# Testing the Validity of Hand Dryer Drying Time Specifications: A Quantitative Study of Residual Water on Hands Using Dyson and Xlerator Dryers in Active Public Restrooms

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## Abstract

Commercial hand dryer manufacturers make precise, certified claims: Dyson specifies 10-12 seconds to achieve ≤0.1g residual moisture; Xlerator specifies 8 seconds to achieve ≤0.25g. These specifications form the basis for purchase decisions, energy calculations, hygiene claims, cost projections, and facility planning industry-wide. After realizing the dry time claims did not match our observations during testing for the first paper in this series (Blouch [1]) we devised a test to determine whether functioning dryers in working public restrooms meet their own claimed and certified standards. With an experimental design similar to UL Solutions and NSF International protocols, we measured residual moisture on hands after drying for manufacturer-specified times across 21 hand dryers (10 Dyson, 11 Xlerator) in active public restrooms. The results are clear: hands retained an average of 2.83g of moisture per trial at either 8 or 12 seconds (95% CI: 2.61–3.05g), exceeding manufacturers' claimed maximum by an average of 1,032 % (range 744 %–3,540 %). Dyson units retained mean 26.9× their claimed 0.1g threshold; Xlerator units retained mean 11.9× their claimed 0.25g threshold. Zero of 21 tests achieved the claimed dryness ($p < 0.001$, Cohen's $d = 5.00$), with the best performing dryer leaving 2.11g of residual moisture on hands—almost two full grams of water above the manufacturer's specification. One Dyson dryer left 3.64g of water, 3540% over specification. The dry time specification fails 100% of the time by at least 2 grams of water. An estimated 1.5 million commercial hand dryers operate in the United States, used approximately 150 million times daily. With 2.83g of water remaining per dry cycle rather than the claimed <0.1g or <0.25g, every downstream manufacturer’s dryer performance claim is compromised: energy per dry, microbial exposure duration, cost calculations, and hygiene outcomes. The user is faced with an impossible choice: either leaving the dryer with wet hands, or keeping hands in the dryer longer, exposing them to increased bacterial load from the dryer as documented in our companion study (Blouch [1]) on microbial load in dryer output air. Patrick et al. established that wet hands transfer up to 500× more bacteria than dry hands. Pulling out early becomes a disease spreading multiplier, well established in public health literature (Patrick, 1). Any user who continues until hands are dry increases energy use beyond manufacturers' and certifiers' claims in every cycle, negating claims these

devices are green products, and exposes their hands in each additional second to a stream of air with 49.6× more microorganisms than the restroom air around them.

**This paper is part of an eleven-study series examining hand hygiene practices in public restrooms. The papers were written in chronological order as testing evolved. Earlier papers are left largely as they were written at the time for detail, historicity, and clarity. Studies in this series may be referenced in each document by series number (Paper 1-11) or by citation number in the reference list:**


Transmission of Bacteria and Fungus via Dyson and Xlerator Hand Dryers in Starbucks, Home Depot and Whole Foods Restrooms: A Comparative Analysis; Blouch, R. A. Jr. (2025) MAIN STUDY [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.15504115 PAPER [1]

Testing the Validity of Hand Dryer Drying Time Specifications: A Quantitative Study of Residual Water on Dyson and Xlerator Dryers in Retail Store Environments; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.15503698 PAPER [2]

Visual Analysis of Water Dispersion Patterns During Hand Drying: A Qualitative Comparison of High-Speed Air Dryers and Paper Towels; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.15503304 PAPER [3]

Bacterial and Fungal Contamination Assessment of Paper Towel Types: A Quantitative Analysis of White versus Brown Varieties in Retail Restrooms; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.15504144 PAPER [4]

Systematic Performance Failure in Commercial Hand Dryers: A Large-Scale Quantitative Analysis of Time-To-Dry on Hands in Dyson and Xlerator Hand Dryers in Public Restrooms; Blouch, R.A Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17858443 PAPER [5]

Baseline Water Mass on Freshly Washed Hands: Establishing Reference Values; Blouch R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17858834 PAPER [6]

An Empirical Refutation of Green Energy Claims for Dyson and Xlerator Hand Dryers in Use in Public Restrooms; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17859198 PAPER [7]

Catastrophic Time-To-Dry Failures by Dyson, Excel and World Dryer Hand Dryers via the Bi-Modal Loose Water and Bound Water Mechanism: A Comprehensive Definitive Analysis; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17869567 PAPER [8]

Validation of Hand Dryer Microbial Amplification Using Broad-Spectrum Growth Media: A Replication Study with Enhanced Detection Methodology; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17859894 PAPER [9]

The Wandering Plume of Filth: A Randomized, Empirical Assessment of Visible Wall Contamination Radiating from Commercial Hand Dryers Versus Paper Towel Dispensers

in Functioning Public Restrooms; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.17860971 PAPER [10]

Performance Failures in Commercial Hand Dryers: An Historical Synthesis and Sequential Summary Review of an Eleven-Study Research Program; Blouch, R. A. Jr. (2025) [Preprint] Retrieved from www.handdryerstudy.com/. DOI: 10.5281/zenodo.18322481 PAPER [11]

# 1. Introduction

Dyson and Excel Dryer (Xlerator) are dominant manufacturers in the commercial hand dryer market, with both companies prominently advertising specific drying times as key selling points for their products. Dyson claims their Airblade models dry hands completely in 10-12 seconds, stating in their technical documentation: "Dry time determined using Dyson test method 769 based on NSF P335 using a measurement of 1/10th of one gram residual moisture" (Dyson [11]). Similarly, Xlerator advertises complete drying in just 8 seconds, specifying in their product documentation: "Dry time and energy use testing performed by SGS International on standard XLERATOR Hand Dryer with 0.8" nozzle to one quarter of a gram or less of residual moisture, pursuant to the UL Environment Global Product Category Rules (PCR) for Hand Dryers" (Excel Dryer [12]).

On nearly every page of their websites and in their promotional materials Dyson and Excel Dryer explicitly and repeatedly claim to leave 0.1g and 0.25g of residual water on hands at the completion of their specified drying times of 12 and 8 seconds, respectively. These are precise, certified specifications with defined measurement protocols backed by multiple certifying and testing organizations with claims of extensive testing and validation.

These highly specific claims about drying efficiency are cited as justification for installation in high-traffic public facilities. Dyson has received certification and listing by NSF International for dryer time performance and hygiene in accordance with its P335 standard. Excel cites SGS International as having tested its dryers to meet manufacturers' claims and the standards in the ULE_HandDryer_PCR_7-13-16.

## Why the Specification Matters

The scale of the installed base is substantial: an estimated 1.5 million commercial hand dryers in the United States serve approximately 150 million daily uses. The manufacturer specification is the foundation upon which the entire product category's value proposition rests:

- Energy claims assume 8-12 seconds of operation per use
- Cost savings projections assume 8-12 seconds per dry
- Throughput calculations assume 8-12 seconds per user

- Hygiene claims assume hands achieve the ≤0.25g "dry" threshold
- Environmental comparisons to paper towels assume these specifications are accurate

If the specification fails, every downstream claim built on it is invalid. Any systematic failure to achieve claimed dryness would affect population-level energy consumption, cost calculations, and pathogen transfer risk.

## The Public Health Context

The accuracy of these manufacturer-specified drying times has significant implications for facility planning, user experience, and hand hygiene outcomes. Previous research by Patrick et al. [1] and Marples and Towers [18] established that residual moisture on hands significantly impacts bacterial transfer to surfaces—wet hands transferred up to 68,000 organisms compared to properly dried hands transferring as few as 140 organisms (85% vs 0.05%, respectively). As summarized by Huang [3], Patrick et al. [1] found that a drying time of 45 seconds was required to dry hands in hand dryers. This relationship between residual hand moisture and bacterial and fungal transfer underscores the importance of both effective drying and minimizing exposure to microbial contaminants during the drying process.

## Study Origin

During extensive testing of hand dryers for microbial output in ~110 stores in four Middle Atlantic states and the District of Columbia we consistently observed that hands dried for 8 or 12 seconds were still wet. There is limited independent verification of the drying efficacy of air driven hand dryers, prompting us to verify experimentally what we were seeing during the testing described in the co-studies in this series (Blouch [5] [6] [7]).

We designed this test and completed experimentation before discovering that Underwriter's Laboratories details the same testing procedure in its hand dryer manufacturer's guide ULE_HandDryer_PCR_7-13-16 [4]. We had created an unexpectedly fully blinded test set that was later validated by detailed prior art from the leading product certifying authority in the United States.

This study aims to directly assess the validity of manufacturer-specified drying times through quantitative measurement of residual moisture following the recommended drying duration.

The primary research question is straightforward: Do Dyson and Xlerator hand dryers achieve complete hand drying—using the manufacturers' and certifiers’ own stated criteria for dry hands—within the specified drying times?

We hypothesized that hands would not be dry within the manufacturers' specified drying time for their machines.

## 2. Materials and Methods

### Testing Protocol

A standardized testing procedure to quantify residual moisture on hands after using commercial hand dryers for their manufacturer-specified drying times was designed from scratch, later discovering it tightly aligned with Underwriters Laboratories Product Category Rules for Hand Dryers detailed in the second appendix to ULE_HandDryer_PCR_7-13-16 [4]. The methodology was designed to provide objective, replicable measurements of hand drying performance under real-world conditions, similar to approaches used by Snelling et al. [13] in their comparative evaluation of hand dryer efficacy.

### Test Locations and Sample Size

Testing was conducted in 21 different locations across Central Pennsylvania between March 6–7, 2025, incorporating:

- 10 Dyson Airblade units
- 11 Xlerator units

All units were in active use in public restrooms, representing the actual performance conditions users would encounter.

### Measurement Procedure

**1. Initial Hand Washing:** Hands were washed in the sink as if normally washing hands but without soap. Soap was avoided to limit repeated chemical exposure on bare hands by the testers and to create a consistent metric removing brand as a variable.

**2. Baseline Water Mass Determination:**

- Two paper towels were weighed using a precision digital scale accurate to 0.01g (dry mass recorded in grams)
- Hands were dried completely using the paper towels
- The wet paper towels were weighed (wet mass recorded in grams)
- Total water mass was calculated (wet mass − dry mass = water mass)

**3. Hand Dryer Testing:**

- Hands were washed again following identical procedure
- One tester was used for all tests. Adult male, age 42, 5’ 9”, 220 pounds.

- Hands were dried using the hand dryer for as close to the manufacturer-specified time as possible: Dyson units: ~12 seconds (as specified by manufacturer); Xlerator units: ~8 seconds (as specified by manufacturer). Actual drying times were recorded and ranged from 8.0–13.0 seconds (see Appendix 3)
- A fresh set of pre-weighed paper towels was used to dry hands after the manufacturer-specified drying time
- The paper towels were weighed (wet mass recorded)
- Residual moisture was calculated (wet mass − dry mass = residual water mass)

**4. Final Drying Check:**

- A final set of paper towels was weighed (dry mass recorded)
- Hands were dried a second time with these towels after the hand dryer test was complete to capture any remaining moisture
- The paper towels were weighed (wet mass recorded)
- Final residual moisture was calculated (wet mass − dry mass = final water mass)
- Total residual moisture was determined by adding both post-dryer paper towel water masses

### Data Analysis

Residual moisture differential weights in grams were calculated as a percentage of initial water mass to determine the proportion of water remaining after the manufacturer-specified drying time. Statistical analysis calculated mean, standard deviation, 95% confidence interval, and range of residual moisture and percentages retained across all units and for each dryer type. One-sample t-tests compared residual moisture to the UL threshold (0.25g) and brand-specific claims (Dyson: 0.1g, Xlerator: 0.25g).

## 3. Results

### Overall Hand Dryer Performance

Our testing revealed 744%–3540% (2.11g-3.64g) retained water after drying, directly contradicting claims of complete drying within these timeframes.

**Initial Water Mass**

Average across all units (n=21): 7.30g (±0.64g, 95% CI: 7.03–7.57g) of water.

**Residual Moisture After Manufacturer-Specified Drying Time**

**All Units (n=21):**

- Average residual moisture: 2.83g (±0.52g, 95% CI: 2.61–3.05g)
- Percentage of initial water mass: 39.2% (±8.8%, 95% CI: 35.4–43.0%)
- Range: 1.80–3.72g (25.5–61.2%)

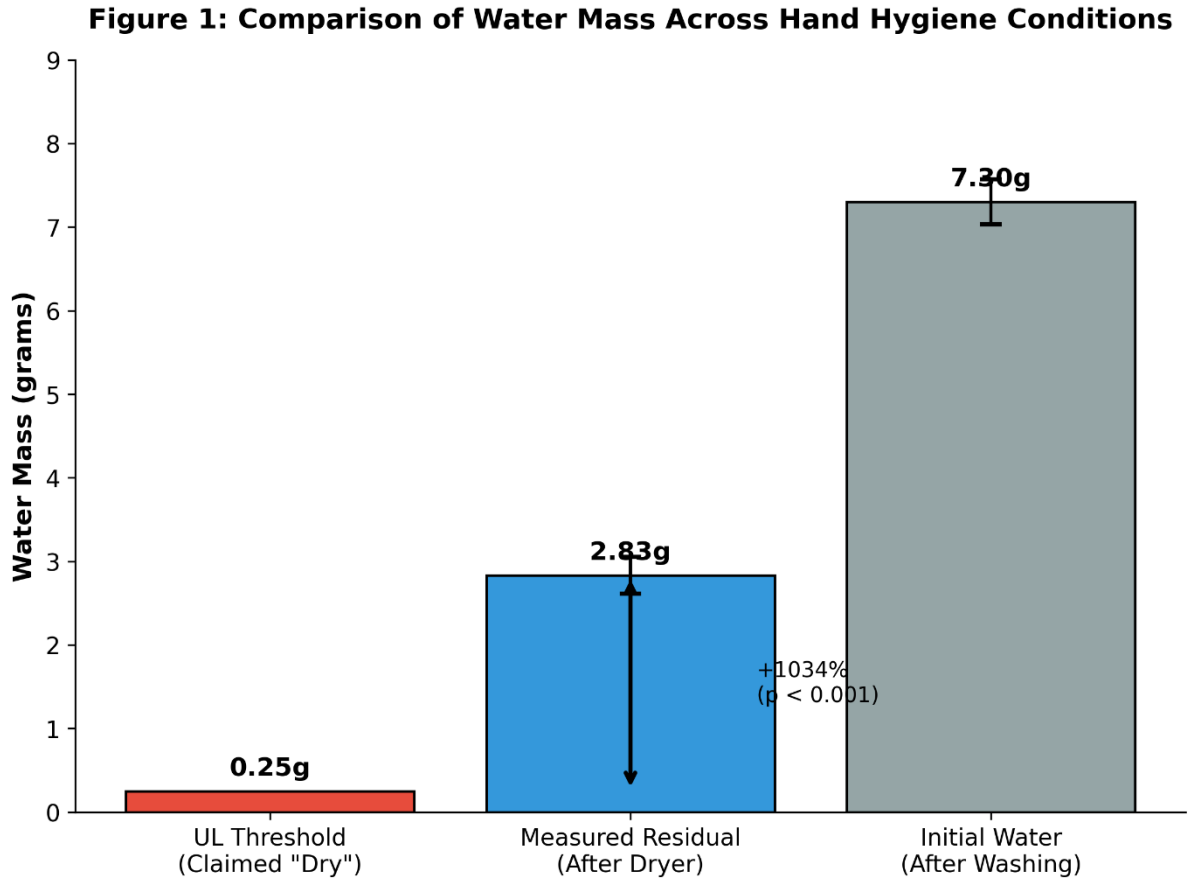


*Figure 1. Comparison of water mass across hand hygiene conditions. The UL residual moisture threshold (0.25g) is shown alongside the average measured residual moisture following hand drying with electric dryers (2.83g; 95% CI: 2.61–3.05g) and the initial water mass deposited after handwashing (7.30g; 95% CI: 7.03–7.57g). The measured residual moisture significantly exceeded manufacturers' claimed thresholds by ~1800% on average ($t(20) = 22.91$, $p < 0.001$, Cohen's $d = 5.00$). Error bars represent 95% confidence intervals.*

## Statistical Analysis of Combined Manufacturer Claims

The measured residual moisture (mean = 2.83g) significantly exceeded manufacturers' claimed thresholds by approximately 1800% (range: 744%–3540%) ($t(20) = 22.91$, $p < 0.001$, Cohen's $d = 5.00$). Figure 1 illustrates this discrepancy.

**Table 1: Claimed vs. Measured Residual Moisture Across Hand Dryers**

| Dryer Type | Claimed Residual Moisture | Actual Measured Residual Moisture (Average) | 95% CI | Statistical Significance | Percent Difference |
|---|---|---|---|---|---|
| All Units | 0.25g (UL threshold) | 2.83g | 2.61–3.05g | $p < 0.001$ | +744%–3540% |

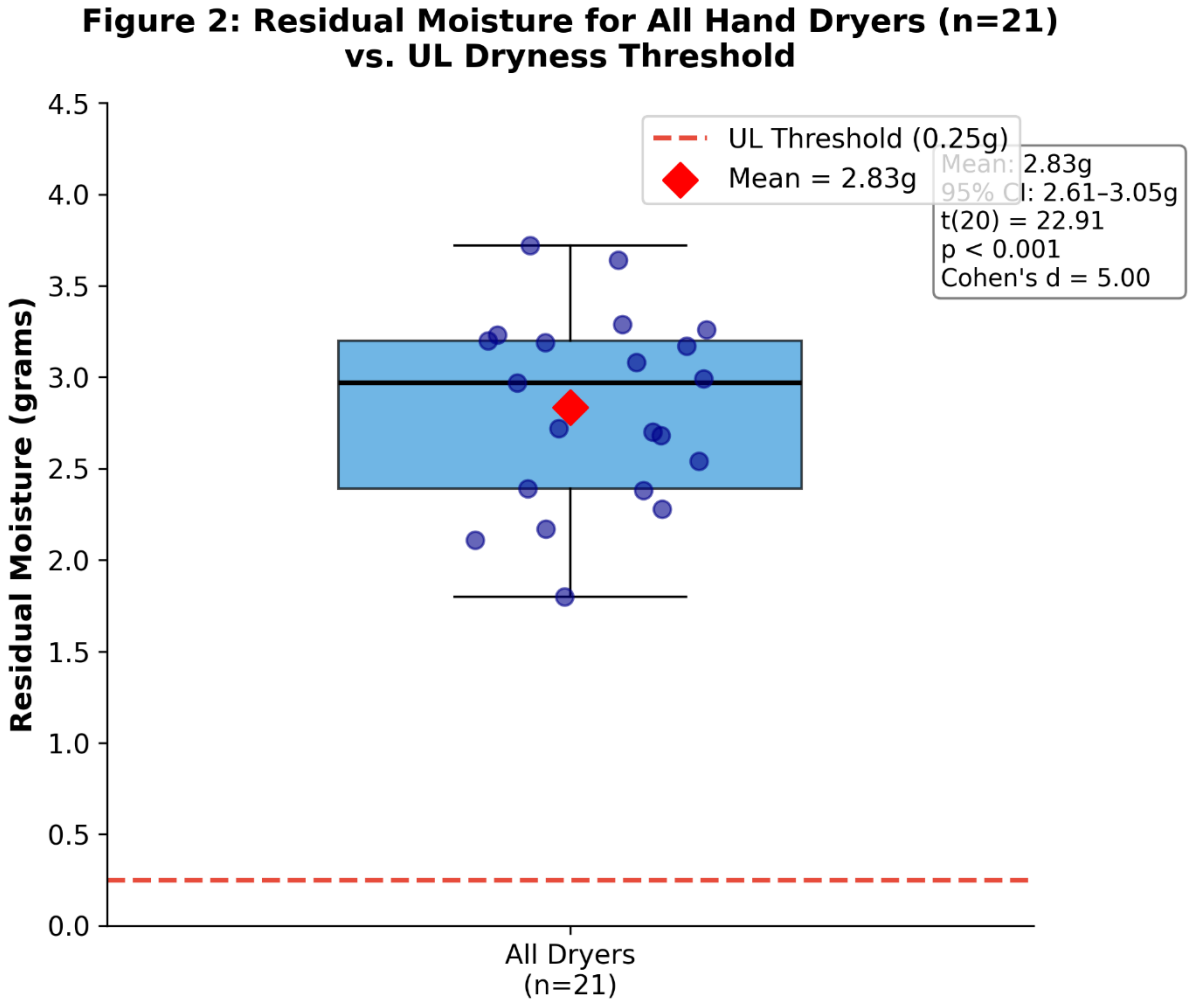


*Figure 2: Box plot of residual moisture for 21 hand dryers (n=21, mean 2.83g, range 1.80–3.72g) compared to the UL threshold (0.25g), showing significant discrepancy ($p < 0.001$, $t=22.91$).*

## Specification Compliance

The data demonstrates a clear pattern across all test locations and units:

- All 21 tested units failed to achieve the claimed residual moisture thresholds by a minimum of nearly 2 grams of water
- Residual moisture levels were consistently high across all locations
- Minimal variation was observed between different installation environments

**The specification fails 100% of the time.**

| Metric | Manufacturer Specification | Measured Reality |
|---|---|---|
| Units achieving ≤0.25g | 21 of 21 (100%) | 0 of 21 (0%) |

| Metric | Manufacturer Specification | Measured Reality |
|---|---|---|
| Units exceeding 0.25g | 0 of 21 (0%) | 21 of 21 (100%) |

# 4. Discussion

## Interpretation of Results

These findings decisively contradict manufacturer claims, with 39.2% residual moisture remaining after drying from a mean tested baseline of 7.30 grams of water for the specified drying cycle for each device (mean 2.83g, 95% CI: 2.61–3.05g), significantly exceeding manufacturers' claimed thresholds by 744%–3540% (Figures 1 and 2).

One-sample t-tests confirmed significant discrepancies for all units and brands ($t(20) = 22.91$, $p < 0.001$, Cohen's $d = 5.00$), indicating users are left with damp hands after following manufacturer-specified drying times.

The statistical analysis demonstrates that these differences are not due to chance or measurement error. The t-tests comparing our measured values to manufacturer claims yielded p-values less than 0.001 for all comparisons, indicating an extremely low probability (less than 0.1%) that these discrepancies would be observed if the manufacturer claims were accurate. The magnitude of the difference is stark: actual residual moisture levels averaged 2.83g across all units, dramatically higher than the 0.1–0.25g thresholds claimed by manufacturers.

These results directly contradict the Underwriters Laboratories testing protocol for hand dryers (ULE_HandDryer_PCR_7-13-16) [4] and the NSF P335 [19], which establish a dryness threshold of 0.25 grams and 0.1g, respectively, of residual moisture or less. Further, they contradict the manufacturers' own dryness threshold specifications. The residual moisture levels we measured, with a 95% confidence interval of 2.61–3.05g across all units, far exceed those thresholds.

While our data did show a small-to-moderate difference between the two tested brands (Cohen's $d = -0.54$), this brand difference is not statistically significant ($p = 0.230$) compared to the overwhelming evidence that all tested units substantially failed to meet their manufacturer and UL specified claims ($p < 0.001$, with an extremely large effect size). The brand comparison is interesting because of the differences between specified manufacturers' drying thresholds (0.1g, Dyson; 0.25g Xlerator) and was therefore included as an aside. The focus remains on the industry-wide pattern of overstated drying performance rather than on modest differences between brands.

**The Odd 30 Second Dryer Blow Cycle**

Hands inserted into all current and recently designed models of both manufacturers dryers trigger a 30 second blowing period before the dryer shuts off. Casually observed variations in the machines we tested showed that the cycle lasted from 30 to 35 seconds. The 30-second default cycle—2.5–3.75 times the claimed drying time—suggests manufacturers anticipate users will require additional drying beyond specifications.

## Implications for Downstream Claims

If the 8-12 second specification fails—and our data shows it fails 100% of the time by at least 744%—then every claim built on that specification is compromised:

**Energy Claims:** Manufacturers calculate energy consumption based on 8-12 seconds of operation. If actual drying requires 70-90 seconds, energy consumption per dry increases 6-10×.

**Cost Projections:** Facility cost savings assume the specified drying time. Longer actual drying times mean higher operating costs and different ROI calculations than those presented to purchasers.

**Throughput:** Restroom capacity planning assumes 8-12 seconds per user. Actual drying times reduce throughput proportionally.

**Hygiene Claims:** The ≤0.1g and ≤0.25g thresholds exist because moisture above this level significantly increases pathogen transfer. Hands at 2.83g are not hygienic by the industry's own standard.

**Environmental Comparisons:** Life cycle analyses comparing hand dryers to paper towels assume the 8-12 second specification. Those comparisons are invalid if the specification is invalid.

## Implications for Hand Hygiene

At population scale, these findings represent 150 million daily hand-drying events that fail to achieve the 0.1g and 0.25g dryness thresholds. If manufacturer claims were accurate, 100% of users would leave with dry hands. Empirical measurement shows 0% compliance—every user leaves with wet hands or pulls out before they are done. Appendix 2 quantifies this at population scale.

Residual moisture (39.2% of initial water mass, 2.83g) leaves wet hands, increasing bacterial transfer (up to 68,000 organisms vs. 140 for dry hands per Patrick et al. [1]), virus dispersal (Kimmitt and Redway [9]), and aerosol exposure (Blouch [5, 6]), Giao [16], undermining hand hygiene. Our companion studies show extended drying (45–90s) increases bacterial and fungal exposure, compounding risks from leaving with wet

hands. Jensen et al. [15] emphasize that incomplete drying negates hand washing benefits, aligning with our findings.

The substantial residual moisture remaining after manufacturer-specified drying times has potential implications for hand hygiene. The levels of residual moisture documented in our study (39.2% of initial water mass on average) suggest that hands dried according to manufacturer specifications remain wet enough to facilitate microbial transfer, particularly in light of the findings of our bacterial and fungal study (Blouch [5]). Wet hands were infused with amplified volumes of bacteria and fungus, not benignly left in their freshly washed state.

This concern is further supported by Best et al. [8], who found that inadequate drying can significantly impact the transfer of microorganisms to surfaces. That's of particular concern for food service employees and their customers who are mandated to wash hands and dry them in owner supplied dryers, Borchgrevink [17]. Best, et al. emphasized the critical role thorough hand drying plays in preventing cross-contamination in various environments. Similarly, Kimmitt and Redway [9] and Moura et al [14] demonstrated the potential for virus dispersal during hand drying, noting that inadequate drying could contribute to pathogen spread.

Jensen et al. [15] further quantified this relationship, showing that the efficacy of pathogen removal is directly related to both hand washing duration and proper drying technique. Their research demonstrated that incomplete drying can significantly undermine the benefits of thorough hand washing, a finding that directly relates to our observation of substantial residual moisture after manufacturer-recommended drying times.

## Facility Planning Considerations

The consistency of results ($p < 0.001$, $d = 5.00$) across 21 locations indicates a systematic industry issue (Figures 1 and 2). Actual drying times for dry hands are 4–11 times longer than specified (10–13s Dyson, 8s Xlerator), based on 39.2% residual moisture and observed drying times of 45–90s (Blouch [7]). Our companion paper towel study (Blouch [6]) shows paper towels dry hands in 15–20s and white paper towels tested as substantially bacteria and fungus free, offering a faster, properly hygienic alternative.

## Limitations

This study was conducted in Central Pennsylvania in a specific set of retail locations and may not represent all installation environments. Additionally, while our methodology was designed to be objective, some variability in individual hand washing and drying techniques is inevitable. However, the consistency of results across multiple locations and test subjects suggests that our findings reflect genuine performance trends rather than methodological artifacts.

## 5. Conclusion

This study provides clear empirical evidence that manufacturer and certifier-specified drying times for commercial hand dryers do not produce the claimed outcome. We tested the manufacturers' stated and certified specifications. The dryers failed.

Dyson and Xlerator hand dryers fail to meet their own specified drying times, leaving an average residual moisture of 39.2% as compared to baseline paper towel hand drying of mean 7.30g (2.83g, 95% CI: 2.61–3.05g), exceeding manufacturers' claimed thresholds by 744%–3540%. Statistical analysis confirms significant discrepancies ($t(20) = 22.91$, $p < 0.001$, $d = 5.00$), with wet hands persisting across all 21 units and all 21 trials at a minimum of 2.11g versus 0.1g claimed. The specification fails 100% of the time. It fails in spectacular fashion.

At 150 million daily US uses, this represents 150 million daily events where the certified specifications fail to produce the claimed, expected, and certified outcome. Annually, 54.75 billion hand-drying events fail to achieve claimed dryness. The downstream implications—for energy claims, cost projections, throughput calculations, and hygiene outcomes—follow necessarily from this finding. If the specification is false, everything built on it is compromised.

These findings are so substantial that the burden of proof is now placed on the manufacturers to publicly show us our error. These findings raise serious questions about the certification processes employed by NSF International, SGS International, and Underwriters Laboratories (UL). We suspect there has never been a production hand dryer in history that has remotely approached the claimed standard of less than a quarter gram of water in less than 15 seconds of drying.

All raw data supporting the findings of this study—including full weighing logs, digital scale photographs, calibration records, and video documentation of each trial—are preserved on air-gapped storage. These materials are available to regulatory bodies (CDC, OSHA, state Attorneys General), certification organizations (UL, NSF, SGS), and judicial proceedings upon formal request.

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# Appendix 1: Detailed Statistical Analysis

## Descriptive Statistics

We measured initial water mass, residual moisture, and percentage of initial moisture retained across 21 hand dryers (10 Dyson, 11 Xlerator) in 21 trials. The primary analysis compares residual moisture to the UL threshold of 0.25g, with secondary comparisons to brand-specific claims (Dyson: 0.1g, Xlerator: 0.25g). Results are in Table A1.

**Table A1: Descriptive Statistics for Hand Dryer Performance**

**Moisture Retention Metrics by Hand Dryer Type**

| Metric | All Units (n=21) | Dyson (n=10) | Xlerator (n=11) |
|---|---|---|---|
| Initial Water Mass | | | |
| Mean | 7.30g | 7.46g | 7.16g |
| SD | 0.64g | 0.61g | 0.66g |
| 95% CI | 7.03–7.57g | — | — |
| Range | 6.08–8.78g | 6.75–8.66g | 6.08–8.78g |
| Residual Moisture | | | |
| Mean | 2.83g | 2.69g | 2.97g |
| SD | 0.52g | 0.50g | 0.52g |
| 95% CI | 2.61–3.05g | 2.38–3.00g | 2.66–3.27g |
| Range | 1.80–3.72g | 1.80–3.64g | 2.11–3.72g |
| % Initial Moisture Retained | | | |
| Mean | 39.2% | 36.4% | 41.7% |
| SD | 8.8% | 8.5% | 8.7% |
| 95% CI | 35.4–43.0% | — | — |
| Range | 25.5–61.2% | 25.5–53.0% | 31.5–61.2% |

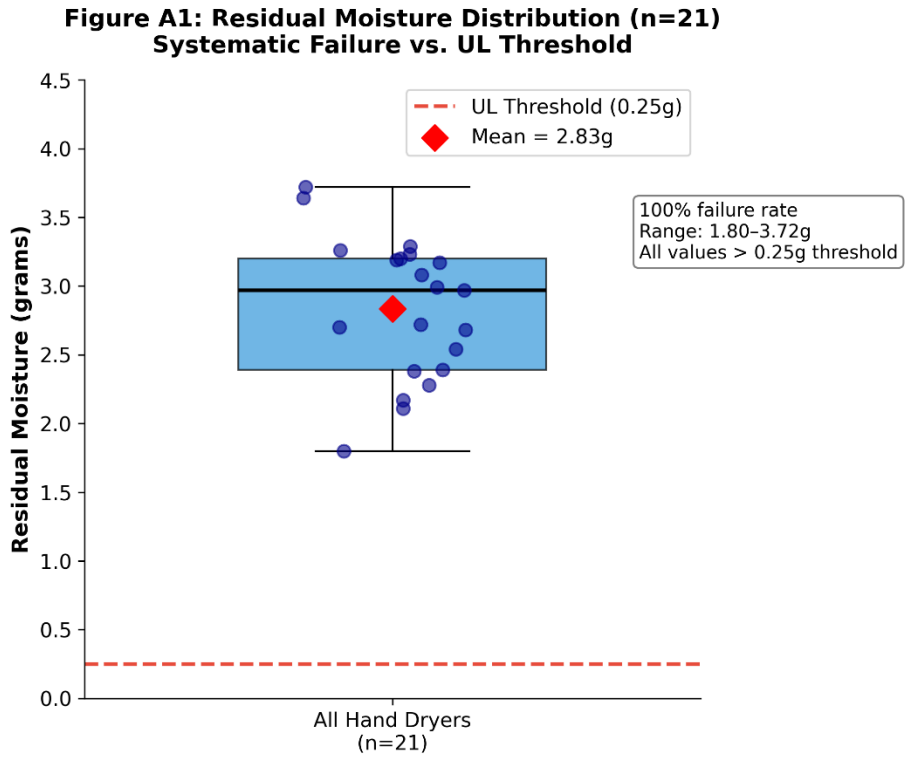


*Figure A1: Box plot of residual moisture across all hand dryers (1.80–3.72g, mean 2.83g, n=21) compared to the UL threshold (0.25g) illustrates the systematic failure of commercial dryers ($p < 0.001$, $t=22.91$).*

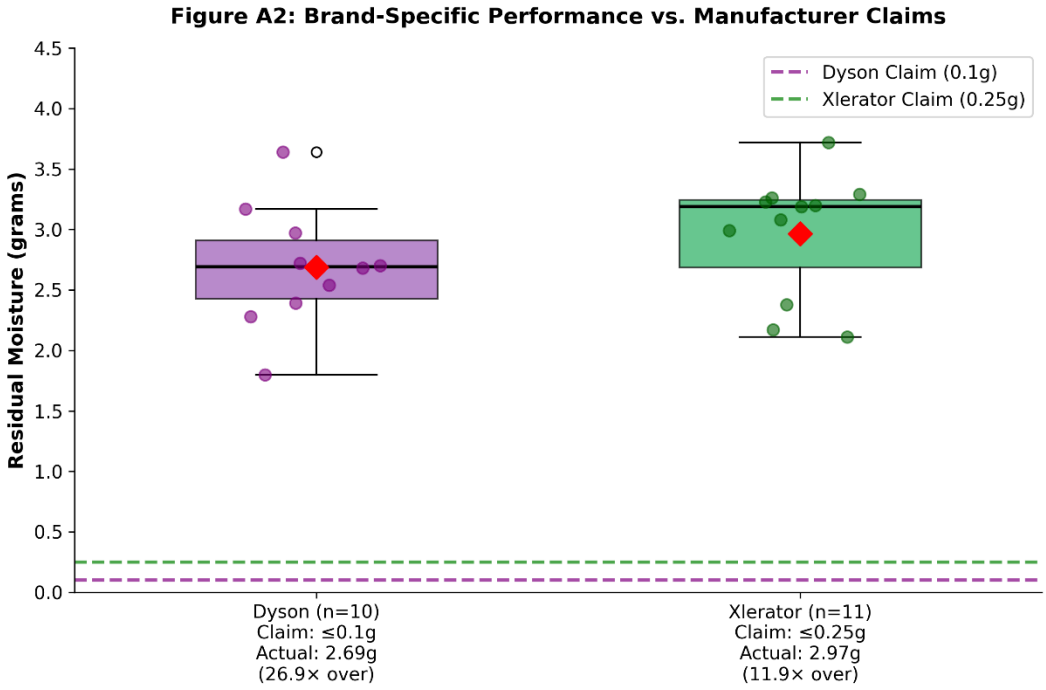


*Figure A2: Box plot comparing Dyson (1.80–3.64g, mean 2.69g, n=10) and Xlerator (2.11–3.72g, mean 2.97g, n=11) to their respective claims (0.1g, 0.25g) highlights brand-specific discrepancies ($p < 0.001$, $t=16.25$ Dyson vs 0.1g, $t=17.47$ Xlerator).*

## Inferential Statistics

One-sample t-tests compared residual moisture to the UL threshold (0.25g):

**All Units (n=21):**

- t(20) = 22.91, p < 0.001
- Mean difference: +2.58g (+~1800% vs brand claims)
- Range of individual exceedances: 744%–3540%
- Cohen's d = 5.00

**Dyson (n=10) vs. 0.1g claim:**

- t(9) = 16.25, p < 0.001
- Mean difference: +2.59g (+2589%)
- Range: 1700%–3540%

**Dyson (n=10) vs. 0.25g UL threshold:**

- t(9) = 15.31, p < 0.001
- Mean difference: +2.44g (+976%)
- Range: 620%–1356%

**Xlerator (n=11) vs. 0.25g:**

- t(10) = 17.47, p < 0.001
- Mean difference: +2.72g (+1086%)
- Range: 744%–1388%

All tests confirm residual moisture substantially exceeds claims.

## Methodological Considerations

- Measurement Reliability: 0.01g scale precision, three measurements per unit (initial, residual, final), standardized paper towel weighing, 8s (Xlerator) or 12s (Dyson) drying times per UL protocols.
- Statistical Power: n=21 yields power >0.99 for large effects (d > 0.8).
- Error Analysis: Minimal impact from hand washing or towel variability given consistent results.

## Statistical Interpretation

- Residual moisture (2.83g) exceeds manufacturers' claimed thresholds by 744%–3540%, p < 0.001
- Dyson: +976% vs. 0.25g UL threshold; +2589% vs. 0.1g manufacturer claim

- Xlerator: +1086% vs. 0.25g
- Very large effect size (d = 5.00) indicates practical significance
- 95% CI (2.61–3.05g) does not overlap with claims (0.1–0.25g)
- ~39% moisture retained suggests systematic failure impacting hygiene (bacterial transmission) and user experience

## Brand Comparison

An independent samples t-test compared residual moisture between brands:

- Dyson mean: 2.69g vs. Xlerator mean: 2.97g
- Difference: -0.28g
- t(19) = -1.24, p = 0.230
- Cohen's d = -0.54

**Conclusion:** No statistically significant difference between brands (p > 0.05). Both brands fail to meet claimed dryness thresholds by similar margins.

# Appendix 2: Appendix: U.S. Installed Base, Usage Estimates, and Population Impact

**Purpose**
This appendix quantifies the installed base of commercial hand dryers in the United States and applies empirical findings from this study series to estimate population-scale impact. The methodology uses multiple estimation approaches with cross-validation against market data.

**Section 1: Installed Base Estimation**
**Methodology**
Two independent approaches were used to estimate the U.S. installed base of commercial hand dryers, then reconciled against market data.

**Approach 1: Market Value Analysis**

| Parameter | Value | Source |
|---|---|---|
| U.S. hand dryer market (2025) | $423.11M | Mordor Intelligence, 2025 |
| Average unit cost | ~$1,000 | Industry average |
| Estimated installed units | ~1.27 million | Calculated |

**Approach 2: Sector-by-Sector Analysis**

Restroom Inventory by Sector:

| Sector | Facilities | Restrooms/Facility | Total Restrooms | Source |
|---|---|---|---|---|
| Airports | 655 | 15 | 9,825 | FAA, 2022 |
| Restaurants | 500,000 × 50% chains | 1.5 | 375,000 | NRA, 2023 |
| Office Buildings | 125,000 | 12 | 1,500,000 | IBC, 2018 |
| Schools (K-12) | 80,000 | 10 | 800,000 | NCES, 2023 |
| Universities | 4,000 | 30 | 120,000 | NCES, 2023 |
| Shopping Malls | 100,000 | 5 | 500,000 | ICSC, 2023 |
| Hospitals | 6,200 | 30 | 186,000 | AHA, 2023 |
| Total | — | — | ~3,490,000 | — |

Hand Dryer Installation by Sector:

| Sector | Restrooms | Adoption | Dryers/RR | Operating | Installed |
|---|---|---|---|---|---|
| Airports | 9,825 | 80% | 2.0 | 80% | 12,576 |
| Restaurants | 375,000 | 50% | 1.0 | 80% | 150,000 |
| Offices | 1,500,000 | 40% | 1.5 | 80% | 720,000 |
| Schools | 920,000 | 30% | 1.5 | 80% | 331,200 |
| Malls | 500,000 | 60% | 2.0 | 80% | 480,000 |
| Hospitals | 186,000 | 20% | 1.5 | 80% | 44,640 |
| Total | — | — | — | — | ~1,738,000 |

**Reconciled Estimate**

| Method | Estimate |
|---|---|
| Market value approach | ~1.27 million |
| Sector analysis approach | ~1.74 million |
| Reconciled estimate | 1.5 million (range: 1.3–1.7 million) |

**Section 2: Usage Estimates**

**Daily and Annual Usage**

| Parameter | Value | Calculation |
|---|---|---|
| Installed dryers | 1.5 million | Reconciled estimate |
| Uses per dryer per day | 100 | Industry standard |
| Operating hours | 10 hours (8 AM–6 PM) | Conservative estimate |
| Daily uses (U.S.) | 150 million | 1.5M × 100 |
| Annual uses (U.S.) | 54.75 billion | 150M × 365 |

**Simultaneous Users**

| Parameter | Value | Calculation |
|---|---|---|
| Daily uses | 150 million | — |
| Operating window | 600 minutes | 10 hours |
| Average cycle duration | 30 seconds | Observed |
| Uses per minute | 250,000 | 150M ÷ 600 |
| Simultaneous users | ~125,000 | 250,000 × 0.5 min |

At any given moment during business hours, approximately 125,000 people (range: 100,000–150,000) are using commercial hand dryers in the United States.

**Section 3: Empirical Findings Applied to Population**

**Study Results Summary**

Based on findings from this study series (n=21 trials for moisture; n=87 trials for microbial):

| Metric | Manufacturer Specification | Empirical Finding |
|---|---|---|
| Residual moisture | ≤0.1g (Dyson), ≤0.25g (Xlerator) | 2.83g (95% CI: 2.61–3.05g) |
| Excess over specification | — | 744%–3540% |
| Compliance rate | 100% | 0% |
| Microbial amplification | Filtered/clean air | 49.6× ambient (median 67 CFU) |
| Water dispersal range | Contained | Up to 1.0m observed |

**Daily Population Impact**

| Metric | If Specification Accurate | Measured Reality |
|---|---|---|
| Residual moisture per use | ≤0.25g | 2.83g |
| Total residual moisture | ≤37.5 metric tons | 424.5 metric tons |
| Excess moisture | — | 387 metric tons |

| Metric | If Specification Accurate | Measured Reality |
|---|---|---|
| Users achieving "dry" (≤0.25g) | 150 million (100%) | 0 (0%) |
| Users with wet hands | 0 (0%) | 150 million (100%) |
| High pathogen-transfer events* | 0 | 150 million |

**Per Patrick et al. [1]: wet hands transfer up to 500× more bacteria than dry hands*

**Annual Population Impact**

| Metric | If Specification Accurate | Measured Reality |
|---|---|---|
| Residual moisture per use | ≤0.25g | 2.83g |
| Total residual moisture | ≤13,688 metric tons | 154,943 metric tons |
| Excess moisture | — | 141,255 metric tons |
| Users achieving "dry" | 54.75 billion (100%) | 0 (0%) |
| High pathogen-transfer events | 0 | 54.75 billion |

**Section 4: Drying Efficiency Analysis**

**Moisture Removal Performance**

| Metric | Manufacturer Specification | Empirical Finding |
|---|---|---|
| Starting water on hands | ~7g | 7.30g (measured) |
| Residual after specified time | ≤0.25g | 2.83g |
| Water removed | 96.3% | 61.2% |
| Water remaining | 3.7% | 38.8% |
| Time to specification | 8–12 seconds | 70–90 seconds (observed) |

**The Cascade Effect**

If the 8–12 second specification fails, every downstream claim is affected:

| Claim Category | Based On | If Specification Fails |
|---|---|---|
| Energy per dry | 8–12 sec operation | 6–10× higher |
| Cost per dry | 8–12 sec operation | 6–10× higher |
| User throughput | 8–12 sec/user | 6–10× lower |
| Hygiene outcome | ≤0.25g achieved | Not achieved |
| Environmental comparison | 8–12 sec assumptions | Invalid basis |

**Section 5: Pathogen Transfer Implications**

**Established Science**

Patrick et al. [1] demonstrated the relationship between hand moisture and bacterial transfer:

• Wet hands: up to 68,000 organisms transferred

• Dry hands: as few as 140 organisms transferred

• Differential: ~500× increase in pathogen transfer from wet hands

The 0.25g threshold was established by Underwriters Laboratories (ULE_HandDryer_PCR_7-13-16) precisely because moisture levels above this significantly increase pathogen transfer risk.

**Specification Compliance at Population Scale**

| Metric | Manufacturer Specification | Empirical Finding |
|---|---|---|
| Users achieving ≤0.25g (dry) | 100% | 0% |
| Users exceeding 0.25g (wet) | 0% | 100% |

In all trials across this study series, zero users achieved the UL dryness threshold after manufacturer-specified drying times.

**The Impossible Choice**

Combined with microbial amplification findings (Blouch [1]), users face an impossible choice:

**Option A: Follow manufacturer specifications (8–12 seconds)**

• Hands remain wet (2.83g vs. 0.25g threshold)

• Pathogen transfer risk increased up to 500×

• User believes hands are dry

**Option B: Continue until hands are actually dry (70–90 seconds)**

• Extended exposure to amplified microbial load (67 CFU median, 49.6× ambient)

• Additional 58–78 seconds of contaminated airflow exposure

• Actual drying achieved at significant microbial cost

**Neither option delivers the hygienic outcome users expect and manufacturers claim.**

**Section 6: Conservative Nature of Estimates**

These projections are conservative:

• Testing used manufacturer-specified optimal drying times (8–12 seconds)

• Real-world users often terminate drying earlier

• Environmental factors (humidity, temperature) may increase residual moisture

• Usage estimates based on standard business hours; 24-hour facilities would increase totals

• Adoption rates are estimates; actual installation may be higher in some sectors

• Operating rate (80%) may underestimate functional units

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# Appendix 3: Complete Dataset — Residual Moisture Measurements

**Table A3-1: Individual Trial Results with Brand-Specific Water Multipliers**

**N** = 21 trials | **Locations** = 9 | **Testing Dates**: March 6–7, 2025

## Summary Statistics

**Dyson** (n=10, claimed threshold: 0.1g)

- Residual moisture: 2.69g (range: 1.80–3.64g)
- Water multiplier: 26.9× (range: 18.0×–36.4×)

**Xlerator** (n=11, claimed threshold: 0.25g)

- Residual moisture: 2.97g (range: 2.11–3.72g)
- Water multiplier: 11.9× (range: 8.4×–14.9×)

**Overall** (n=21)

- Water multiplier: 19.0× (range: 8.4×–36.4×)
- 95% CI: 15.4×–22.7×

## Complete Data

| # | Brand | Location | Dry Time (s) | Initial Water (g) | Residual (g) | Threshold (g) | % Remaining | Multiplier |
|---|---|---|---|---|---|---|---|---|
| 1 | Dyson | Starbucks | 12.0 | 6.90 | 3.64 | 0.10 | 53.0% | 36.4× |
| 2 | Dyson | Crunch Fitness 2 | 12.0 | 7.20 | 3.17 | 0.10 | 44.3% | 31.7× |
| 3 | Dyson | Starbucks | 12.0 | 7.20 | 2.97 | 0.10 | 41.3% | 29.7× |
| 4 | Dyson | Crunch Fitness 1 | 12.0 | 7.20 | 2.72 | 0.10 | 37.8% | 27.2× |
| 5 | Dyson | Crunch Fitness 2 | 12.0 | 7.90 | 2.70 | 0.10 | 34.2% | 27.0× |
| 6 | Dyson | Starbucks | 12.9 | 6.80 | 2.68 | 0.10 | 39.7% | 26.8× |
| 7 | Dyson | Starbucks | 8.2 | 8.70 | 2.54 | 0.10 | 29.3% | 25.4× |
| 8 | Dyson | Crunch Fitness 1 | 12.1 | 7.90 | 2.39 | 0.10 | 30.3% | 23.9× |
| 9 | Dyson | Starbucks | 13.0 | 7.90 | 2.28 | 0.10 | 28.8% | 22.8× |
| 10 | Dyson | Starbucks | 12.0 | 7.10 | 1.80 | 0.10 | 25.5% | 18.0× |
| 11 | Xlerator | Giant | 8.0 | 6.10 | 3.72 | 0.25 | 61.2% | 14.9× |

| # | Brand | Location | Dry Time (s) | Initial Water (g) | Residual (g) | Threshold (g) | % Remaining | Multiplier |
|---|---|---|---|---|---|---|---|---|
| 12 | Xlerator | 7-Eleven* | 12.0 | 7.30 | 3.29 | 0.25 | 45.4% | 13.2× |
| 13 | Xlerator | Home Depot | 8.5 | 7.00 | 3.26 | 0.25 | 46.4% | 13.0× |
| 14 | Xlerator | Giant | 8.0 | 7.30 | 3.23 | 0.25 | 44.3% | 12.9× |
| 15 | Xlerator | REI | 8.0 | 8.80 | 3.20 | 0.25 | 36.4% | 12.8× |
| 16 | Xlerator | Starbucks | 8.0 | 7.00 | 3.19 | 0.25 | 45.4% | 12.8× |
| 17 | Xlerator | Target | 8.0 | 7.20 | 3.08 | 0.25 | 42.5% | 12.3× |
| 18 | Xlerator | Chipotle | 8.0 | 7.10 | 2.99 | 0.25 | 42.1% | 12.0× |
| 19 | Xlerator | Starbucks | 8.0 | 7.50 | 2.38 | 0.25 | 31.9% | 9.5× |
| 20 | Xlerator | Starbucks | 8.0 | 6.80 | 2.17 | 0.25 | 31.9% | 8.7× |
| 21 | Xlerator | Home Depot | 8.0 | 6.70 | 2.11 | 0.25 | 31.5% | 8.4× |

## Notes

1. *Row 12 (7-Eleven, 147 Gettysburg Pike): Dry time recorded as 12s due to field timing variance; data reported as measured

2. **Water Multiplier** = Residual Moisture ÷ Claimed Threshold

3. Dyson claims ≤0.1g residual moisture after 10–12 seconds

4. Xlerator claims ≤0.25g residual moisture after 8 seconds

5. All measurements taken in active public restrooms

6. Testing protocol aligned with UL PCR Hand Dryer methodology (ULE_HandDryer_PCR_7-13-16)

## Calculation Methodology

The water multiplier quantifies how many times actual residual moisture exceeds the manufacturer's claimed threshold:

*Water Multiplier = Measured Residual Moisture (g) ÷ Manufacturer Claimed Threshold (g)*

For Dyson (threshold = 0.1g): A measurement of 2.69g yields a multiplier of 26.9×

For Xlerator (threshold = 0.25g): A measurement of 2.97g yields a multiplier of 11.9×

This approach compares each brand to its own published specification rather than applying a single threshold across all brands.

## APPENDIX 4: Brand-Specific Performance Data

**Dyson Units (10–13 seconds specified drying time):**

- Average residual moisture: 2.69g (±0.50g, 95% CI: 2.38–3.00g)
- Percentage of initial water mass: 36.4% (±8.5%)
- Range: 1.80–3.64g (25.5–53.0%)

Dyson (n=10) averaged 2.69g, 2589% above the 0.1g claim ($t(9) = 16.25$, $p < 0.001$, range: 1700%–3540%).

**Xlerator Units (8 seconds specified drying time):**

- Average residual moisture: 2.97g (±0.52g, 95% CI: 2.66–3.27g)
- Percentage of initial water mass: 41.7% (±8.7%)
- Range: 2.11–3.72g (31.5–61.2%)

Xlerator (n=11) averaged 2.97g, 1086% above the 0.25g claim ($t(10) = 17.47$, $p < 0.001$, range: 744%–1388%).

**Analysis:**

The differences between dryer brands are not statistically significant in context with the study hypothesis ($t(20) = 22.91$, $p < 0.001$, with an extremely large effect size). Because each manufacturer claims a different standard of dryness the data become interesting. Xlerator units left slightly more residual moisture than Dyson units with a dry time four seconds shorter ($t(19) = -1.24$, $p = 0.230$, Cohen's $d = -0.54$). Figure 3 compares brands to their claims.

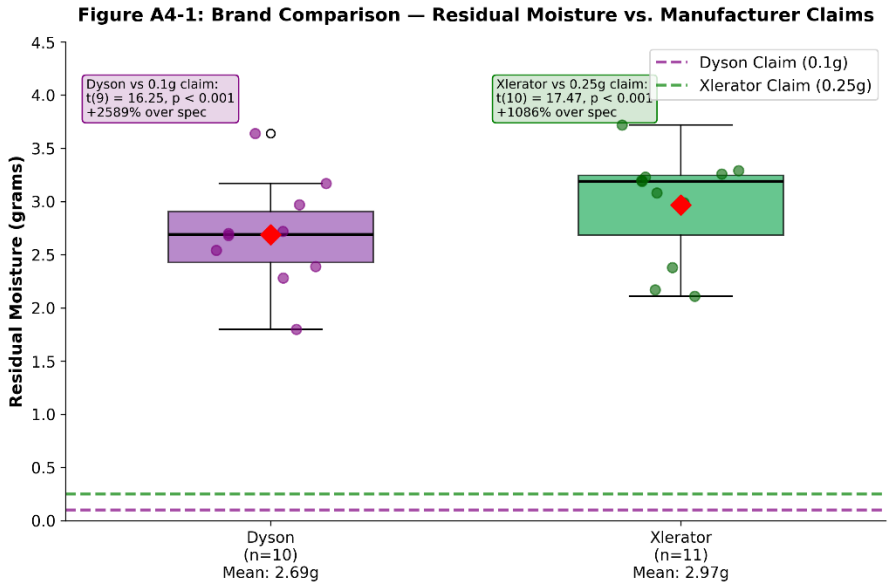


*Figure A3: Box plot comparing residual moisture for Dyson (n=10, mean 2.69g, range 1.80–3.64g) and Xlerator (n=11, mean 2.97g, range 2.11–3.72g) to their claims (0.1g, 0.25g), showing significant discrepancies ($p < 0.001$, $t=16.25$ Dyson vs 0.1g, $t=17.47$ Xlerator vs 0.25g).*