Table 2. Eighteen Cell Phantom Protocol Matrix

<table>
<thead>
<tr>
<th>Style</th>
<th>Pouches and Bags</th>
<th>Form-Fill-Seal</th>
<th>Rigid Trays</th>
</tr>
</thead>
<tbody>
<tr>
<td>EO Coated</td>
<td>1073B</td>
<td>X74</td>
<td>X75</td>
</tr>
<tr>
<td>EO Uncoated</td>
<td>1073B</td>
<td>X61</td>
<td></td>
</tr>
<tr>
<td>Gamma Coated</td>
<td>1073B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma Uncoated</td>
<td>1073B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electron-beam Coated</td>
<td>1073B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electron-beam Uncoated</td>
<td>1073B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO Coated</td>
<td>1059B</td>
<td>X77</td>
<td></td>
</tr>
<tr>
<td>EO Uncoated</td>
<td>1059B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam Coated</td>
<td>1073B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam Uncoated</td>
<td>1073B</td>
<td>X69</td>
<td>X70</td>
</tr>
<tr>
<td>Dry Heat Coated</td>
<td>1073B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Temp. H₂O₂ Coated</td>
<td>1073B</td>
<td>X76</td>
<td></td>
</tr>
<tr>
<td>Low Temp. C₂H₂O₃ Coated</td>
<td>1073B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma Coated</td>
<td>1059B</td>
<td>X72</td>
<td></td>
</tr>
<tr>
<td>Electron-beam Coated</td>
<td>1059B</td>
<td>X73</td>
<td></td>
</tr>
</tbody>
</table>
• 5-Year Real-Time Aging conditions were nominally 25 °C and monitored ambient relative humidity.

Paired data sets (Transition Protocol material vs. Legacy Tyvek®) for each cell were generated and analyzed from the following tests:

  o Seal Strength: ASTM F88
  o Microbial Barrier: ASTM F2638
  o Package Integrity: ASTM F1929
  o Visual Inspection: ASTM F1886M (Only reported for Pre-sterilization and Post-sterilization time points; no aging visual inspection results will be reported)

This Industry Summary Report summarizes the 5-Year Real-Time Aging data for all 78 cells. More detailed and comprehensive reports than Industry Summary Reports will be prepared and submitted to the U.S. FDA and other regulatory bodies under Confidentiality Agreements. Recall that with the submission of the 1-Year Real-Time Aging report to the U.S. FDA, a letter affirming Functional Equivalence was issued and can be viewed at transitiondata.tyvek.com. 5-Year Real-Time Aging data is a continuation of the test plan outlined in the U.S. FDA Transition Protocol. Industry Summary Reports for other aging time points will be published as data generation and analysis are completed.

**TESTING and RESULTS OVERVIEW**

Data were analyzed for the three different attributes detailed in the approved study design for 5-Year Real-Time Aging: seal strength, microbial barrier, and package integrity. In the following sections, a brief overview of the study design and associated statistical methods is provided, followed by a high-level summary of the results.

It should be noted that for the Pre-sterilization and Post-sterilization time points, three sealing conditions across the sealing window were tested for both the Test Material (also called Test or Transition Protocol material) and the Control Material (also called Control). Please note that in previous reports, Control Material was also referred to as Current Tyvek®, but it is now referred to as Legacy Tyvek®. These three sealing conditions were denoted as Lower, Nominal, and Upper sealing conditions. However, for accelerated and real-time aging time points, only one sealing condition across the sealing window was tested. This sealing condition was specified by the Medical Device Manufacturers (“MDMs”) for each cell and was based on the sealing condition used by the MDMs for their original stability testing during package qualification.

For the majority of cells, test packages for aging time points were manufactured with Nominal sealing conditions, while Lower sealing conditions were used for the remainder. No Upper sealing conditions were used for any aging time points.

**Seal Strength (ASTM F88)**

Seal strength was assessed via ASTM F88 in accordance with metric details specified by the MDMs. These metric details include a designation of either Maximum Load or Average Load as the response, as well as the testing apparatus/material orientation used. See Figure 1 for a visual description of the different seal strength methods/techniques employed in the study.
At the chosen sealing condition, 48 samples were tested for both Test Material and Control Material. For most cells, this consisted of 4 test strips cut from each of 12 packages. However, some packages were too small to obtain 4 samples per package so either 1 or 2 test strips were cut per package resulting in a total of 48 and 24 packages per condition, respectively.

Functional Equivalence was assessed by calculating the appropriate 90% confidence interval on the Difference in the Means (Test-Control) for each cell at the chosen sealing condition. If this interval was contained within the Functional Equivalence bounds, then the Seal Strength was declared Functionally Equivalent. While the Transition Protocol material must satisfy the Functional Equivalence criteria, Transition Protocol material packages must also meet or exceed Legacy Tyvek® package performance with respect to achieving minimum seal strength requirements, as defined by the MDMs.

In the two figures that follow, the Average Percent Change in Seal Strength relative to the Control is calculated and presented in Figure 2 for all cells designated as Maximum Load. Figure 3 details the results for Average Load cells. Note this Average Percent Change is computed by calculating individual cell percent changes:

\[
\text{Percent Change} = \frac{\text{Mean (Test-Control)}}{\text{Mean (Control)}} \times 100
\]
and then taking the average of the individual cell percent change values. Average Percent Changes for Maximum Load cells for 5-Year Real-Time Aging are ~5-6%, which are in-line with Pre-sterilization, Post-sterilization, 1-Year Accelerated Aging, 3-Year Accelerated Aging, 5-Year Accelerated Aging, 1-Year Real-Time Aging and 3-Year Real-Time Aging results (~4-6%). Average Percent Changes for Average Load cells for 5-Year Real-Time Aging are ~4-7%, which overlap with the ranges for all previous study periods, including 3-Year Real-Time Aging (~6-7%), 1-Year Real-Time Aging (~3-7%), 5-Year Accelerated Aging (~4-7%), 3-Year Accelerated Aging (~2-7%), 1-Year Accelerated Aging (~3-7%) and Pre- and Post-sterilization results (~5-9%).

As noted in the Pre-Sterilization and Post-Sterilization Industry Summary Report, packages from three cells in the study contained non-peelable seals due to their constructions as vent, Kwibreathe™ True Header, or weld seal bags. Because non-peelable seals were outside the scope of the study, these packages were not included in the Percent Change calculations. Moreover, in creating the Maximum and Average Load Figures, five cells were double packages and both the inner and outer seal strength data were included. In all, there were 80 peelable seal strength assessments: N=58 (Maximum Load) + N=22 (Average Load) totals N=80, determined from 78 cells – 3 cells (design) + 5 cells (double). For 5-Year Real-Time Aging, only 79 seal strength assessments are being reported because for one Average Load cell, the majority of the package seal failures in both the Transition Protocol and Control materials were due to a failure mode other than peeling of the seal. Hence, N=21 Average Load assessments.

Figure 2. Avg. Percent Change in Mean Seal Strength (Test-Control) for Maximum Load Cells; N=58

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Test = Transition Protocol Material
Control = Legacy Tyvek®
A high-level summary of the results tested for each package configuration, material and sterilization combination is shown in Table 3. There are 78 instances of Functional Equivalence for 5-Year Real-Time Aging. All cells with peelable seals met the Functional Equivalence criteria with the exception of one cell—an uncoated 1073B pouch. This cell failed the Functional Equivalence criteria by 0.07 lb/in. on the upper end of the equivalence limit, indicating the Transition Protocol material produced higher seal strength than the Control material.
### Table 3. Summary of Seal Strength Functional Equivalence Results*

**Industry Summary: MPTP Test Results after 5-Year Real-Time Aging, Pass/Fail Summary for Seal Strength* — ASTM F88**

<table>
<thead>
<tr>
<th>Tyvek* Style</th>
<th>Coating Type</th>
<th>Sterilization Type</th>
<th>Pouches and Bags</th>
<th>Form-Fill-Seal</th>
<th>Rigid Trays</th>
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</thead>
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<td></td>
<td></td>
<td></td>
<td>Pass</td>
<td>Fail</td>
<td>Pass</td>
</tr>
<tr>
<td>1073B</td>
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<td>EO</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gamma</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dry Heat</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Low Temp. H₂O₂</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Low Temp. C₂H₂O₃</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Uncoated</td>
<td>EO</td>
<td>7</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gamma</td>
<td>2</td>
<td>1***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electron-beam</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Steam</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1059B</td>
<td>Coated</td>
<td>EO</td>
<td>5</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gamma</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electron-beam</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Uncoated</td>
<td>EO</td>
<td>5</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

**THERE ARE NO CELLS IN THE MPTP FOR THIS CATEGORY**

*Vent bag, Kwikbreathe® True Header bag and weld seal bag seal strengths are not included; the failure modes were non-peelable seals. (3 cells)

**Transition Protocol material and Control material (Legacy Tyvek®) exhibited a majority of seal failures that were not peel failures; thus, the seal strength results were not included in the final analysis. (1 cell)

***One package configuration exceeded the upper end of the equivalence limit by 0.07 lb/in., implying that the Transition Protocol material seal strength was stronger than the Control material (Legacy Tyvek®). (1 cell)
A Root Cause Failure Analysis (“RCFA”) identified a phenomenon denoted as “Tail Flipping,” which increased the variability of the Maximum Load measurement designated for the cell, as the root cause of the nonequivalence. This same phenomenon was observed in the 3-Year Accelerated Aging Time Period as well. “Tail Flipping” is shown in Figure 4 and has only been observed for seal strength testing Technique “C”. Sources of variability discounted as causes of “Tail Flipping” include sterilization type, Tyvek® style and coatings. The investigation concluded that less stiff, lighter gauge film systems, and to a lesser extent package fiber orientation, were the key influences in conjunction with Technique “C” and Maximum Load measurements. However, the higher Test material seal strength should not compromise package integrity; rather it should improve it. Thus, the logical juxtaposition of statistical and physical evidence leads DuPont to conclude seal strength Functional Equivalence.

Figure 4. “Tail Flipping” Phenomenon

![Image of Tail Flipping Phenomenon]

- Start of Peel
- Tail begins to “flip” near end of peel
- Tail has flipped
- End of peel
**Microbial Barrier (ASTM F2638)**

Microbial barrier performance was tested using ASTM F2638. The % pMax value for three Test samples and three Control samples from each cell was determined; a lower/smaller % pMax value indicates better microbial barrier performance. A statistical test of non-inferiority was performed to indicate the Test material does not underperform Control material. A 95% student’s upper confidence bound was calculated and compared to the pre-established non-inferiority criteria from the study design.

The Difference in the Means (Test-Control) for % pMax was calculated for each cell. These differences were then sorted according to Tyvek® style (1059B or 1073B) and coating status (coated or uncoated). The endpoints of each of the bars shown in Figure 5 represent the highest and the lowest Difference in the Means (Test-Control) observed for % pMax. A 0.00 value for the Difference in the Means indicates that the Transition Protocol material Mean and the Legacy Tyvek® Mean are the same. The dashed line in each bar represents the Mean of the Difference in the Means for each group. Dashed lines which fall below 0.00 (i.e., negative values) indicate the Transition Protocol material had a lower/smaller Mean than Control material (and thus better barrier). **All 78 cells pass the Microbial Barrier Non-Inferiority Criteria for 5-Year Real-Time Aging, representing 78 instances.**

It should be noted that the vertical scale in Figure 5, as well as vertical scales on microbial barrier graphs in the Appendix, are very small numbers and represent minimal differences in the Means. Moreover, due to the outstanding microbial barrier performance of Tyvek®, individual % pMax values used in calculating differences were very small as well.

*Figure 5. Range of Differences in % pMax Mean (Test-Control) for All Cells by Tyvek® Style, Time Point, and Coating Status*
Package Integrity Testing (ASTM F1929)

ASTM F1929 was applied to assess package integrity via a dye penetration test. In the 5-Year Real-Time Aging phase of the study, package integrity testing was performed at the Lower or Nominal sealing condition, whichever was defined by the MDM for the cell. Nine Transition Protocol material packages and nine Legacy Tyvek® packages were tested for each cell; Figure 6 shows a summary of the data. No package failed the dye penetration test due to a material related defect; there are 702 instances of no dye penetration in Transition Protocol material and 702 instances of no dye penetration in Legacy Tyvek® for a total of 1,404 instances of no dye penetration.

Due to the discrete nature of this data, the overall pass/fail criteria for package integrity is assessed in the Industry Executive Summary Report.

**Figure 6. Package Integrity Testing Summary**

5-Year Real-Time Aging

<table>
<thead>
<tr>
<th>Material</th>
<th>Not Penetrated</th>
<th>Penetrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transition Protocol</td>
<td>702</td>
<td>0</td>
</tr>
<tr>
<td>Legacy Tyvek®</td>
<td>702</td>
<td>0</td>
</tr>
</tbody>
</table>

Sealing Condition: Lower, Nominal

CONCLUSIONS

In summary, 5-Year Real-Time Aging testing indicates:

- 78 out of 79 instances of seal strength **Functional Equivalence**
- 78 out of 78 instances of microbial barrier **Non-Inferiority**
- 1,404 out of 1,404 instances of **No Dye Penetration**

Results from the 5-Year Real-Time Aging study time point indicate **Functional Equivalence** for Seal Strength and Microbial Barrier. The **Industry Executive Summary Report** details a functional equivalence assessment for all time points to-date of all 16,848 Package Integrity results.
APPENDIX A: CATEGORY RESULTS

5-Year Real-Time Aging overall testing results were presented in the previous section. Appendix A presents the data in a different format, i.e. by category, where it is broken down in further detail to help facilitate industry risk assessments. As evaluations are done, be cognizant of the number of cells represented by each Figure.

A set of 5-Year Real-Time Aging Seal Strength, Microbial Barrier and Package Integrity results are shown for each of the following categories:

- Coated 1073B Pouches/Bags
- Coated 1073B Form-Fill-Seal
- Coated 1073B Lids/Rigid Trays
- Uncoated 1073B Pouches/Bags
- Coated 1059B Form-Fill-Seal
- Uncoated 1059B Pouches/Bags
- Uncoated 1059B Form-Fill-Seal
Coated 1073B Pouches/Bags

Figure A1. Avg. Percent Change in Mean Seal Strength (Test-Control) for Coated 1073B Pouches/Bags

Figure A2. Range of Differences in % pMax Mean (Test-Control) for Coated 1073B Pouches/Bags

Percent Change = Mean (Test-Control)/Mean(Control)*100

Test = Transition Protocol Material
Control = Legacy Tyvek®
Figure A3. Package Integrity Summary for Coated 1073B Pouches/Bags

Figure A4. Avg. Percent Change in Mean Seal Strength (Test-Control) for Coated 1073B Form-Fill-Seal
Figure A5. Range of Differences in % pMax Mean (Test-Control) for Coated 1073B Form-Fill-Seal

Dashed line (---) = Mean of the difference in the means
Test = Transition Protocol Material
Control = Legacy Tyvek®

Figure A6. Package Integrity Summary for Coated 1073B Form-Fill-Seal

Sealing Condition:  
- Lower
- Nominal
Coated 1073B Lids/Rigid Trays

Figure A7. Avg. Percent Change in Mean Seal Strength (Test-Control) for Coated 1073B Lids/Rigid Trays

Percent Change = Mean (Test-Control)/Mean(Control)*100

Test = Transition Protocol Material
Control = Legacy Tyvek®

Figure A8. Range of Differences in % pMax Mean (Test-Control) for Coated 1073B Lids/Rigid Trays

Dashed line (−−−) = Mean of the difference in the means
Test = Transition Protocol Material
Control = Legacy Tyvek®
Figure A9. Package Integrity Summary for Coated 1073B Lids/Rigid Trays

Uncoated 1073B Pouches/Bags

Figure A10. Avg. Percent Change in Mean Seal Strength (Test-Control) for Uncoated 1073B Pouches/Bags

Test = Transition Protocol Material
Control = Legacy Tyvek®
Figure A11. Range of Differences in % pMax Mean (Test-Control) for Uncoated 1073B Pouches/Bags

Dashed line (−−−−) = Mean of the difference in the means
Test = Transition Protocol Material
Control = Legacy Tyvek®

Figure A12. Package Integrity Summary for Uncoated 1073B Pouches/Bags
Coated 1059B Form-Fill-Seal

Figure A13. Avg. Percent Change in Mean Seal Strength (Test-Control) for Coated 1059B Form-Fill-Seal

Figure A14. Range of Differences in % pMax Mean (Test-Control) for Coated 1059B Form-Fill-Seal
Figure A15. Package Integrity Summary for Coated 1059B Form-Fill-Seal

Figure A16. Avg. Percent Change in Mean Seal Strength (Test-Control) for Uncoated 1059B Pouches/Bags
Figure A17. Range of Differences in % pMax Mean (Test-Control) for Uncoated 1059B Pouches/Bags

Dashed line (−−−) = Mean of the difference in the means
Test = Transition Protocol Material
Control = Legacy Tyvek®

Figure A18. Package Integrity Summary for Uncoated 1059B Pouches/Bags
Uncoated 1059B Form-Fill-Seal

Figure A19. Avg. Percent Change in Mean Seal Strength (Test-Control) for Uncoated 1059B Form-Fill-Seal

Figure A20. Range of Differences in % pMax Mean (Test-Control) for Uncoated 1059B Form-Fill-Seal

Test = Transition Protocol Material
Control = Legacy Tyvek®

Dashed line (− − − ) = Mean of the difference in the means
Test = Transition Protocol Material
Control = Legacy Tyvek®
Figure A21. Package Integrity Summary for Uncoated 1059B Form-Fill-Seal

![Bar chart showing the count of not penetrated and penetrated samples for Transition Protocol Material and Legacy Tyvek®.]

Sealing Condition: Lower  Nominal

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