United States Department of the Interior
National Park Service
National Center for Preservation Technology and Training
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Study on the Durability of Traditional and Modified Limewash Recipes

Results Weathered Wood and Rough-sawn New Wood

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Executive Summary
Results from limewash study of wood samples
August 30, 2005

Introduction

This report is an executive summary of testing undertaken by NCPTT in partnership with the Cane River Creole National Historical Park (CARI) and Quality Finish.

In December 2003 meetings were held to discuss applying limewash to the brick cabins at Magnolia Plantation in hopes of prolonging the life of the structures. We developed a study to determine the durability of traditional and modified limewash recipes within certain criteria. We wanted to identify a low cost limewash that would last for five years when applied in approximately three coats As the project progressed we decided to test limewash on wood, since CARI expressed interest in applying limewash to wood structures at Oakland plantation. Epoxy filler is being used at CARI to help stabilize historic wood structures, leading us to add epoxy fillers as a third material of study. In collaboration with its partners, NCPTT designed a program of testing for limewash on brick, wood, and epoxy.

Quality Finish researched possible limewash recipes that may have been used locally by interviewing community members. They were not able to identify recipes used in the community and thus turned to published limewash recipes, including a limewash identified through NPS contracting schedules. We worked together to prepare wood and brick test samples. Starting in November 2004, Quality Finish applied nine separate washes on weathered wood and rough-sawn new wood. On all wood samples, an Edison acrylic emulsion was used as a primer since the limewash alone would not bind to the wood. The same nine recipes plus an additional wash containing lime putty and water were applied to handmade and modern bricks. Table 1 contains information about the limewashes tested. Sarah Jackson, a student intern at NCPTT, manufactured epoxy samples for testing. The limewash recipes that perform the best on wood samples will be applied to epoxy samples and run through the same tests.

As of August 2005, NCPTT has completed scheduled testing on the wood samples. We expect results on limewash on brick samples by mid-October 2005. This report will focus on the results of durability testing of limewash recipes on wood.

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	Graymont, "Ivory" hydrated lime	Graymont, Niagara lime putty	Virginia Limeworks lime putty
Class C, Molasses, Alum, Salt, Lime, Water	Wash A	Wash B	Wash C
Lime, Molasses, Casein, Clove Oil,	Wash D	Wash E	Wash F
Lime, Water, Acrylic Binder	Wash G	Wash H	Wash I

Table 1. A Matrix showing the in ingredients in each limewash tested.

Testing methods

We tested limewashed wood samples using artificial weathering, adhesion, and abrasion testing according to ASTM standard methods of testing. We photographed samples before and after each test and monitored them for color change with a Minolta colorimeter. To perform artificial weathering, we placed the samples in a QUV weatherometer and subjected them to four hours of UV light exposure and four hours of condensation in the dark continuously alternating for 800 hours. This accelerated weathering gives us an idea of how the limewash may age over time. For the adhesion test, we cut an "X" through the limewash to the sample, then placed pressure sensitive tape over the cut. Upon removal of the tape, we assessed how much limewash was removed. This test evaluates how firmly the limewash bonds to the samples. In the abrasion test, we placed samples in a holder and poured measured amounts of falling sand on to the surface to determine how much sand is needed to remove a 4 mm (.1575 inch) diameter circular area of limewash. The abrasion test allows us to rank how a limewash will stand up to abrasion from wind- and rain-borne particles and from people touching the buildings. With the help of Quality Finish, we also performed a solids test to determine how much limewash is being applied to the samples.

Test results

We evaluated limewashed wood samples before and after artificial weathering using visual appearance, abrasion testing and adhesion testing. We represent test results as an average of the results from the individual samples for each wash. We prepared three replicates for each wash. Individual results for each sample are recorded in the appendix that is included with the report. All limewash on wood performed average at best and completely failed at worst.

For unweathered samples, washes E, H, and F performed the best in adhesion testing. This means that washes E, H, and F bound most tightly to the wood prior to weathering. Upon abrasion testing, unweathered samples of washes B, A, and G performed the best. This means that they formed a harder coating that was more cohesive.

The performance of artificially weathered limewashes was similar to unweathered samples with some slight variations. After artificial weathering, we visually evaluated each wash and found that washes D, E, and I outperformed the other limewashes. Also, we found that washes E, G, and F were better performers in the adhesion tests. When we performed abrasion tests on the weathered limewashed samples, we found washes B, G, and D were slightly better than other washes.

We devised a ranking system in order to evaluate the results of each test. Based on their performance, we ranked each limewash from best to worst for change in appearance, adhesion, and abrasion for samples both before and after weathering. This was a relative ranking from best to worst. Those with the best performance ranked a 9 and those with the worst performance ranked a 1. Then we totaled the rankings for each wash.

Based on our ranking system, we found that overall limewash recipe E performed the best out of the recipes we tested on the wood samples. Wash E is made from Graymont's Niagara lime putty, water, casein binder, molasses, and clove oil. Wash E had a better appearance upon artificial weathering, and performed well in the adhesion tests both before and after weathering. Wash E only performed in the middle of the group, not being either the best or the worst, in abrasion tests both before and after weathering. We should note that Wash E had one sample that performed unusually better than other wash E samples in the abrasion test and was omitted as an outlier.

We found the second best performer was wash G which is made from Graymont's "Ivory" hydrated lime, water, and acrylic binder. Wash G performed well in three of the tests -- in abrasion testing both before and after weathering and in the adhesion test after weathering. However, it should be noted that wash G produced a powdery surface which lacked cohesiveness. It performed poorly when judged by appearance after artificial weathering and in adhesion testing before weathering.

We found the third best performer was Wash D which is made from Graymont's "Ivory" hydrated lime, water, casein binder, molasses, and clove oil. For the artificial weathering it performed on par with Wash E and for the other tests it was in the middle of the group.

Recommendations based on results

Based on current analysis of the results, we can state that none of the limewashes tested were highly durable. Most washes tested display average to marginal performance when applied to wood based on our laboratory testing. Of the recipes tested, wash E was the best performer and is our recommendation for use at the Cane River Creole National Historical Park. It performed well in most tests and maintained good appearance upon artificial weathering.

Alternative limewashes include wash G and wash D. While wash G, which includes an acrylic binder, was the second best performer, we feel that the recipe is not a true limewash but rather a weak paint. The powdery nature of the surface observed upon weathering is likely the result of the acrylic medium encapsulating the lime particles and hindering the ability of the lime to fully carbonate. Wash D holds a good appearance but is an average performer in adhesion and abrasion testing.

We note that all samples were subjected to color analysis before and after artificial aging. All limewashes display some color change over time and tend to darken and yellow. Since all washes changed approximately the same, we did not include these tests in our recommendations.

Limewash Experiment: Weathered and Rough-Sawn New Wood

Limewash Recipes

	Lime	Part A	Part B	Mix
Wash A	Graymont Ivory hydrated lime	1lb. Table salt, .5 oz alum, 1/3 cup unsulphured molasses, 1/12 tsp laundry bluing. Mix in 2 1/2 cups hot water.	4 1/4 cups hydrated lime mixed with 4 1/2 cups hot water let stand 12 hours	Mix parts A & B in equal parts. Viscosity 17 seconds at 70 degrees in #4 Ford cup.
Wash B	Graymont Niagara lime putty	1lb. Table salt, .5 oz alum, 1/3 cup unsulphured molasses, 1/12 tsp laundry bluing. Mix in 3 cups hot water.	Mix 8 1/2 cups Niagara putty with 4 cups hot water. Let stand 12 hours.	Mix parts A & B in equal parts. Viscosity 17 seconds at 70 degrees in #4 Ford cup.
Wash C	Virginia Limeworks lime putty	1lb. Table salt, .5 oz alum, 1/3 cup unsulphured molasses, 1/12 tsp laundry bluing. Mix in 2 1/2 cups hot water.	Mix 8 1/2 cups Virginia Limeworks with 4.75 cups hot water.	Mix parts A & B in equal parts. Viscosity 17 seconds at 70 degrees in #4 Ford cup.
Wash D	Graymont Ivory hydrated lime.	1/3 cup unsulphered molasses, 1/12 tsp laundry bluing, 1/4 tsp clove oil. Mix with 1.5 cups hot water.	4 1/4 cups hydrated lime mixed with 2 1/2 cups hot water. Let stand 12 hours.	Mix together A & B. Viscosity same as A. Add 4 tsp. Schmincke Casein Binding Medium per 1 cup limewash.
Wash E	Graymont Niagara lime putty	1/3 cup unsulphered molasses, 1/12 tsp laundry bluing, 1/4 tsp clove oil. Mix with 2 1/2 cups hot water.	8 1/2 cups putty with 2 1/4 cups hot water. Let stand 12 hours.	Mix together A & B. Viscosity same as A. Add 4 tsp. Schmincke Casein Binding Medium per 1 cup limewash.
Wash F	Virginia Limeworks lime putty	1/3 cup unsulphered molasses, 1/12 tsp laundry bluing, 1/4 tsp clove oil. Mix with 1 1/2 cups hot water.	8 1/2 cups Virginia Limeworks putty mixed with 2 1/4 cups hot water. Let stand 12 hours.	Mix together A & B. Viscosity same as A. Add 4 tsp. Schmincke Casein Binding Medium per 1 cup limewash.
Wash G	Graymont Ivory hydrated lime	4 1/4 cups hydrated lime mixed with 7 1/2 cups hot water. Let stand 12 hours.		Check viscosity 17 seconds at 70 degrees. For each 1 cup of limewash, add 2 tablespoons of Edison.
Wash H	Graymont Niagara lime putty	8 1/2 cups Niagara lime putty mixed with 5 cups hot water. Let stand 12 hours.		Check viscosity 17 seconds at 70 degrees. For each 1 cup of limewash, add 2 tablespoons of Edison.
Wash I	Virginia Limeworks lime putty	8 1/2 cups Virginia lime putty with 5 cups hot water. Let stand 12 hours.		Check viscosity 17 seconds at 70 degrees. For each 1 cup of limewash, add 2 tablespoons of Edison.
Wash K	Virginia Limeworks lime putty	8 1/2 cups Virginia lime putty with 5 cups hot water. Let stand 12 hours		Check viscosity 17 seconds at 70 degrees in #4 Ford cup.

Applied to handmade brick, modern brick, weathered wood, and rough-sawn new wood with primer.

Applied to handmade and modern brick with primer.

Prepared by
Sarah Jackson

Recipes Provided by
Quality Finish

10/20/2005

Limewash Experiment: Weathered Wood and Rough-sawn New Wood

Graymont, "Ivory" hydrated lime

Wash A (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
W-001-A	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-002-A	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-003-A	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-004-A	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-005-A	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-006-A	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-007-A	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-008-A	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-009-A	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-010-A	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-011-A	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-012-A	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-013-A	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-014-A	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-015-A	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-016-A	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash B (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
W-017-B	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-018-B	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-019-B	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-020-B	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-021-B	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-022-B	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-023-B	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-024-B	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-025-B	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-026-B	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-027-B	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-028-B	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-029-B	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-030-B	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-031-B	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-032-B	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash C (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
W-033-C	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no
W-034-C	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-035-C	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-036-C	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-037-C	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-038-C	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-039-C	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-040-C	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-041-C	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-042-C	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-043-C	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-044-C	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-045-C	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-046-C	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-047-C	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-048-C	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no

No. of samples this page = 48
No. of brick samples total = 150

Limewash Experiment: Weathered Wood and Rough-sawn New Wood

Graymont, "Ivory" hydrated lime

Wash D (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
W-049-D	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-050-D	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-051-D	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-052-D	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-053-D	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-054-D	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-055-D	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-056-D	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-057-D	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-058-D	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-059-D	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-060-D	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-061-D	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-062-D	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-063-D	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-064-D	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash E (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
W-065-E	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-066-E	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-067-E	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-068-E	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-069-E	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no
W-070-E	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-071-E	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-072-E	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-073-E	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-074-E	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-075-E	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-076-E	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-077-E	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-078-E	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-079-E	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-080-E	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes

Virginia Limeworks lime putty

Wash F (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
W-081-F	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-082-F	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-083-F	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-084-F	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-085-F	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-086-F	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-087-F	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-088-F	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-089-F	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-090-F	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-091-F	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-092-F	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-093-F	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-094-F	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-095-F	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-096-F	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 150

Limewash Experiment: Weathered Wood and Rough-sawn New Wood

Graymont, "Ivory" hydrated lime

Wash G (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
W-097-G	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-098-G	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-099-G	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-100-G	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-101-G	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-102-G	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-103-G	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-104-G	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-105-G	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-106-G	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-107-G	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-108-G	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-109-G	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-110-G	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-111-G	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-112-G	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash H (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
W-113-H	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-114-H	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-115-H	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-116-H	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-117-H	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-118-H	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-119-H	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-120-H	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-121-H	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-122-H	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-123-H	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-124-H	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-125-H	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-126-H	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-127-H	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-128-H	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash I (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
W-129-I	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-130-I	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-131-I	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-132-I	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-133-I	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-134-I	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-135-I	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-136-I	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-137-I	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-138-I	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-139-I	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
W-140-I	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
W-141-I	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
W-142-I	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
W-143-I	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
W-144-I	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 150

Limewash Experiment: Weathered Wood and Rough-sawn New Wood

Controls

						Wash J													
#	Wash	Photo	Color	Mass	QUV	Mass	Photo	Color											
W-145-J	no	yes	yes	yes	yes	yes	yes	yes											
W-146-J	no	yes	yes	yes	yes	yes	yes	yes											
W-147-J	no	yes	yes	yes	yes	yes	yes	yes											
W-148-J	no	yes	yes	yes	no	no	no	no											
W-149-J	no	yes	yes	yes	no	no	no	no											
W-150-J	no	yes	yes	yes	no	no	no	no											

Testing

QUV-Artificial Weathering

Adhesion by Tape Test

Abrasion by Falling Sand

Artificial Weathering: QUV

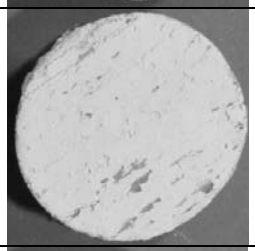
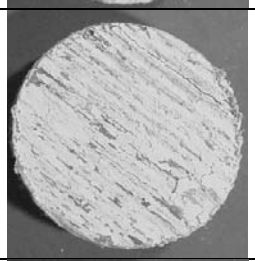
Artificial weathering was selected as one of the steps in the study to decrease the amount of time required to age the samples while imparting changes due to weathering.

Weathering Cycle

The weathering cycle selected for the study is 4 hours of UV light exposure at 60℃ (˜120℉), followed by 4 hours of condensation in the dark at 50℃ (˜140 ℉). This cycle will be repeated for a period of 800 hours. Calibrating the irradiance and temperature of the QUV prior to performing the experiment is important to ensure accurate and repeatable test results.

Prepared by
Sarah Jackson

Limewash Experiment: QUV Rating

5A	No peeling or removal		
4A	Trace peeling or removal		
3A	Jagged removal up to 1/16 inch		
2A	Jagged removal up to 1/8 inch		
1A	Removal from most of the area		
0A	Removal from most of the sample		

Prepared by
Sarah Jackson

Designation: D 3359 – 95

Standard Test Methods for Measuring Adhesion by Tape Test[1]

This standard is issued under the fixed designation D 3359; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

These methods have been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 These test methods cover procedures for assessing the adhesion of coating films to metallic substrates by applying and removing pressure-sensitive tape over cuts made in the film.

1.2 Test Method A is primarily intended for use at job sites while Test Method B is more suitable for use in the laboratory. Also, Test Method B is not considered suitable for films thicker than 5 mils (125 μm).

NOTE 1—Subject to agreement between the purchaser and the seller, Test Method B can be used for thicker films if wider spaced cuts are employed.

1.3 These test methods are used to establish whether the adhesion of a coating to a substrate is at a generally adequate level. They do not distinguish between higher levels of adhesion for which more sophisticated methods of measurement are required.

NOTE 2—It should be recognized that differences in adherability of the coating surface can affect the results obtained with coatings having the same inherent adhesion.

1.4 In multicoat systems adhesion failure may occur between coats so that the adhesion of the coating system to the substrate is not determined.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 609 Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products[2]

D 823 Practice for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels[2]

D 1000 Test Methods For Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications[3]

D 1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting[4]

D 2092 Practices for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting[5]

D 2197 Test Methods for Adhesion of Organic Coatings by Scrape Adhesion[2]

D 2370 Test Method for Tensile Properties of Organic Coatings[2]

D 3330 Test Method for Peel Adhesion of Pressure-Sensitive Tape of 180° Angle[6]

D 3924 Specification for Standard Environment for Conditioning and Tesing Paint, Varnish, Lacquers, and Related Materials[2]

D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser[2]

3. Summary of Test Methods

3.1 *Test Method A*—An X-cut is made in the film to the substrate, pressure-sensitive tape is applied over the cut and then removed, and adhesion is assessed qualitatively on the 0 to 5 scale.

3.2 *Test Method B*—A lattice pattern with either six or eleven cuts in each direction is made in the film to the substrate, pressure-sensitive tape is applied over the lattice and then removed, and adhesion is evaluated by comparison with descriptions and illustrations.

4. Significance and Use

4.1 If a coating is to fulfill its function of protecting or decorating a substrate, it must adhere to it for the expected service life. Because the substrate and its surface preparation (or lack of it) has a drastic effect on the adhesion of coatings, a method of evaluation adhesion of a coating to different substrates or surface treatments, or of different coatings to the same substrate and treatment, is of considerable usefulness in the industry.

4.2 The limitations of all adhesion methods and the specific limitation of this test method to lower levels of adhesion (see 1.3) should be recognized before using it. The intra- and inter-laboratory precision of this test method is similar to other widely-accepted tests for coated substrates (for example, Test Method D 2370 and Test Method D 4060), but this is partly the result of it being insensitive to all but large differences in adhesion. The limited scale of 0 to 5 was selected deliberately to avoid a false impression of being sensitive.

[1] These test methods are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and are the direct responsibility of Subcommittee D01.23 on Physical Properties of Applied Paint Films.

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[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 10.01.

[4] *Annual Book of ASTM Standards*, Vol 02.05.

[5] *Annual Book of ASTM Standards*, Vol 06.02.

[6] *Annual Book of ASTM Standards*, Vol 15.09.

TEST METHOD A—X-CUT TAPE TEST

5. Apparatus and Materials

5.1 *Cutting Tool*—Sharp razor blade, scalpel, knife or other cutting devices. It is of particular importance that the cutting edges be in good condition.

5.2 *Cutting Guide*—Steel or other hard metal straightedge to ensure straight cuts.

5.3 *Tape*—One-inch (25-mm) wide semitransparent pressure-sensitive tape with an adhesion strength agreed upon by the supplier and the user is needed[7]. Because of the variability in adhesion strength from batch-to-batch and with time, it is essential that tape from the same batch be used when tests are to be run in different laboratories. If this is not possible the test method should be used only for ranking a series of test coatings.

5.4 *Rubber Eraser*, on the end of a pencil.

5.5 *Illumination*—A light source is helpful in determining whether the cuts have been made through the film to the substrate.

6. Test Specimens

6.1 When this test method is used in the field, the specimen is the coated structure or article on which the adhesion is to be evaluated.

6.2 For laboratory use apply the materials to be tested to panels of the composition and surface conditions on which it is desired to determine the adhesion.

NOTE 3—Applicable test panel description and surface preparation methods are given in Practice D 609 and Practices D 1730 and D 2092.

NOTE 4—Coatings should be applied in accordance with Practice D 823, or as agreed upon between the purchaser and the seller.

NOTE 5—If desired or specified, the coated test panels may be subjected to a preliminary exposure such as water immersion, salt spray, or high humidity before conducting the tape test. The conditions and time of exposure will be governed by ultimate coating use or shall be agreed upon between the purchaser and seller.

7. Procedure

7.1 Select an area free of blemishes and minor surface imperfections. For tests in the field, ensure that the surface is clean and dry. Extremes in temperature or relative humidity may affect the adhesion of the tape or the coating.

7.2 Make two cuts in the film each about 1.5 in. (40 mm) long that intersect near their middle with a smaller angle of between 30 and 45°. When making the incisions, use the straightedge and cut through the coating to the substrate in one steady motion.

7.3 Inspect the incisions for reflection of light from the metal substrate to establish that the coating film has been penetrated. If the substrate has not been reached make another X in a different location. Do not attempt to deepen a previous cut as this may affect adhesion along the incision.

7.4 Remove two complete laps of the pressure-sensitive tape from the roll and discard. Remove an additional length at a steady (that is, not jerked) rate and cut a piece about 3 in. (75 mm) long.

7.5 Place the center of the tape at the intersection of the cuts with the tape running in the same direction as the smaller angles. Smooth the tape into place by finger in the area of the incisions and then rub firmly with the eraser on the end of a pencil. The color under the transparent tape is a useful indication of when good contact has been made.

7.6 Within 90 ± 30 s of application, remove the tape by seizing the free end and pulling it off rapidly (not jerked) back upon itself at as close to an angle of 180° as possible.

7.7 Inspect the X-cut area for removal of coating from the substrate or previous coating and rate the adhesion in accordance with the following scale:

5A	No peeling or removal,
4A	Trace peeling or removal along incisions or at their intersection,
3A	Jagged removal along incisions up to 1/16 in. (1.6 mm) on either side,
2A	Jagged removal along most of incisions up to 1/8 in. (3.2 mm) on either side,
1A	Removal from most of the area of the X under the tape, and
0A	Removal beyond the area of the X.

7.8 Repeat the test in two other locations on each test panel. For large structures make sufficient tests to ensure that the adhesion evaluation is representative of the whole surface.

7.9 After making several cuts examine the cutting edge and, if necessary, remove any flat spots or wire-edge by abrading lightly on a fine oil stone before using again. Discard cutting tools that develop nicks or other defects that tear the film.

8. Report

8.1 Report the number of tests, their mean and range, and for coating systems, where the failure occurred that is, between first coat and substrate, between first and second coat, etc.

8.2 For field tests report the structure or article tested, the location and the environmental conditions at the time of testing.

8.3 For test panels report the substrate employed, the type of coating, the method of cure, and the environmental conditions at the time of testing.

8.4 If the adhesion strength of the tape has been determined in accordance with Test Methods D 1000 or D 3330, report the results with the adhesion rating(s). If the adhesion strength of the tape has not been determined, report the specific tape used and its manufacturer.

9. Precision and Bias[8]

9.1 In an interlaboratory study of this test method in which operators in six laboratories made one adhesion measurement on three panels each of three coatings covering

[7] Permacel 99 manufactured by Permacel, New Brunswick, NJ 08903, and available from various Permacel tape distributors, is reported to be suitable for this purpose. The manufacturer of this tape and the manufacturer of the tape used in the interlaboratory study (see RR: D01-1008), have advised this subcommittee that the properties of these tapes were changed. Users of it should, therefore, check whether current material gives comparable results to previous supplied material.

[8] Supporting data are available from ASTM Headquarters. Request RR: D01-1008.

a wide range of adhesion, the within-laboratories standard deviation was found to be 0.33 and the between-laboratories 0.44. Based on these standard deviations, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

9.1.1 *Repeatability*—Provided adhesion is uniform over a large surface, results obtained by the same operator should be considered suspect if they differ by more than 1 rating unit for two measurements.

9.1.2 *Reproducibility*—Two results, each the mean of triplicates, obtained by different operators should be considered suspect if they differ by more than 1.5 rating units.

9.2 Bias cannot be established for these test methods.

TEST METHOD B—CROSS-CUT TAPE TEST

10. Apparatus and Materials

10.1 *Cutting Tool*—Sharp razor blade, scalpel, knife or other cutting device having a cutting edge angle between 15 and 30° that will make either a single cut or several cuts at once[9]. It is of particular importance that the cutting edge or edges be in good condition.

10.2 *Cutting Guide*—If cuts are made manually (as opposed to a mechanical apparatus) a steel or other hard metal straightedge or template to ensure straight cuts.

10.3 *Rule*—Tempered steel rule graduated in 0.5 mm for measuring individual cuts.

10.4 *Tape*, as described in 5.3.

10.5 *Rubber Eraser*, on the end of a pencil.

10.6 *Illumination*, as described in 5.5.

10.7 *Magnifying Glass*—An illuminated magnifier to be used while making individual cuts and examining the test area.

11. Test Specimens

11.1 Test specimens shall be as described in Section 6. It should be noted, however, that multitip cutters provide good results only on test areas sufficiently plane[10] that all cutting edges contact the substrate to the same degree. Check for flatness with a straight edge such as that of the tempered steel rule (10.3).

12. Procedure

12.1 Where required or when agreed upon, subject the specimens to a preliminary test before conducting the tape test (see Note 3). After drying or testing the coating, conduct the tape test at room temperature as defined in Specification D 3924, unless D 3924 standard temperature is required or agreed.

12.2 Select an area free of blemishes and minor surface imperfections, place on a firm base, and under the illuminated magnifier, make parallel cuts as follows:

12.2.1 For coatings having a dry film thickness up to and including 2.0 mils (50 μm) space the cuts 1 mm apart and make eleven cuts unless otherwise agreed upon.

12.2.2 For coatings having a dry film thickness between 2.0 mils (50 μm) and 5 mils (125 μm), space the cuts 2 mm apart and make six cuts. For films thicker than 5 mils use Test Method A.

12.2.3 Make all cuts about ¾ in. (20 mm) long. Cut through the film to the substrate in one steady motion using just sufficient pressure on the cutting tool to have the cutting edge reach the substrate. When making successive single cuts with the aid of a guide, place the guide on the uncut area.

12.3 After making the required cuts brush the film lightly with a soft brush or tissue to remove any detached flakes or ribbons of coatings.

12.4 Examine the cutting edge and, if necessary, remove any flat spots or wire-edge by abrading lightly on a fine oil stone. Make the additional number of cuts at 90° to and centered on the original cuts.

12.5 Brush the area as before and inspect the incisions for reflection of light from the substrate. If the metal has not been reached make another grid in a different location.

12.6 Remove two complete laps of tape and discard. Remove an additional length at a steady (that is, not jerked) rate and cut a piece about 3 in. (75 mm) long.

12.7 Place the center of the tape over the grid and in the area of the grid smooth into place by a finger. To ensure good contact with the film rub the tape firmly with the eraser on the end of a pencil. The color under the tape is a useful indication of when good contact has been made.

12.8 Within 90 ± 30 s of application, remove the tape by seizing the free end and rapidly (not jerked) back upon itself at as close to an angle of 180° as possible.

12.9 Inspect the grid area for removal of coating from the substrate or from a previous coating using the illuminated magnifier. Rate the adhesion in accordance with the following scale illustrated in Fig. 1:

5B The edges of the cuts are completely smooth; none of the squares of the lattice is detached.

4B Small flakes of the coating are detached at intersections; less than 5 % of the area is affected.

3B Small flakes of the coating are detached along edges and at intersections of cuts. The area affected is 5 to 15 % of the lattice.

2B The coating has flaked along the edges and on parts of the squares. The area affected is 15 to 35 % of the lattice.

1B The coating has flaked along the edges of cuts in large ribbons and whole squares have detached. The area affected is 35 to 65 % of the lattice.

0B Flaking and detachment worse than Grade 1.

12.10 Repeat the test in two other locations on each test panel.

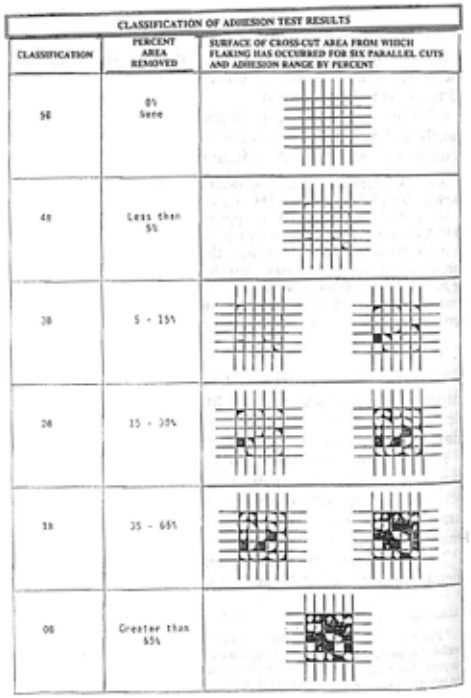

FIG. 1 Classification of Adhesion Test Results

13. Report

13.1 Report the number of tests, their mean and range, and for coating systems, where the failure occurred, that is, between first coat and substrate, between first and second coat, etc.

13.2 Report the substrate employed, the type of coating and the method of cure.

13.3 If the adhesion strength has been determined in accordance with Test Methods D 1000 or D 3330, report the results with the adhesion rating(s). If the adhesion strength of the tape has not been determined, report the specific tape used and its manufacturer.

14. Precision and Bias[9]

14.1 On the basis of two interlaboratory tests of this test method in one of which operators in six laboratories made one adhesion measurement on three panels each of three coatings covering a wide range of adhesion and in the other operators in six laboratories made three measurements on two panels each of four different coatings applied over two other coatings, the pooled standard deviations for within- and between-laboratories were found to be 0.37 and 0.7. Based on these standard deviations, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

14.1.1 *Repeatability*—Provided adhesion is uniform over a large surface, results obtained by the same operator should be considered suspect if they differ by more than one rating unit for two measurements.

14.1.2 *Reproducibility*—Two results, each the mean of duplicates or triplicates, obtained by different operators should be considered suspect if they differ by more than two rating units.

14.2 Bias cannot be established for these test methods.

15. Keywords

15.1 adhesion, tape; crosscut adhesion test method; tape adhesion test method; X-cut adhesion test method

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY

X1.1 Introduction

X1.1.1 Given the complexities of the adhesion process, can adhesion be measured? As Mittal (**1**)[11] has pointed out, the answer is both yes and no. It is reasonable to state that at the present time no test exists that can precisely assess the actual physical strength of an adhesive bond. But it can also be said that it is possible to obtain an indication of relative adhesion performance.

X1.1.2 Practical adhesion test methods are generally of two types: "*implied*" and "*direct*". "Implied" tests include indentation or scribe techniques, rub testing, and wear testing. Criticism of these tests arises when they are used to quantify the strength of adhesive bonding. But this, in fact, is not their purpose. An "implied" test should be used to assess coating performance under actual service conditions. "Direct" measurements, on the other hand, are intended expressly to measure adhesion. Meaningful tests of this type are highly sought after, primarily because the results are expressed by a single discrete quantity, the force required to rupture the coating/substrate bond under prescribed conditions. Direct tests include the Hesiometer and the Adherometer (**2**). Common methods which approach the direct tests are peel, lap-shear, and tensile tests.

X1.2 Test Methods

X1.2.1 In practice, numerous types of tests have been used to attempt to evaluate adhesion by inducing bond rupture by different modes. Criteria deemed essential for a test to warrant large-scale acceptance are: use of a straightforward and unambiguous procedure; relevance to its intended application; repeatability and reproducibility; and quantifiability, including a meaningful rating scale for assessing performance.

X1.2.2 Test methods used for coatings on metals are: peel adhesion or "tape testing"; Gardner impact flexibility testing; and adhesive joint testing including shear (lap joint) and direct tensile (butt joint) testing. These tests do not strictly meet all the criteria listed, but an appealing aspect of these tests is that in most cases the equipment/instrumentation is readily available or can be obtained at reasonable cost.

[9] Multiblade cutters are available from a few sources that specialize in testing equipment for the paint industry. One supplier that has assisted in the refinement of these methods and of Test Methods D 2197 is given in footnote 10.

[10] A multitip cutter for coated pipe surfaces is now available from Paul N. Gardner Co., 316 NE First St., Pompano Beach, FL 33060.

[11] The boldface numbers in parentheses refer to the list of references at the end of this test method.

X1.2.3 A wide diversity of tests methods have been developed over the years that measure aspects of adhesion (1–5). There generally is difficulty, however, in relating these tests to basic adhesion phenomena.

X1.3 The Tape Test

X1.3.1 By far, the most used test for evaluating coating "adhesion" is the peel test. In use since the 1930's, in its simplest version a piece of adhesive tape is pressed against the paint film. The test consists of observing if the film is peeled off when the tape is removed. The method can be refined to measure the force required for film removal. However, if the coating is removed simply by pulling off the tape, the strength of the adhesive bond is at such a low level as to be practically useless. Consequently, in most cases to assess coatings of appreciable adhesion, crosses or a cross-hatched pattern are cut into the coating, a tape applied and removed. The coating removed is assessed against an established rating scale. If a coating debonds from merely cutting an "X" and not applying tape, the adhesion is also very poor.

X1.3.2 The current widely-used version was first published in 1974; two test methods are covered in this standard. Both test methods are used to establish whether the adhesion of a coating to a substrate is at an adequate level; however they do not distinguish between higher levels of adhesion for which more sophisticated methods of measurement are required. Major limitations of the tape test are its low sensitivity, applicability only to coatings of relatively low bond strengths, and non-determination of adhesion to the substrate where failure occurs within a single coat, as when testing primers alone, or within or between coats in multicoat systems. For multicoat systems where adhesion failure may occur between or within coats, the adhesion of the coating system to the substrate is not determined.

X1.3.3 Repeatability within one rating unit is generally observed for coatings on metals for both methods, with reproducibility of one to two units. The tape test enjoys widespread popularity and is viewed as "simple" as well as low in cost. Applied to metals, it is economical to perform, lends itself to job site application, and most importantly, after decades of use, people feel comfortable with it.

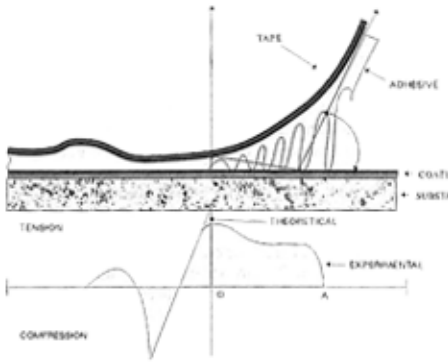

FIG. X1.1 Peel Profile (5)

X1.3.4 When a flexible adhesive tape is applied to a coated rigid substrate surface and then removed, the removal process has been described in terms of the "peel phenomenon," as illustrated in Fig. X1.1.

X1.3.5 Peeling begins at the "toothed" leading edge (at the right) and proceeds along the coating adhesive/interface or the coating/substrate interface, depending on the relative bond strengths. It is assumed that coating removal occurs when the tensile force generated along the latter interface, which is a function of the rheological properties of the backing and adhesive layer materials, is greater than the bond strength at the coating-substrate interface (or cohesive strength of the coating). In actuality, however, this force is distributed over a discrete distance (O-A) in Fig. X1.1, which relates directly to the properties described, not concentrated at a point (O) in Fig. X1.1 as in the theoretical case—though the tensile force is greatest at the origin for both. A significant compressive force arises from the response of the tape backing material to being stretched. Thus both tensile and compressive forces are involved in adhesion tape testing.

X1.3.6 Close scrutiny of the tape test with respect to the nature of the tape employed and certain aspects of the procedure itself reveal several factors, each or any combination of which can dramatically affect the results of the test as discussed (6).

X1.4 Peel Adhesion Testing on Plastic Substrates

X1.4.1 Tape tests have been criticized when used for substrates other than metal, such as plastics. The central issues are that the test on plastics lacks reproducibility and does not relate to the intended application. Both concerns are well founded: poor precision is a direct result of several factors intrinsic to the materials employed and the procedure itself. More importantly, in this instance the test is being applied beyond its intended scope. These test methods were designed for relatively ductile coatings applied to metal substrates, not for coatings (often brittle) applied to plastic parts (7). The unique functional requirements of coatings on plastic substrates cause the usual tape tests to be unsatisfactory for measuring adhesion performance in practice.

X1.5 The Tape Controversy

X1.5.1 With the withdrawal from commerce of the tape specified originally, 3M No. 710, current test methods no longer identify a specific tape. Differences in tapes used can lead to different results as small changes in backing stiffness and adhesive rheology cause large changes in the tension area. Some commercial tapes are manufactured to meet minimum standards. A given lot may surpass these standards and thus be suitable for general market distribution; however, such a lot may be a source of serious and unexpected error in assessing adhesion. One commercially available tape test kit had included a tape with adhesion strength variance of up to 50 % claimed by the manufacturer. Also, because tapes change on storage, bond strengths of the tape may change over time (7, 8).

X1.5.2 While there are tapes available that appear to deliver consistent performance, a given tape does not adhere equally well to all coatings. For example, when the peel removal force of the tape (from the coating) used earlier by Task Group D01.23.10 to establish precision of the method

by 3M No. 710 was examined with seven different electromagnetic interference/radio frequency interference (EMI/RFI) coatings, it was found that, while peel was indeed consistent for a given coating, the value varied by 25 % between the highest and lowest ratings among coatings. Several factors that contribute to these differences include coating composition and topology; as a result, no single tape is likely to be suitable for testing all coatings. Further, the tape test does not give an absolute value for the force required for bond rupture, but serves only as an indicator that some minimum value for bond strength was met or exceeded (7, 8).

X1.6 Procedural Problems

X1.6.1 The tape test is operator intensive. By design it was made as simple as possible to perform, and requires a minimum of specialized equipment and materials that must meet certain specifications. The accuracy and precision depend largely upon the skill of the operator and the operator's ability to perform the test in a consistent manner. Key steps that directly reflect the importance of operator skill include the angle and rate of tape removal and the visual assessment of the tested sample. It is not unexpected that different operators might obtain different results (7, 8).

X1.6.2 *Peel Angle and Rate:* The standard requires that the free end of the tape be removed rapidly at as close to a 180° angle as possible. If the peel angle and rate vary, the force required to remove the tape can change dramatically. Nearly linear increases were observed in peel force approaching 100 % as peel angle was changed from 135 to 180, and similar large differences can be expected in peel force as peel rate varies. These effects are related as they reflect certain rheological properties of the backing and adhesive that are molecular in origin. Variation in pull rate and peel angle can effect large differences in test values and must be minimized to assure reproducibility (9).

X1.6.3 *Visual Assessment:* The final step in the test is visual assessment of the coating removed from the specimen, which is subjective in nature, so that the coatings can vary among individuals evaluating the same specimen (9).

X1.6.3.1 Performance in the tape test is based on the amount of coating removed compared to a descriptive scale. The exposure of the substrate can be due to factors other than coating adhesion, including that arising from the requirement that the coating be cut (hence the synonym "cross-hatch adhesion test"). Justification for the cutting step is reasonable as cutting provides a free edge from which peeling can begin without having to overcome the cohesive strength of the coating layer.

X1.6.3.2 Cutting might be suitable for coatings applied to metal substrates, but for coatings applied to plastics or wood, the process can lead to a misleading indication of poor adhesion due to the unique interfacial zone. For coatings on soft substrates, issues include how deep should this cut penetrate, and is it possible to cut only to the interface?

X1.6.3.3 In general, if adhesion test panels are examined microscopically, it is often clearly evident that the coating removal results from substrate failure at or below the interface, and not from the adhesive failure between the coating and the substrate. Cohesive failure within the coating film is also frequently observed. However, with the tape test, failures within the substrate or coating layers are rare because the tape adhesive is not usually strong enough to exceed the cohesive strengths of normal substrates and organic coatings. Although some rather brittle coatings may exhibit cohesive failure, the tape test adhesion method does not make provision for giving failure locality (7, 8).

X1.6.4 Use of the test method in the field can lead to variation in test results due to temperature and humidity changes and their effect upon tape, coating and substrate.

X1.7 Conclusion

X1.7.1 All the issues aside, if these test methods are used within the Scope Section and are performed carefully, some insight into the approximate, relative level of adhesion can be gained.

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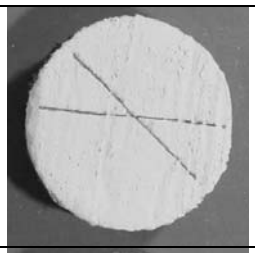
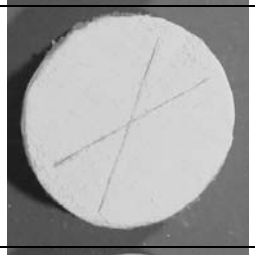
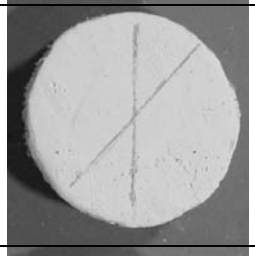
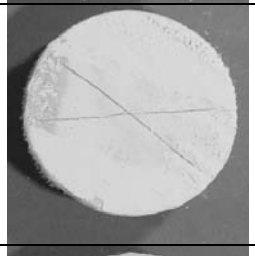
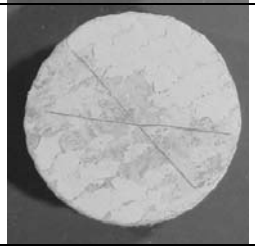
Limewash Experiment: Adhesion Rating

5A	No peeling or removal		
4A	Trace peeling or removal along incisions or at their intersection		
3A	Jagged removal along most of incisions up to 1/16 inch on either side		
2A	Jagged removal along most incisions up to 1/8 inch on either side		
1A	Removal from most of the area of the X under the tape		
0A	Removal beyond the area of the X		

Prepared by
Sarah Jackson

Abrasion Testing Procedure

1. Assemble the apparatus so that the sample holder is directly in-line with the sand tube and funnel, and so that the large collection bin is able to trap all used sand.

2. Choose sample to abrade and mount it in holder directly under the outlet tube, so that the center of the flow will hit the center of the sample.

3. Position the sample so that the nearest portion of it to the end of the outlet tube is exactly one (1) inch from the outlet tube.

4. Fill the one liter beaker with sand to exactly the 1000 mL mark.

5. Load the upper funnel with the sand, thus allowing sand to abrade the sample.

6. Record each 1 L of sand used.

7. Repeat steps 4 through 6 until the sample begins to show substrate, but empty the collection bin of its sand before the sand "backs up" onto the sample.

8. Once substrate begins to show, switch to using 250 mL at a time by using the plastic beaker.

9. Make sure to record exactly the total volume of sand used.

10. The run is complete once a patch of substrate is exposed that measures 4 mm in diameter (no more, no less). Use the longest diameter if the patch is not circular.

11. The final piece of data for each sample is then the volume of sand required to expose a 4 mm diameter patch of substrate.

Revised: 5/2/2005 TWB

Results

Limewash Experiment: Weathered Wood and Rough-sawn New Wood

Graymont, "Ivory" hydrated lime

Wash A (Class C, Molasses, Alum, Salt, Lime, Water)

	#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
	W-001-A	yes	yes	8.6168	10.0148	no	no	no	3 L *	10.0448	no	no	yes	no	no	no	no	no	no
	W-002-A	yes	yes	13.7087	10.1753	no	no	no	no	no	3A	9.7924	yes	5.0230	3A	9.7129	1 L	9.6773	4.2007
	W-003-A	yes	yes	8.0706	10.9771	no	no	no	no	no	2A	10.3669	yes	5.8965	1A	10.2730	n/a	n/a	n/a
	W-004-A	yes	yes	7.2143	8.1337	no	no	no	no	no	1A	7.9425	no	4.2153	0A	7.9127	.75 L	7.9073	4.7806
	W-005-A	yes	yes	9.1255	9.5357	0.6362	no	10.1719	no	no	no	no	no	no	no	no	no	no	no
	W-006-A	yes	yes	11.3568	9.0143	no	2A	9.0136	no	no	no	no	yes	no	no	no	no	no	no
	W-007-A	yes	yes	12.6841	9.0818	no	no	no	20 L	9.0702	no	no	yes	no	no	no	no	no	no
	W-008-A	yes	yes	10.2009	8.8840	0.7468	no	9.6308	no	no	no	no	no	no	no	no	no	no	no
	W-009-A	yes	yes	8.5476	10.7298	no	2A	10.7809	no	no	no	no	yes	no	no	no	no	no	no
◊	W-010-A	yes	yes	13.3890	10.0714	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
◊	W-011-A	yes	yes	8.4145	8.7231	no	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes
	W-012-A	yes	yes	9.5014	9.1026	no	no	no	5 L *	9.1470	no	no	yes	no	no	no	no	no	no
	W-013-A	yes	yes	9.2920	7.9283	0.5412	no	8.4694	no	no	no	no	no	no	no	no	no	no	no
	W-014-A	yes	yes	8.1812	8.0551	no	4A	8.0698	no	no	no	no	yes	no	no	no	no	no	no
◊	W-015-A	yes	yes	14.8962	8.8841	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
	W-016-A	yes	yes	10.0882	10.1312	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash B (Class C, Molasses, Alum, Salt, Lime, Water)

	#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
	W-017-B	yes	yes	6.5094	9.3896	0.9240	no	10.3136	no	no	no	no	no	no	no	no	no	no	no
	W-018-B	yes	yes	4.9656	8.9465	no	no	no	3 L *	8.9777	no	no	yes	no	no	no	no	no	no
	W-019-B	yes	yes	5.3697	10.5177	no	no	no	no	no	1A	10.2633	yes	8.8504	1A	10.1819	.75 L	10.1813	9.3690
	W-020-B	yes	yes	4.7098	8.8498	no	no	no	no	no	2A	8.7296	no	4.0533	1A	8.6436	3.5 L	8.6543	8.0037
	W-021-B	yes	yes	5.2462	10.0602	no	no	no	no	no	2A	9.7791	yes	7.1259	1A	9.6840	2.25 L	9.6764	4.4007
	W-022-B	yes	yes	5.1889	8.5610	no	0A	8.5299	no	no	no	no	yes	no	no	no	no	no	no
	W-023-B	yes	yes	5.2743	8.6142	no	no	no	4.5 L *	8.5809	no	no	yes	no	no	no	no	no	no
	W-024-B	yes	yes	5.0755	8.7255	0.5101	no	9.2355	no	no	no	no	no	no	no	no	no	no	no
	W-025-B	yes	yes	5.2524	10.5130	no	2A	10.2045	no	no	no	no	yes	no	no	no	no	no	no
◊	W-026-B	yes	yes	6.0395	10.4433	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
◊	W-027-B	yes	yes	4.6255	8.5572	no	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes
	W-028-B	yes	yes	5.9919	9.8864	no	no	no	4.5 L *	9.9016	no	no	yes	no	no	no	no	no	no
	W-029-B	yes	yes	6.0454	8.7455	0.6961	no	9.4416	no	no	no	no	no	no	no	no	no	no	no
	W-030-B	yes	yes	4.8615	8.2189	no	2A	8.2214	no	no	no	no	yes	no	no	no	no	no	no
◊	W-031-B	yes	yes	6.1068	8.8912	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
	W-032-B	yes	yes	6.5760	10.4034	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash C (Class C, Molasses, Alum, Salt, Lime, Water)

	#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
	W-033-C	yes	yes	7.8886	9.8425	no	no	no	no	no	no	no	no	no	no	no	no	no	no
	W-034-C	yes	yes	6.6029	8.5678	no	no	no	1.5 L	8.5774	no	no	yes	no	no	no	no	no	no
	W-035-C	yes	yes	8.0579	9.8595	0.8403	no	10.6998	no	no	no	no	no	no	no	no	no	no	no
	W-036-C	yes	yes	9.2286	10.4313	no	1A	10.4283	no	no	no	no	yes	no	no	no	no	no	no
	W-037-C	yes	yes	6.6544	9.9701	no	1A	9.9549	no	no	no	no	yes	no	no	no	no	no	no
◊	W-038-C	yes	yes	4.6324	8.3998	no	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes
	W-039-C	yes	yes	8.7327	10.1761	no	no	no	2.75 L	10.1885	no	no	yes	no	no	no	no	no	no
	W-040-C	yes	yes	7.1196	10.0244	0.9325	no	10.9570	no	no	no	no	no	no	no	no	no	no	no
	W-041-C	yes	yes	7.0106	10.5428	no	1A	10.5095	no	no	no	no	yes	no	no	no	no	no	no
◊	W-042-C	yes	yes	4.6533	8.2222	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
◊	W-043-C	yes	yes	7.1228	10.1823	no	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes
	W-044-C	yes	yes	5.3631	7.9033	no	no	no	2.75 L	7.9156	no	no	yes	no	no	no	no	no	no
	W-045-C	yes	yes	4.8978	8.7119	0.6583	no	9.3702	no	no	no	no	no	no	no	no	no	no	no
	W-046-C	yes	yes	6.4778	8.3028	no	no	no	no	no	2A	8.2427	no	3.7401	1A	8.2069	1 L	8.1916	12.7691
	W-047-C	yes	yes	9.0086	10.2261	no	no	no	no	no	2A	10.0647	yes	5.1582	1A	9.9912	1.25 L	9.9648	11.4217
	W-048-C	yes	yes	5.6125	8.5510	no	no	no	no		3A	8.4797	no	3.6913	1A	8.4371	.75 L	8.4405	15.0632

No. of samples this page = 48
No. of wood samples total = 150

Limewash Experiment: Weathered Wood and Rough-sawn New Wood

Graymont, "Ivory" hydrated lime

Wash D (Lime, Molasses, Casein, Clove Oil, Water)

	#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
	W-049-D	yes	yes	6.7900	10.0082	no	no	no	no	no	4A	10.0656	yes	3.2618	1A	10.0247	1.5 L	10.0284	4.7676
	W-050-D	yes	yes	8.0214		no	no	no	no		5A	8.8499	no	4.2343	1A	8.8095	1.75 L	8.8136	2.3268
	W-051-D	yes	yes	6.8719	10.0387	no	no	no	no	no	4A	10.1090	yes	4.2489	2A	10.0497	1.25 L	10.0503	12.0457
	W-052-D	yes	yes	7.9118	9.0179	no	no	no	2.5 L	9.1133	no	no	yes	no	no	no	no	no	no
	W-053-D	yes	yes	6.5944	10.2050	0.5748	no	10.7798	no	no	no	no	no	no	no	no	no	no	no
	W-054-D	yes	yes	6.8314	10.4366	no	4A	10.5238	no	no	no	no	yes	no	no	no	no	no	no
	W-055-D	yes	yes	7.8743	10.4501	no	no	no	1.75 L	10.5608	no	no	yes	no	no	no	no	no	no
	W-056-D	yes	yes	11.2002	9.0475	0.3730	no	9.4205	no	no	no	no	no	no	no	no	no	no	no
	W-057-D	yes	yes	8.7582	8.0008	no	0A	8.0075	no	no	no	no	yes	no	no	no	no	no	no
◊	W-058-D	yes	yes	8.7142	9.3223	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
◊	W-059-D	yes	yes	6.7581	10.0745	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
	W-060-D	yes	yes	9.9651	9.1128	no	no	no	3 L *	9.2305	no	no	yes	no	no	no	no	no	no
	W-061-D	yes	yes	8.2457	9.3897	0.6142	no	10.0039	no	no	no	no	no	no	no	no	no	no	no
	W-062-D	yes	yes	7.7559	10.2456	no	4A	10.3387	no	no	no	no	yes	no	no	no	no	no	no
◊	W-063-D	yes	yes	10.4830	8.6337	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
	W-064-D	yes	yes	10.5477	8.5862	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash E (Lime, Molasses, Casein, Clove Oil, Water)

	#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
	W-065-E	yes	yes	6.6382	9.7259	no	4A	9.8015	no	no	no	no	yes	no	no	no	no	no	no
	W-066-E	yes	yes	8.8155	8.8685	no	no	no	1 L	8.9446	no	no	yes	no	no	no	no	no	no
	W-067-E	yes	yes	6.6202	9.0562	0.5249	no	9.5811	no	no	no	no	no	no	no	no	no	no	no
	W-068-E	yes	yes	6.0434	9.2188	no	3A	9.3202	no	no	no	no	yes	no	no	no	no	no	no
	W-069-E	yes	yes	7.3234	7.9181	no	no	no	no	no	no	no	no	no	no	no	no	no	no
◊	W-070-E	yes	yes	5.9154	10.5329	no	no	no	no	no	yes	yes	yes	yes	no	no			
	W-071-E	yes	yes	7.9523	7.9599	no	no	no	.75 L	8.0247	no	no	yes	no	no	no	no	no	no
	W-072-E	yes	yes	6.2176	10.0919	0.5688	no	10.6607	no	no	no	no	no	no	no	no	no	no	no
	W-073-E	yes	yes	6.6333	9.8687	no	4A	9.9494	no	no	no	no	yes	no	no	no	no	no	no
◊	W-074-E	yes	yes	6.2871	9.7905	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
◊	W-075-E	yes	yes	7.5987	8.0034	no	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes
	W-076-E	yes	yes	6.3726	10.1036	no	no	no	3.25 L	10.1865	no	no	yes	no	no	no	no	no	no
	W-077-E	yes	yes	5.8503	10.1173	0.4377	no	10.5550	no	no	no	no	no	no	no	no	no	no	no
	W-078-E	yes	yes	4.8355	10.2243	no	no	no	no		5A	10.2666	no	7.9867	4A	10.2379	1.75 L	10.2381	7.8902
	W-079-E	yes	yes	5.6665	10.4410	no	no	no	no	no	4A	10.4173	no	5.5209	2A	10.3301	.75 L	10.3307	1.0964
	W-080-E	yes	yes	6.2334	8.2473	no	no	no	no	no	4A	8.3150	yes	4.0797	4A	8.2796	5.5 L	8.2826	2.2439

Virginia Limeworks lime putty

Wash F (Lime, Molasses, Casein, Clove Oil, Water)

	#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
	W-081-F	yes	yes	8.1719	10.0452	0.3417	no	10.3869	no	no	no	no	no	no	no	no	no	no	no
	W-082-F	yes	yes	8.8602	8.4827	no	no	no	1 L *	8.5919	no	no	yes	no	no	no	no	no	no
	W-083-F	yes	yes	5.4735	10.2624	no	no	no	no	no	3A	10.2025	yes	6.1605	2A	10.1677	n/a	n/a	n/a
	W-084-F	yes	yes	7.0278	9.1839	no	no	no	no		5A	9.2230	no	5.9804	3A	9.1987	.75 L	9.2074	4.1438
	W-085-F	yes	yes	5.5039	9.9259	no	no	no	no	no	3A	9.9619	yes	3.9222	2A	9.9083	1.25 L	9.9288	14.8269
	W-086-F	yes	yes	6.6384	10.0672	no	2A	10.0979	no	no	no	no	yes	no	no	no	no	no	no
	W-087-F	yes	yes	6.1091	10.5111	no	no	no	.5 L	10.5645	no	no	yes	no	no	no	no	no	no
	W-088-F	yes	yes	8.7344	9.0519	0.4865	no	9.5384	no	no	no	no	no	no	no	no	no	no	no
	W-089-F	yes	yes	9.2751	9.1304	no	3A	9.2040	no	no	no	no	yes	no	no	no	no	no	no
◊	W-090-F	yes	yes	9.4632	8.2890	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
◊	W-091-F	yes	yes	9.7461	7.5393	no	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes
	W-092-F	yes	yes	8.8817	7.8438	no	no	no	.5 L	7.9483	no	no	yes	no	no	no	no	no	no
	W-093-F	yes	yes	6.3021	9.9158	0.4277	no	10.3434	no	no	no	no	no	no	no	no	no	no	no
	W-094-F	yes	yes	7.9918	9.4462	no	3A	9.8232	no	no	no	no	yes	no	no	no	no	no	no
◊	W-095-F	yes	yes	8.4504	9.0566	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
	W-096-F	yes	yes	8.8244	8.3403	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of wood samples total = 150

Limewash Experiment: Weathered Wood and Rough-sawn New Wood

Graymont, "Ivory" hydrated lime

Wash G (Lime, Water, acrylic binder)

	#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
	W-097-G	yes	yes	3.3292	8.5428	no	0A	8.5292	no	no	no	no	yes	no	no	no	no	no	no
	W-098-G	yes	yes	2.2117	10.5696	no	no	no	4.5 L	10.6074	no	no	yes	no	no	no	no	no	no
	W-099-G	yes	yes	1.8506	9.2543	0.2566	no	9.5109	no	no	no	no	no	no	no	no	no	no	no
	W-100-G	yes	yes	2.3173	9.0041	no	no	no	no	no	5A	8.5798	yes	8.9016	4A	8.8849	2.5 L	8.8917	1.8410
	W-101-G	yes	yes	2.5303	10.1913	no	no	no	no	no	3A	9.7847	yes	10.0689	2A	10.0220	1 L	10.0363	6.5266
	W-102-G	yes	yes	3.8042	10.5343	no	no	no	no	no	3A	9.8504	no	10.4238	2A	10.3941	1.5 L	10.4077	0.7415
	W-103-G	yes	yes	2.8451	7.3568	no	no	no	1.75 L	7.3684	no	no	yes	no	no	no	no	no	no
	W-104-G	yes	yes	2.7810	8.4325	0.3208	no	8.7533	no	no	no	no	no	no	no	no	no	no	no
	W-105-G	yes	yes	2.7422	9.0059	no	4A	9.0227	no	no	no	no	yes	no	no	no	no	no	no
◊	W-106-G	yes	yes	3.2127	8.5931	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
◊	W-107-G	yes	yes	2.7921	9.9302	no	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes
	W-108-G	yes	yes	3.9740	10.2399	no	no	no	2.75 L	10.2725	no	no	yes	no	no	no	no	no	no
	W-109-G	yes	yes	2.0800	8.6293	0.2258	no	8.8552	no	no	no	no	no	no	no	no	no	no	no
	W-110-G	yes	yes	2.3386	8.0164	no	4A	8.0188	no	no	no	no	yes	no	no	no	no	no	no
◊	W-111-G	yes	yes	2.3158	8.4254	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
	W-112-G	yes	yes	2.2595	8.5031	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash H (Lime, Water, acrylic binder)

	#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
	W-113-H	yes	yes	3.0143	8.3653	no	no	no	.75 L	8.4028	no	no	yes	no	no	no	no	no	no
	W-114-H	yes	yes	2.7871	9.6907	no	no	no	1.25 L	9.8029	no	no	yes	no	no	no	no	no	no
	W-115-H	yes	yes	1.9884	9.3641	0.2745	no	9.6386	no	no	no	no	no	no	no	no	no	no	no
	W-116-H	yes	yes	3.8140	7.9907	no	4A	7.9990	no	no	no	no	yes	no	no	no	no	no	no
	W-117-H	yes	yes	2.9607	10.1718	0.4167	no	10.5884	no	no	no	no	no	no	no	no	no	no	no
◊	W-118-H	yes	yes	2.4642	8.8181	no	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes
	W-119-H	yes	yes	2.5574	8.6802	no	no	no	.75 L	8.7128	no	no	yes	no	no	no	no	no	no
	W-120-H	yes	yes	2.7856	10.5869	0.3562	no	10.9430	no	no	no	no	no	no	no	no	no	no	no
	W-121-H	yes	yes	2.1370	8.3258	no	1A	8.3162	no	no	no	no	yes	no	no	no	no	no	no
◊	W-122-H	yes	yes	3.5191	8.7154	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
	W-123-H	yes	yes	2.4417	8.0499	no	no	no	no	no	4A	7.9718	yes	2.3839	1A	7.9355	1.25 L	7.9508	17.3191
	W-124-H	yes	yes	2.9595	10.4803	no	no	no	no	no	3A	10.3855	yes	5.4516	2A	10.3586	n/a	n/a	n/a
	W-125-H	yes	yes	2.4009	7.9374	no	no	no	no		4A	7.8523	no	3.7036	1A	7.7669	.5 L	7.8125	12.2682
	W-126-H	yes	yes	2.2171	8.2508	no	4A	8.2704	no	no	no	no	yes	no	no	no	no	no	no
◊	W-127-H	yes	yes	3.0887	8.6332	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
	W-128-H	yes	yes	2.5118	9.7719	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash I (Lime, Water, acrylic binder)

	#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
	W-129-I	yes	yes	3.3980	9.7557	0.3469	no	10.1026	no	no	no	no	no	no	no	no	no	no	no
	W-130-I	yes	yes	2.0875	9.0695	no	1A	9.0707	no	no	no	no	yes	no	no	no	no	no	no
	W-131-I	yes	yes	2.3904	8.6508	no	no	no	no	no	5A	8.5798	yes	1.1044	3A	8.5636	1.25 L	8.5860	0.9123
	W-132-I	yes	yes	3.4712	9.8627	no	no	no	no	no	4A	9.7847	yes	3.7480	1A	9.7594	n/a	n/a	n/a
	W-133-I	yes	yes	3.4196	9.9541	no	no	no	no	no	4A	9.8504	yes	6.4299	2A	9.8230	1.5 L	8.8459	5.3386
	W-134-I	yes	yes	4.2756	9.4008	no	no	no	1.25 L	9.4243	no	no	yes	no	no	no	no	no	no
	W-135-I	yes	yes	2.9982	10.1524	no	no	no	3.5 L	10.2025	no	no	yes	no	no	no	no	no	no
	W-136-I	yes	yes	3.3933	9.9810	0.2880	no	10.2690	no	no	no	no	no	no	no	no	no	no	no
	W-137-I	yes	yes	1.9981	8.9412	no	1A	8.9381	no	no	no	no	yes	no	no	no	no	no	no
◊	W-138-I	yes	yes	2.6162	10.5344	no	no	no	no	yes	yes	yes	yes	no	yes	yes	no	no	no
◊	W-139-I	yes	yes	2.3328	10.3394	no	no	no	no	yes	yes	yes	yes	yes	no	no	yes	yes	yes
	W-140-I	yes	yes	1.8254	7.9564	no	no	no	1.25 L	7.9851	no	no	yes	no	no	no	no	no	no
	W-141-I	yes	yes	3.1179	10.2582	0.2345	no	10.4927	no	no	no	no	no	no	no	no	no	no	no
	W-142-I	yes	yes	2.5087	10.1089	no	1A	10.1151	no	no	no	no	yes	no	no	no	no	no	no
◊	W-143-I	yes	yes	2.4437	8.1716	no	no	no	no	yes	yes	yes	yes	yes	yes	yes	no	no	no
	W-144-I	yes	yes	4.1589	9.1988	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of wood samples total = 150

Limewash Experiment: Weathered Wood and Rough-sawn New Wood

Controls

Wash J

	#	Wash	Photo	Color	Mass	QUV	Mass	Photo	Color										
◊	W-145-J	no	yes	36.6203	8.4523	i.p.	yes	yes	yes										
◊	W-146-J	no	yes	10.6217	8.0710	i.p.	yes	yes	yes										
◊	W-147-J	no	yes	58.7861	10.0409	i.p.	yes	yes	yes										
	W-148-J	no	yes	57.8975	9.6975	no	no	no	no										
	W-149-J	no	yes	34.8375	7.2459	no	no	no	no										
	W-150-J	no	yes	54.3780	9.7248	no	no	no	no										

No. of samples this page = 6
No. of wood samples total = 150

◊ Samples that were unable to fit in QUV for the first run
* Abrasion test with 3'6" tube
i.p. In Progress

Limewash Experiment: Weathered Wood or Rough-sawn New Wood

Solids Test

Initial					After Limewash Application			
	Mass 1	Mass 2	Mass Avg.			Mass 1	Mass 2	Mass Avg.
W-005-A	9.5361	9.5353	9.5357		W-005-A	10.1721	10.1716	10.17185
W-008-A	8.8839	8.884	8.88395		W-008-A	9.6307	9.6308	9.63075
W-013-A	7.9284	7.9281	7.92825		W-013-A	8.4696	8.4692	8.4694
W-017-B	9.3898	9.3893	9.38955		W-017-B	10.3136	10.3136	10.3136
W-024-B	8.7251	8.7258	8.72545		W-024-B	9.2354	9.2356	9.2355
W-029-B	8.7455	8.7455	8.7455		W-029-B	9.4415	9.4417	9.4416
W-035-C	9.8595	9.8594	9.85945		W-035-C	10.6999	10.6997	10.6998
W-040-C	10.0246	10.0242	10.0244		W-040-C	10.9571	10.9568	10.95695
W-045-C	8.712	8.7117	8.71185		W-045-C	9.3702	9.3701	9.37015
W-053-D	10.2049	10.205	10.20495		W-053-D	10.7799	10.7796	10.77975
W-056-D	9.0474	9.0475	9.04745		W-056-D	9.4206	9.4203	9.42045
W-061-D	9.3896	9.3898	9.3897		W-061-D	10.004	10.0038	10.0039
W-067-E	9.056	9.0564	9.0562		W-067-E	9.5812	9.581	9.5811
W-072-E	10.092	10.0917	10.09185		W-072-E	10.6607	10.6606	10.66065
W-077-E	10.1173	10.1172	10.11725		W-077-E	10.5551	10.5548	10.55495
W-081-F	10.0454	10.0449	10.04515		W-081-F	10.3869	10.3868	10.38685
W-088-F	9.0519	9.0519	9.0519		W-088-F	9.5386	9.5381	9.53835
W-093-F	9.9158	9.9157	9.91575		W-093-F	10.3434	10.3434	10.3434
W-099-G	9.2543	9.2542	9.25425		W-099-G	9.511	9.5108	9.5109
W-104-G	8.4334	8.4316	8.4325		W-104-G	8.7535	8.7531	8.7533
W-109-G	8.6294	8.6292	8.6293		W-109-G	8.8553	8.855	8.85515
W-115-H	9.3639	9.3642	9.36405		W-115-H	9.6385	9.6386	9.63855
W-117-H	10.1717	10.1718	10.17175		W-117-H	10.5885	10.5883	10.5884
W-120-H	10.5869	10.5868	10.58685		W-120-H	10.9431	10.9429	10.943
W-129-I	9.7557	9.7557	9.7557		W-129-I	10.1027	10.1025	10.1026
W-136-I	9.9809	9.9811	9.981		W-136-I	10.269	10.2689	10.26895
W-147-I	10.2579	10.2585	10.2582		W-147-I	10.4928	10.4925	10.49265

Limewash Experiment: Weathered Wood and Rough-Sawn New Wood

	Limewash		Limewash Avg.	Limewash Std. Dev.
W-005-A	0.6362	**Wash A**	0.6414	0.1029
W-008-A	0.7468			
W-013-A	0.5412			
W-017-B	0.9240	**Wash B**	0.7101	0.2074
W-024-B	0.5101			
W-029-B	0.6961			
W-035-C	0.8403	**Wash C**	0.8104	0.1396
W-040-C	0.9325			
W-045-C	0.6583			
W-053-D	0.5748	**Wash D**	0.5207	0.1294
W-056-D	0.3730			
W-061-D	0.6142			
W-067-E	0.5249	**Wash E**	0.5105	0.0667
W-072-E	0.5688			
W-077-E	0.4377			
W-081-F	0.3417	**Wash F**	0.4186	0.0728
W-088-F	0.4865			
W-093-F	0.4277			
W-099-G	0.2566	**Wash G**	0.2678	0.0484
W-104-G	0.3208			
W-109-G	0.2258			
W-115-H	0.2745	**Wash H**	0.3491	0.0713
W-117-H	0.4167			
W-120-H	0.3562			
W-129-I	0.3469	**Wash I**	0.2898	0.0562
W-136-I	0.2880			
W-147-I	0.2345			

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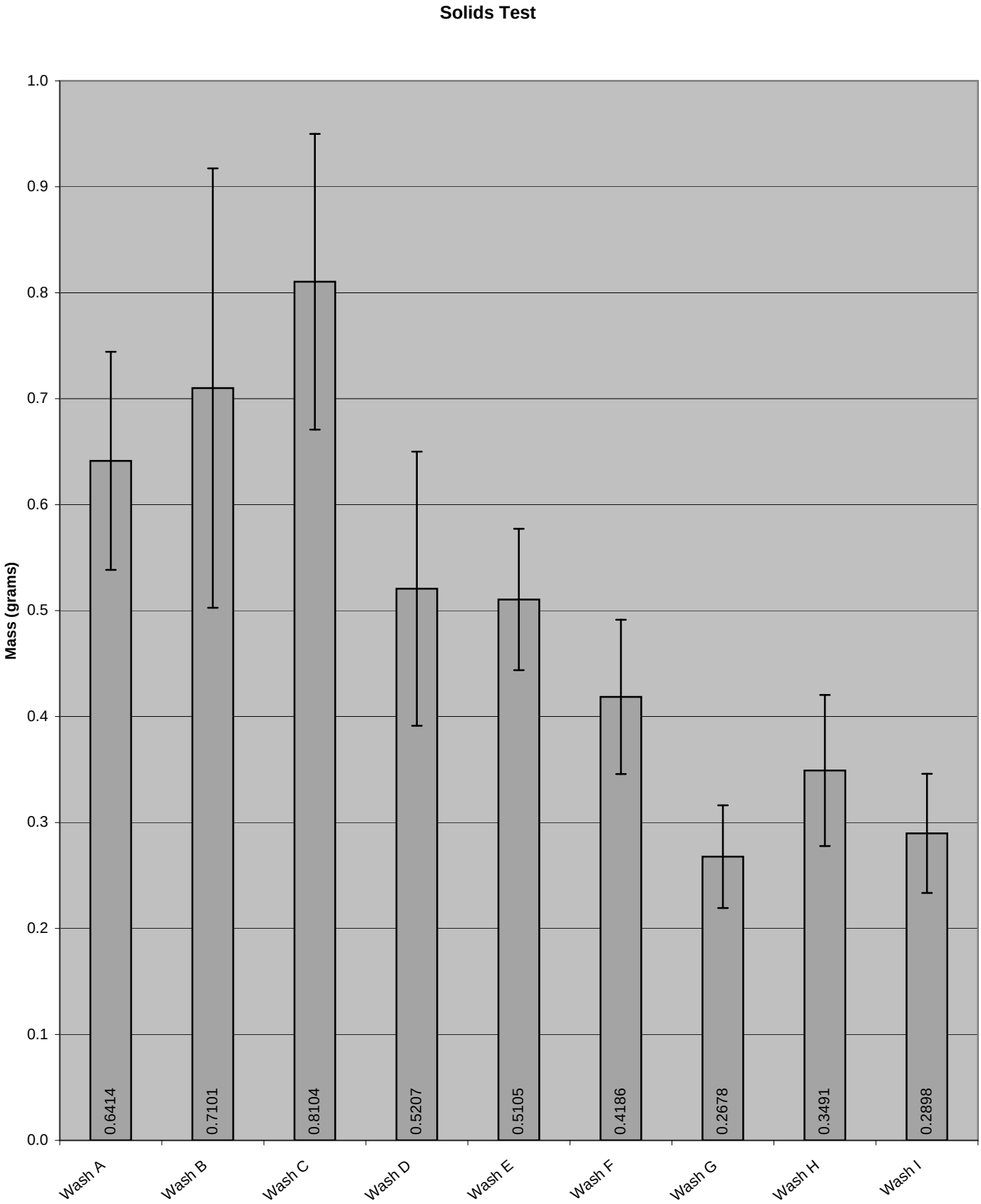
Sarah Jackson

Data provided
by Quality Finish

Limewash Experiment: Weathered Wood and Rough-sawn New Wood



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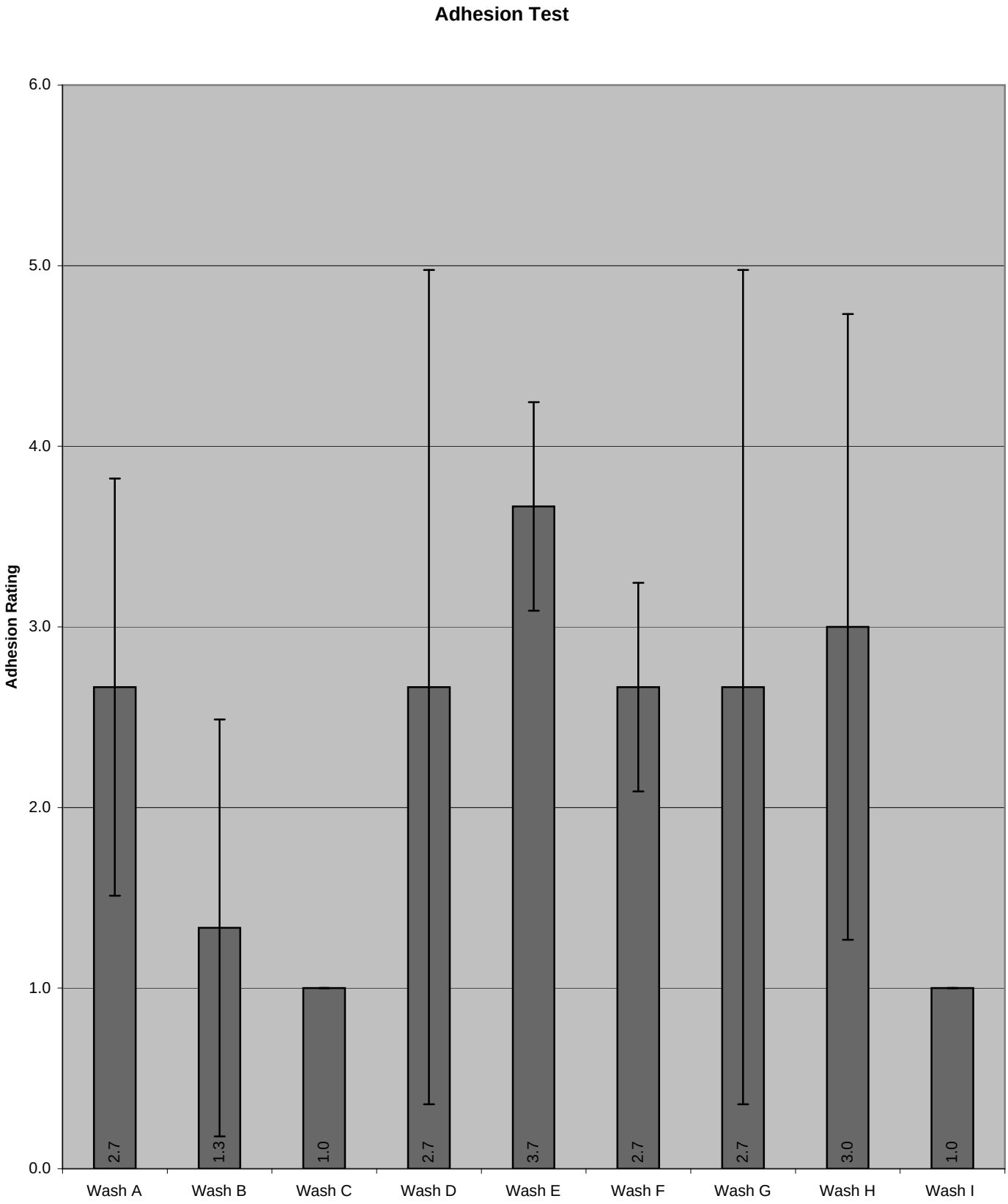
solids.xls

Limewash Experiment: Weathered Wood or Rough-sawn New Wood

Measuring Adhesion by Tape Test

	Adhesion Rating			Average	Std. Dev.
W-006-A	2A		Wash A	2.7	1.2
W-009-A	2A				
W-014-A	4A				
				Average	Std. Dev.
W-022-B	0A		Wash B	1.3	1.2
W-025-B	2A				
W-030-B	2A				
				Average	Std. Dev.
W-036-C	1A		Wash C	1.0	0.0
W-037-C	1A				
W-041-C	1A				
				Average	Std. Dev.
W-054-D	4A		Wash D	2.7	2.3
W-057-D	0A				
W-062-D	4A				
				Average	Std. Dev.
W-065-E	4A		Wash E	3.7	0.6
W-068-E	3A				
W-073-E	4A				
				Average	Std. Dev.
W-086-F	2A		Wash F	2.7	0.6
W-089-F	3A				
W-094-F	3A				
				Average	Std. Dev.
W-097-G	0A		Wash G	2.7	2.3
W-105-G	4A				
W-110-G	4A				
				Average	Std. Dev.
W-116-H	4A		Wash H	3.0	1.7
W-121-H	1A				
W-126-H	4A				
				Average	Std. Dev.
W-130-I	1A		Wash I	1.0	0.0
W-137-I	1A				
W-142-I	1A				

Limewash Experiment: Weathered Wood or Rough-sawn New Wood



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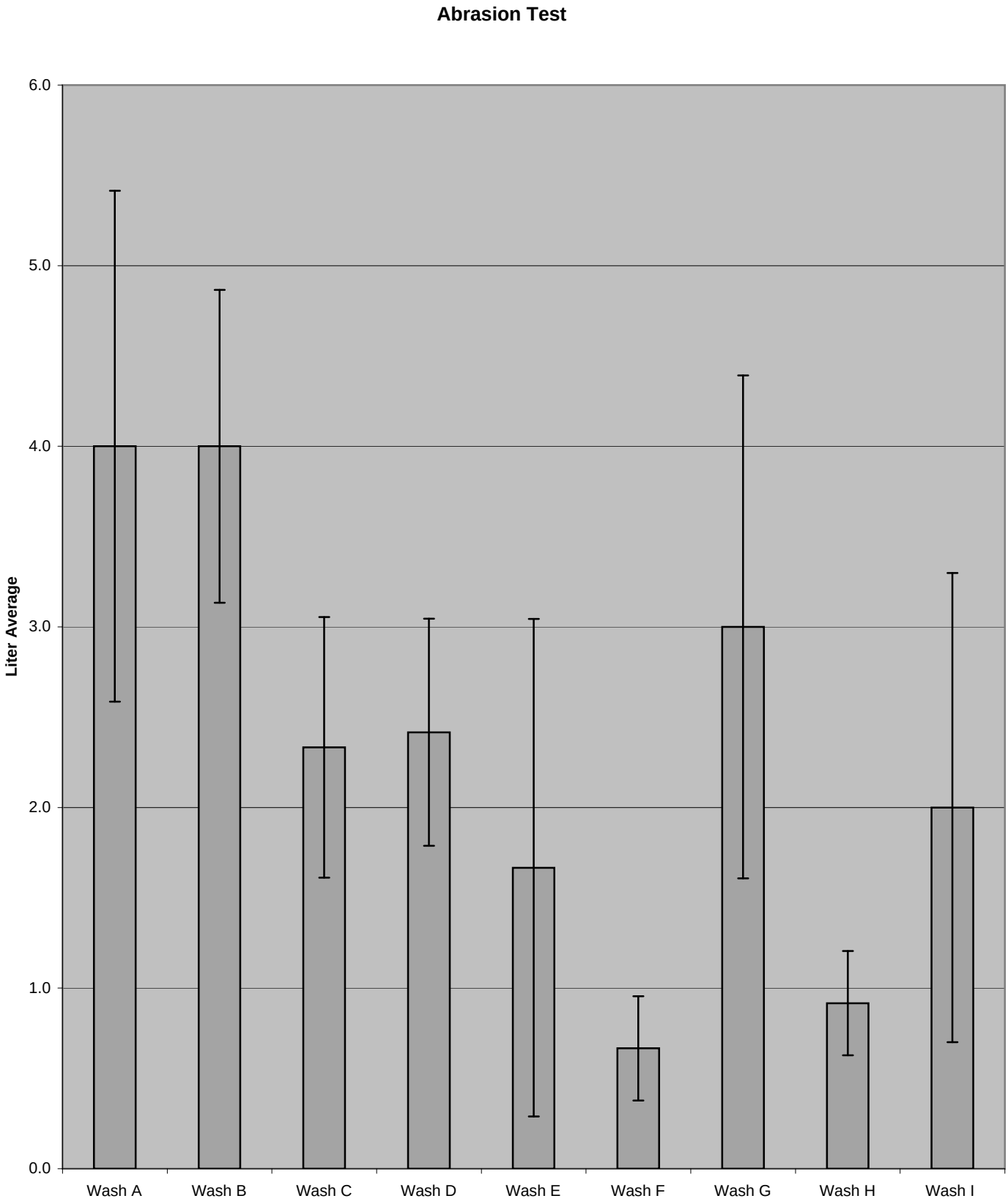
new wood data.xls

Limewash Experiment: Weathered Wood or Rough- Sawn New Wood

Abrasion test

#	Abrade			Average	Std. Dev.
W-001-A	3 L *		Wash A	4.0000	1.4142
W-007-A	20 L				
W-012-A	5 L *				
				Average	**Std. Dev.**
W-018-B	3 L *		Wash B	4.0000	0.8660
W-023-B	4.5 L *				
W-028-B	4.5 L *				
				Average	**Std. Dev.**
W-034-C	1.5 L		Wash C	2.3333	0.7217
W-039-C	2.75 L				
W-044-C	2.75 L				
				Average	**Std. Dev.**
W-052-D	2.5 L		Wash D	2.4167	0.6292
W-055-D	1.75 L				
W-060-D	3 L *				
				Average	**Std. Dev.**
W-066-E	1 L		Wash E	1.6667	1.3769
W-071-E	.75 L				
W-076-E	3.25 L				
				Average	**Std. Dev.**
W-082-F	1 L *		Wash F	0.6667	0.2887
W-087-F	.5 L				
W-092-F	.5 L				
				Average	**Std. Dev.**
W-098-G	4.5 L		Wash G	3.0000	1.3919
W-103-G	1.75 L				
W-108-G	2.75 L				
				Average	**Std. Dev.**
W-113-H	.75 L		Wash H	0.9167	0.2887
W-114-H	1.25 L				
W-119-H	.75 L				
				Average	**Std. Dev.**
W-134-I	1.25 L		Wash I	2.0000	1.2990
W-135-I	3.5 L				
W-140-I	1.25 L				

Limewash Experiment: Weathered Wood or Rough-sawn New Wood



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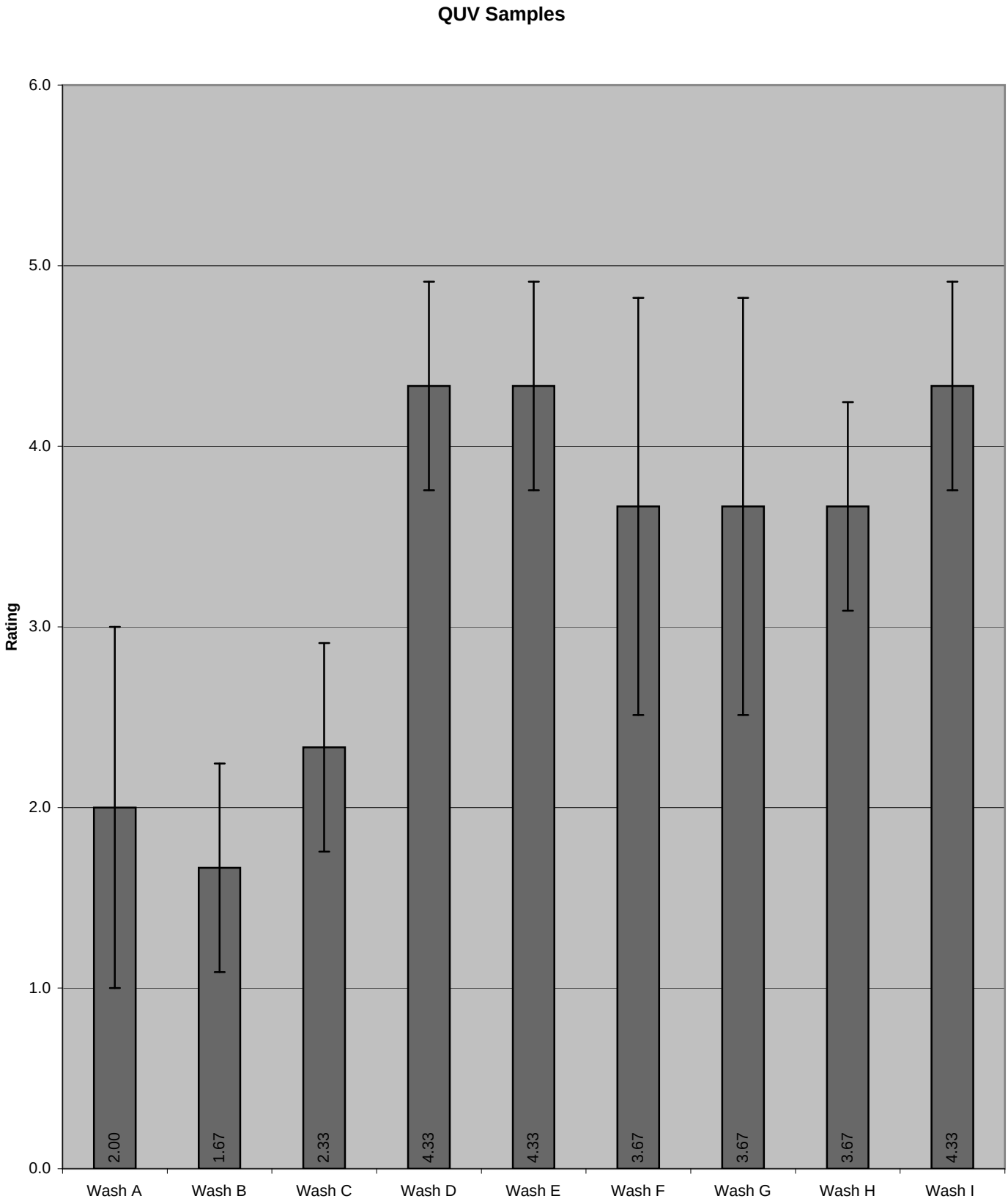
new wood data.xls

Limewash Experiment: Weathered Wood or Rough-sawn New Wood

QUV Samples

#	QUV			Average	Std. Dev.
W-002-A	3A		Wash A	2.00	1.00
W-003-A	2A				
W-004-A	1A				
				Average	**Std. Dev.**
W-019-B	1A		Wash B	1.67	0.58
W-020-B	2A				
W-021-B	2A				
				Average	**Std. Dev.**
W-046-C	2A		Wash C	2.33	0.58
W-047-C	2A				
W-048-C	3A				
				Average	**Std. Dev.**
W-049-D	4A		Wash D	4.33	0.58
W-050-D	5A				
W-051-D	4A				
				Average	**Std. Dev.**
W-078-E	5A		Wash E	4.33	0.58
W-079-E	4A				
W-080-E	4A				
				Average	**Std. Dev.**
W-083-F	3A		Wash F	3.67	1.15
W-084-F	5A				
W-085-F	3A				
				Average	**Std. Dev.**
W-100-G	5A		Wash G	3.67	1.15
W-101-G	3A				
W-102-G	3A				
				Average	**Std. Dev.**
W-123-H	4A		Wash H	3.67	0.58
W-124-H	3A				
W-125-H	4A				
				Average	**Std. Dev.**
W-131-I	5A		Wash I	4.33	0.58
W-132-I	4A				
W-133-I	4A				

Limewash Experiment: Weather Wood or Rough-sawn New Wood



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new wood data.xls

Limewash Experiment: Weathered and Rough-saw New Wood

Colorimetry

		W-Before-QUV					W-After-QUV		
Parameters:					Parameters:				
Std Status:	CREELL				Std Status:	CREELL			
Color Mode	L*a*b*				Color Mode	L*a*b*			
Observer	2°				Observer	2°			
Primary Illuminant	C				Primary Illuminant	C			
		C/2°					C/2?		
	Name	L*	a*	b*		Name	L*	a*	b*
	Standard	93.8767	1.0391	1.5099		Standard	97.0797	0.1773	1.8095
	W-002-A	89.2915	0.5088	12.9799		W-002-A	84.9113	1.4108	10.6928
	W-003-A	92.2592	0.5024	8.1684		W-003-A	86.4562	1.0592	9.0535
	W-004-A	92.4006	0.3479	7.1880		W-004-A	88.3271	0.5116	6.1163
	W-019-B	92.6960	0.2743	4.7868		W-019-B	84.9969	1.0567	9.0811
	W-020-B	94.3268	0.4632	5.7607		W-020-B	91.1605	-0.0344	3.2795
	W-021-B	94.0489	0.1629	5.9810		W-021-B	87.0554	0.6446	7.2604
	W-046-C	92.4367	0.5957	6.1995		W-046-C	89.0580	0.4356	4.6036
	W-047-C	89.9821	0.5979	7.2270		W-047-C	84.8522	0.9132	6.7888
	W-048-C	92.7407	0.4219	5.2467		W-048-C	89.6862	0.2031	3.1856
	W-049-D	91.9489	0.3458	6.1379		W-049-D	88.6890	0.2497	6.1964
	W-050-D	92.0760	0.7850	7.9472		W-050-D	93.2098	0.1345	3.9197
	W-051-D	92.5053	0.4061	6.8230		W-051-D	88.8020	1.0856	8.7921
	W-078-E	93.7584	0.3121	5.2097		W-078-E	86.7249	0.8174	8.9596
	W-079-E	93.9012	0.5210	6.3856		W-079-E	88.4933	0.5574	7.4963
	W-080-E	93.8167	0.4155	7.0116		W-080-E	94.6213	0.0548	3.0283
	W-083-F	94.0049	0.4975	6.2237		W-083-F	89.4141	-0.1372	2.1650
	W-084-F	93.3863	0.2220	7.6811		W-084-F	94.7056	-0.0091	1.8526
	W-085-F	94.0812	0.3680	6.3160		W-085-F	92.4125	-0.1085	2.7986
	W-100-G	95.4340	0.8599	0.2137		W-100-G	95.0612	0.1989	0.6605
	W-101-G	94.9268	0.9455	0.6066		W-101-G	79.7750	1.4401	9.8851
	W-102-G	93.9410	0.7995	-0.3381		W-102-G	87.3791	0.2942	3.3300
	W-123-H	95.2538	0.8048	0.2079		W-123-H	93.0427	0.3526	0.9758
	W-124-H	94.6563	0.8208	0.1379		W-124-H	89.4892	0.3322	1.8060
	W-125-H	94.9882	0.2393	2.8559		W-125-H	92.3128	0.2323	0.2949
	W-131-I	95.2343	0.7375	0.2945		W-131-I	94.2814	0.2380	0.0451
	W-132-I	94.0996	0.8357	0.0627		W-132-I	90.7667	0.2694	1.6809
	W-133-I	93.8975	0.6986	0.5945		W-133-I	89.2260	0.3398	4.9981

Limewash Experiment: Weathered and Rough-saw New Wood

Colorimetry

	▲ L*	▲ a*	▲ b*	▲ E*	
W-002-A	-4.3802	0.9020	-2.2871	5.0230	5.0230
W-003-A	-5.8030	0.5568	0.8851	5.8965	5.8965
W-004-A	-4.0735	0.1637	-1.0717	4.2153	4.2153
W-019-B	-7.6991	0.7824	4.2943	8.8504	8.8504
W-020-B	-3.1663	-0.4976	-2.4812	4.0533	4.0533
W-021-B	-6.9935	0.4817	1.2794	7.1259	7.1259
W-046-C	-3.3787	-0.1601	-1.5959	3.7401	3.7401
W-047-C	-5.1299	0.3153	-0.4382	5.1582	5.1582
W-048-C	-3.0545	-0.2188	-2.0611	3.6913	3.6913
W-049-D	-3.2599	-0.0961	0.0585	3.2618	3.2618
W-050-D	1.1338	-0.6505	-4.0275	4.2343	4.2343
W-051-D	-3.7033	0.6795	1.9691	4.2489	4.2489
W-078-E	-7.0335	0.5053	3.7499	7.9867	7.9867
W-079-E	-5.4079	0.0364	1.1107	5.5209	5.5209
W-080-E	0.8046	-0.3607	-3.9833	4.0797	4.0797
W-083-F	-4.5908	-0.6347	-4.0587	6.1605	6.1605
W-084-F	1.3193	-0.2311	-5.8285	5.9804	5.9804
W-085-F	-1.6687	-0.4765	-3.5174	3.9222	3.9222
W-100-G	-0.3728	-0.6610	0.4468	0.8806	0.8806
W-101-G	-15.1518	0.4946	9.2785	17.7739	17.7739
W-102-G	-6.5619	-0.5053	3.6681	7.5345	7.5345
W-123-H	-2.2111	-0.4522	0.7679	2.3839	2.3839
W-124-H	-5.1671	-0.4886	1.6681	5.4516	5.4516
W-125-H	-2.6754	-0.0070	-2.5610	3.7036	3.7036
W-131-I	-0.9529	-0.4995	-0.2494	1.1044	1.1044
W-132-I	-3.3329	-0.5663	1.6182	3.7480	3.7480
W-133-I	-4.6715	-0.3588	4.4036	6.4299	6.4299

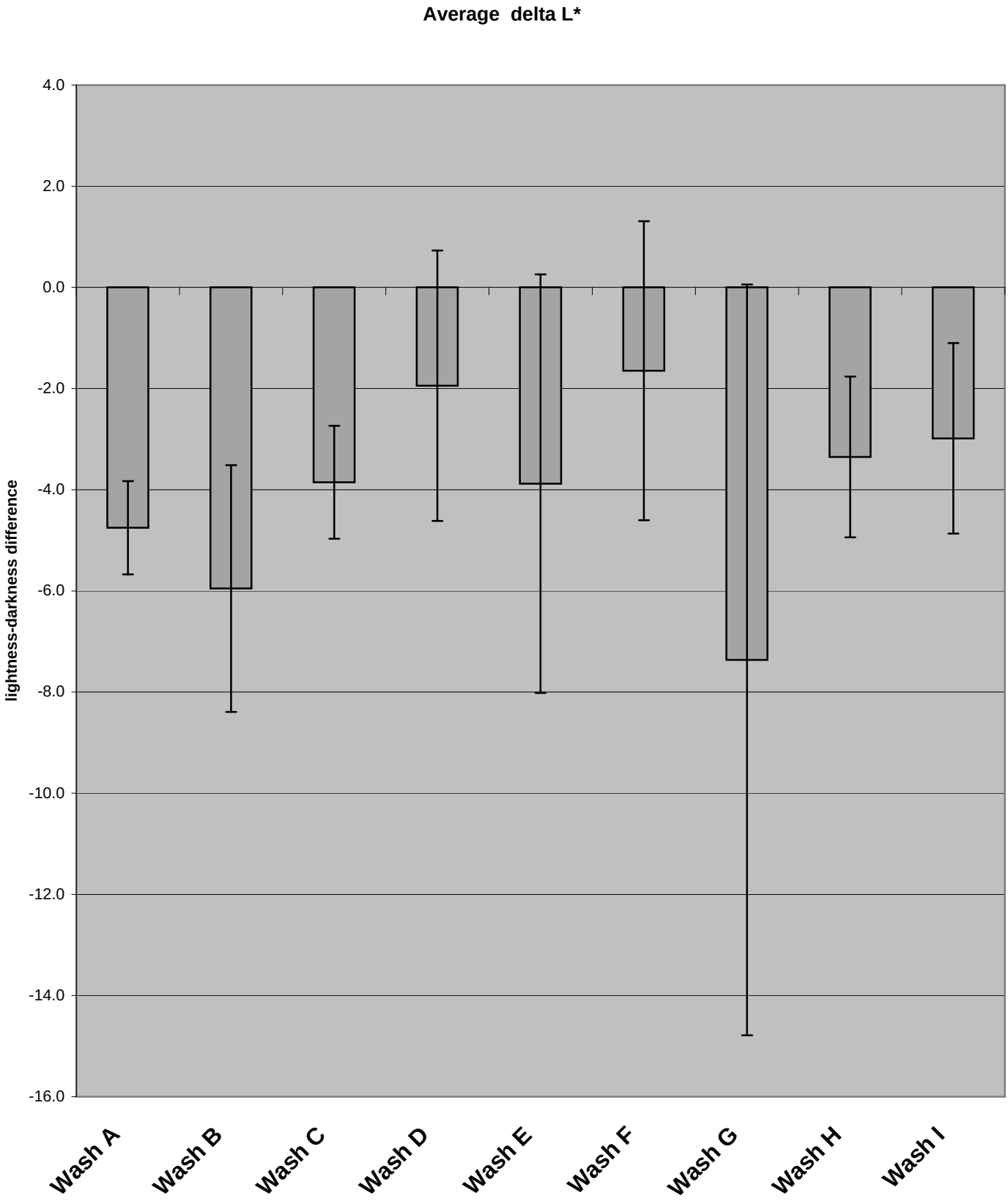
Limewash Experiment: Weathered and Rough-saw New Wood

Colorimetry

	▲ L* Avg	▲ a* Avg	▲ b* Avg	▲ E* Avg		▲ L* SD	▲ a* SD	▲ b* SD	▲ E* SD
Wash A	-4.7522	0.5408	-0.8246	5.0449		0.9228	0.3694	1.6005	0.8408
Wash B	-5.9530	0.2555	1.0308	6.6765		2.4390	0.6693	3.3946	2.4299
Wash C	-3.8544	-0.0212	-1.3651	4.1965		1.1165	0.2929	0.8357	0.8332
Wash D	-1.9431	-0.0224	-0.6666	3.9150		2.6739	0.6681	3.0634	0.5657
Wash E	-3.8789	0.0603	0.2924	5.8624		4.1367	0.4335	3.9310	1.9757
Wash F	-1.6467	-0.4474	-4.4682	5.3544		2.9551	0.2034	1.2087	1.2435
Wash G	-7.3622	-0.2239	4.4645	8.7297		7.4219	0.6271	4.4694	8.5098
Wash H	-3.3512	-0.3159	-0.0417	3.8464		1.5897	0.2682	2.2278	1.5388
Wash I	-2.9858	-0.4749	1.9241	3.7608		1.8834	0.1059	2.3415	2.6628
Wash L	-5.9330	2.0792	-1.9931	6.6586		2.3947	0.1391	0.8915	2.2997
Wash M	-9.0928	2.2195	5.8005	11.1889		3.8643	0.7747	3.8758	4.9643
Wash N	-7.0453	1.4302	-0.3917	7.7000		2.9588	0.2402	3.0723	2.8829

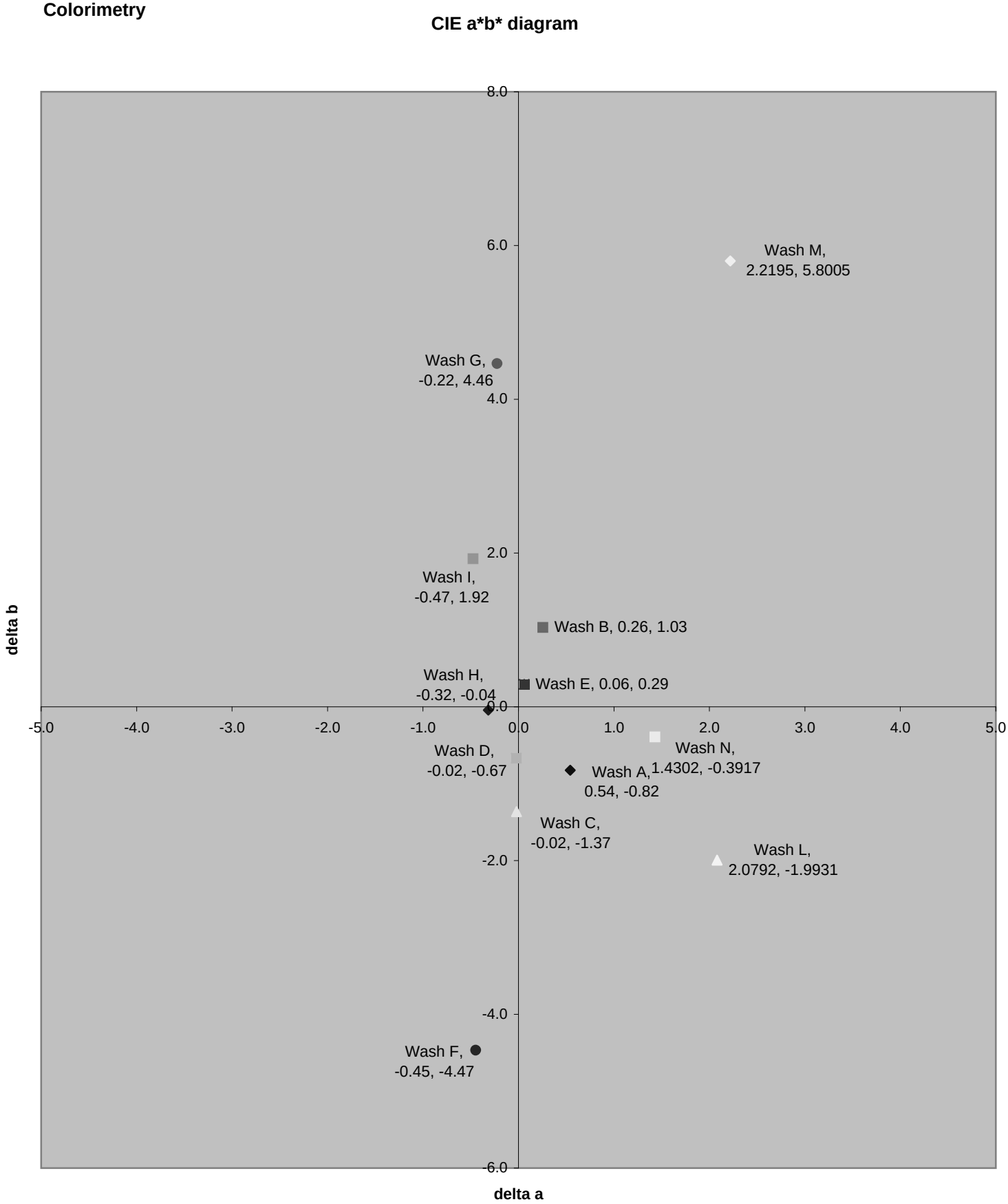
Limewash Experiment: Weatered and Rough-sawn New Wood

Colorimetry



Limewash Experiment: Weathered and Rough-sawn New Wood

Colorimetry



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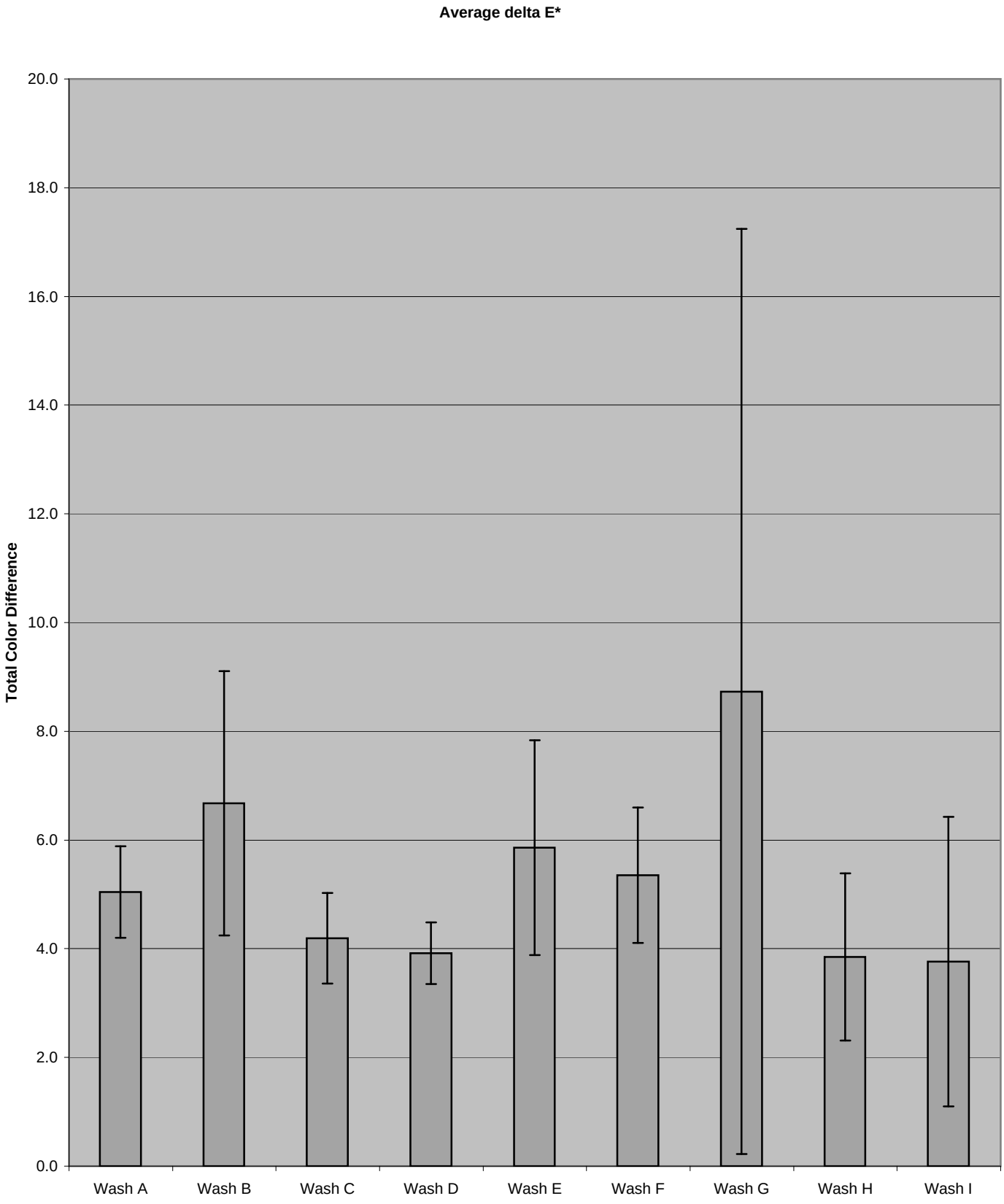
Limewash Experiment: Weathered Wood and Rough-Sawn New Wood



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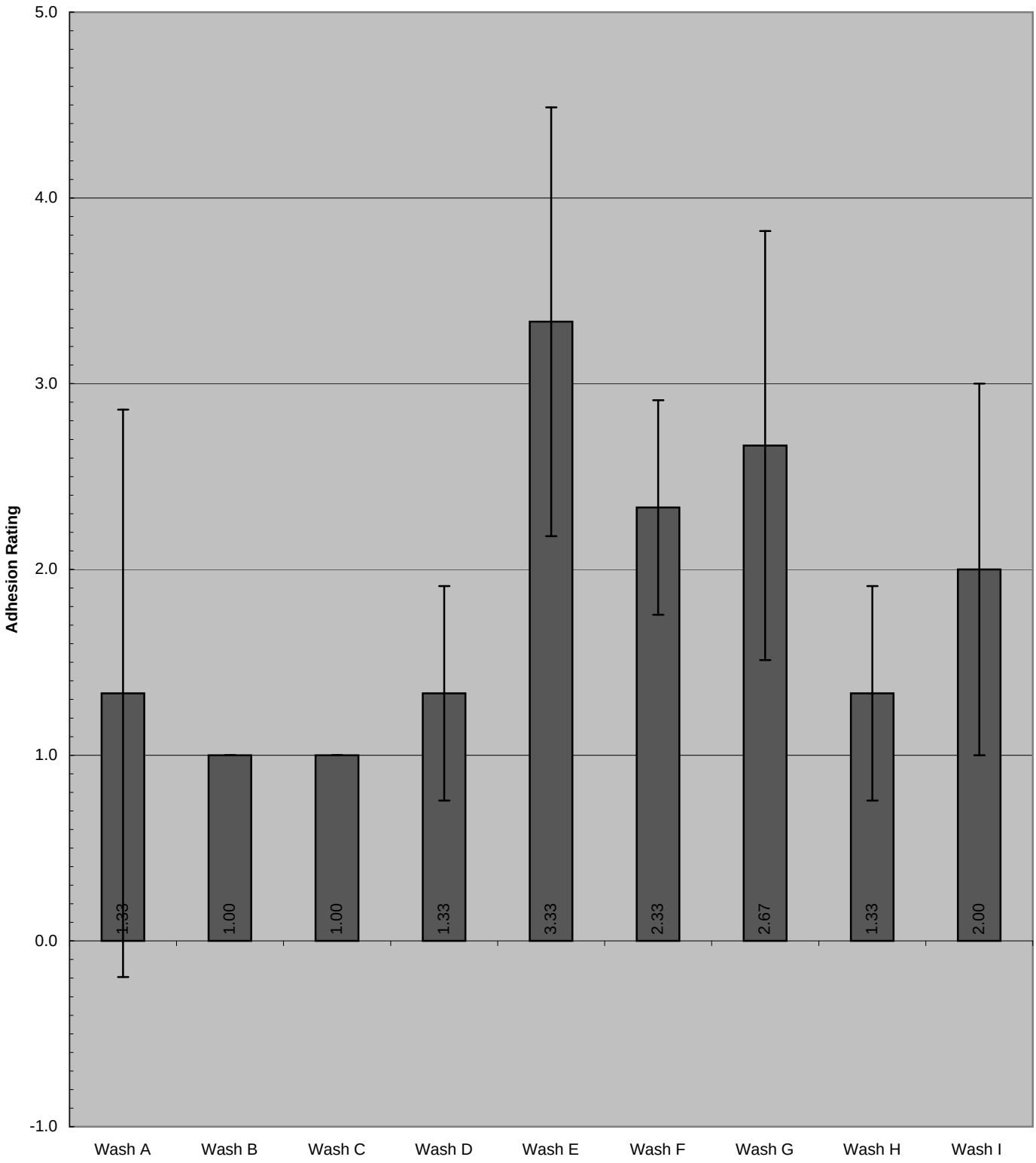
Limewash Experiment: Weathered Wood or Rough-sawn New Wood

Adhesion Test on QUV Samples

#	Tape			Average	Std. Dev.
W-002-A	3A		Wash A	1.33	1.53
W-003-A	1A		Wash B	1.00	0.00
W-004-A	0A		Wash C	1.00	0.00
			Wash D	1.33	0.58
W-019-B	1A		Wash E	3.33	1.15
W-020-B	1A		Wash F	2.33	0.58
W-021-B	1A		Wash G	2.67	1.15
			Wash H	1.33	0.58
W-046-C	1A		Wash I	2.00	1.00
W-047-C	1A				
W-048-C	1A				
W-049-D	1A				
W-050-D	1A				
W-051-D	2A				
W-078-E	4A				
W-079-E	2A				
W-080-E	4A				
W-083-F	2A				
W-084-F	3A				
W-085-F	2A				
W-100-G	4A				
W-101-G	2A				
W-102-G	2A				
W-123-H	1A				
W-124-H	2A				
W-125-H	1A				
W-131-I	3A				
W-132-I	1A				
W-133-I	2A				

Limewash Experiment: Weathered Wood or Rough-sawn New Wood



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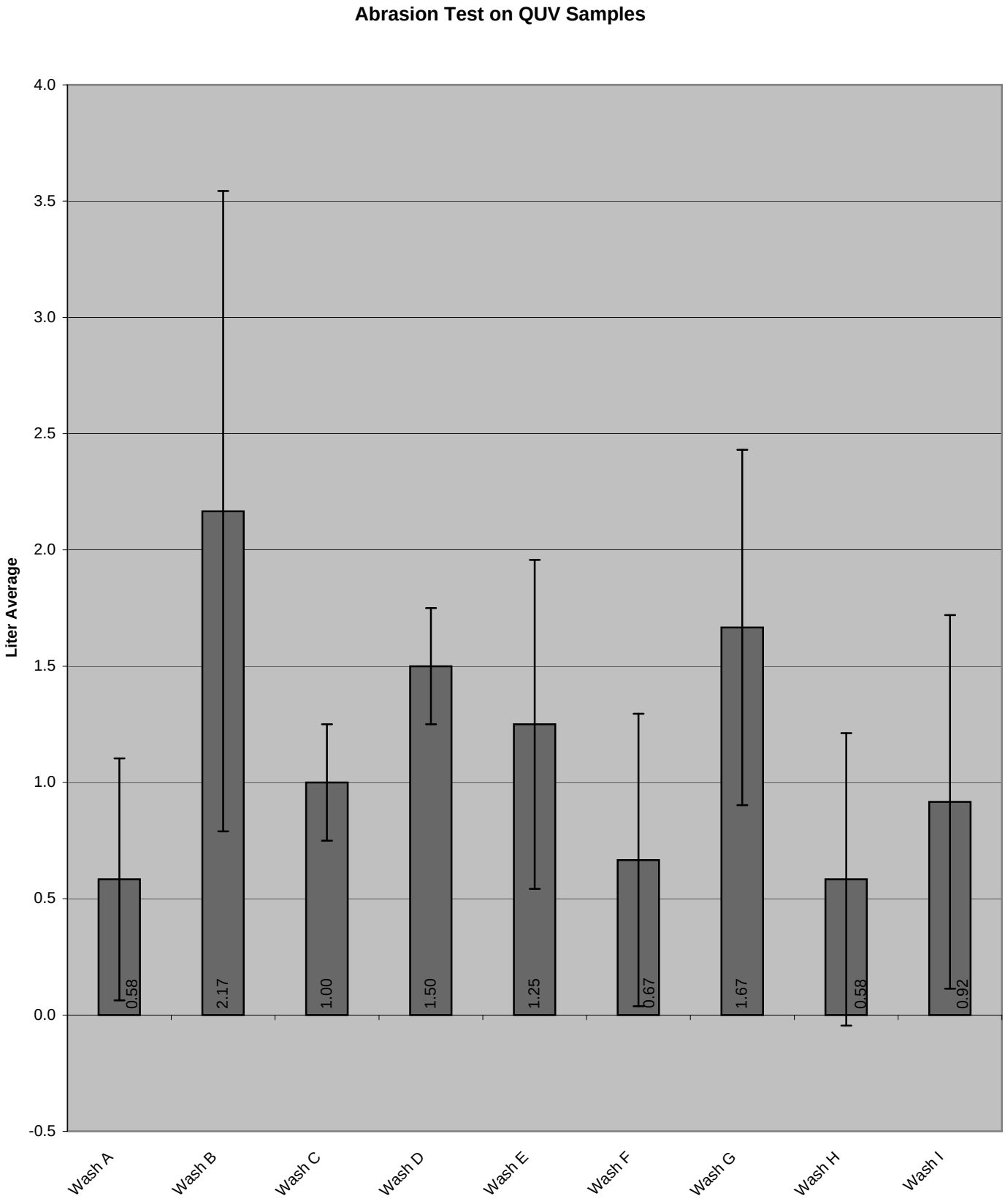
Limewash Experiment: Weathered Wood or Rough-sawn New Wood

Abrasion test on QUV Samples

#	Abrade			Average	Std. Dev.
W-002-A	1 L		**Wash A**	0.5833	0.5204
W-003-A	0 L				
W-004-A	.75 L				
				Average	**Std. Dev.**
W-019-B	.75 L		**Wash B**	2.1667	1.3769
W-020-B	3.5 L				
W-021-B	2.25 L				
				Average	**Std. Dev.**
W-046-C	1 L		**Wash C**	1.0000	0.2500
W-047-C	1.25 L				
W-048-C	.75 L				
				Average	**Std. Dev.**
W-049-D	1.5 L		**Wash D**	1.5000	0.2500
W-050-D	1.75 L				
W-051-D	1.25 L				
				Average	**Std. Dev.**
W-078-E	1.75 L		**Wash E**	2.6667	2.5042
W-079-E	.75 L				
W-080-E	5.5 L				
				Average	**Std. Dev.**
W-083-F	0 L		**Wash F**	0.6667	0.6292
W-084-F	.75 L				
W-085-F	1.25 L				
				Average	**Std. Dev.**
W-100-G	2.5 L		**Wash G**	1.6667	0.7638
W-101-G	1 L				
W-102-G	1.5 L				
				Average	**Std. Dev.**
W-123-H	1.25 L		**Wash H**	0.5833	0.6292
W-124-H	0 L				
W-125-H	.5 L				
				Average	**Std. Dev.**
W-131-I	1.25 L		**Wash I**	0.9167	0.8036
W-132-I	0 L				
W-133-I	1.5 L				

Limewash Experiment: Weathered Wood or Rough-sawn New Wood



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Limewash Experiment: Weathered Wood and Rough-Sawn New Wood

Overall Rating

	Rating	Adhesion	Abrasion	QUV	QUV-Adhesion	QUV-Abrasion	
Best	9	E	B	D, E, I	E	B	
	8	H	A*		G	G	
	7	F	G	H	F	D	
	6	A	D	F, G	I	E	
	5	D, G	C		H, D	C	
	4		I			I	
	3	B	E	C	A	F	
	2	C, I	H	A	B, C	A	
Worst	1		F	B		H	

	Samples	Adhesion	Abrasion	QUV	QUV-Adhesion	QUV-Abrasion	Sum
	Wash A	6	8	2	3	2	21
	Wash B	3	9	1	2	9	24
	Wash C	2	5	3	2	5	17
	Wash D	5	6	9	5	7	32
	Wash E	9	3	9	9	6	36
	Wash F	7	1	6	7	3	24
	Wash G	5	7	6	8	8	34
	Wash H	8	2	7	5	1	23
	Wash I	2	4	9	6	4	25

	Wash	**Total**					
Best	**E**	**36**					
	G	**34**					
	D	**32**					
	I	**25**					
	B	**24**					
	F	**24**					
	H	**23**					
	A	**21**					
Worst	**C**	**17**					

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8/30/2005