# The Effect of Ethylene Glycol and Sodium Borate Solutions on the Adhesion of Epoxy to White Oak and White Pine Samples.

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## Abstract

The search for low toxicity wood preservatives results in the use of products that may affect the adhesion of finishes and glues in wood construction. Ethylene glycol and sodium borate are two such products that have been used singly and in combination for their fungicidal qualities. This paper reports the results of tests of solutions of these compounds in varying concentrations. Results indicate that a 75% ethylene glycol/25% sodium borate solution has a marked detrimental effect on the adhesion of epoxy to white oak, and to a lesser extent reduces adhesion of epoxy to white pine. Other concentrations of ethylene glycol and water increase adhesion of epoxy to wood substrates. Recommendations are provided for the use of WEST SYSTEM(R) 105/206 epoxy on white oak and white pine that has been treated with various concentrations of these solutions.

## Introduction

With the heightened environmental awareness of today's society, both professional and amateur boat builders and restorers have begun searching for wood preservatives of minimal environmental and occupational safety impact. Wood preservatives of relatively high toxicity have been in use for decades, as a prophylactic in new construction and as a remedial treatment in repair and reconstruction. The effect of such preservatives on adhesion of finishes and glues is reasonably well known.

Both sodium borate and ethylene glycol solutions have been promoted as low toxicity preservatives for use in timber frame construction and marine applications, and as low toxicity fungicides and termaticides. The efficacy and limitations of these solutions in preventing wood deterioration is well documented. However, other than anecdotal experiences and the assurances of producers, little information documents the effects of ethylene glycol and sodium borate solutions on the adhesion of finishes and glues.

The Gougeon Brothers lab has adhesion data from seven years of standardized testing of various wood and epoxy combinations. Tests have included the use of WEST SYSTEM(R) epoxies as both adhesives and coatings. Relevant to the instant experiment, in 1991 Gougeon Brothers tested the effects of oil based, alcohol based and water based stains on the adhesion of epoxy coatings. These tests indicated that with oil based stains adhesion can be seriously jeopardized, while adhesion is satisfactory with alcohol and water based stains.

This paper relates the results of a preliminary test of WEST SYSTEM(R) 105/206 epoxy adhesion to substrates of white oak and white pine treated with solutions containing varying concentrations of ethylene glycol, sodium borate, or both. While the results described below are promising for the use of certain solutions in combination with WEST SYSTEM(R) 105/206 as a bonding or coating agent, further testing is needed to better report definitive effects on adhesion and bonding strength.

## Methodology

The Pneumatic Adhesion Tensile Testing Instrument (PATTI) manufactured by SEMicro Corporation is the standard instrument used by Gougeon Brothers to determine the adhesion strength of epoxies on various substrates. In addition to internal standardization within Gougeon Brothers labs, the PATTI conforms to the American Society for Testing and Materials 'Standard for Pull-off Strength of Coatings Using Portable Adhesion Testers' ASTM Standard D 4541-85(89). The ASTM standard provides the procedure used by Gougeon Brothers to determine adhesion strength of epoxies on various substrates.

Lengths of 1"X6" white pine and white oak panels served as the substrate for testing to provide an indication of adhesion in soft wood and hard wood. The panels received one of five treatments,

listed below.

1. Control - no treatment provided.
2. 75% ethylene glycol / 25% sodium borate
3. 50% (75% ethylene glycol/25% sodium borate) / 50% water
4. 50% ethylene glycol / 50% water
5. 100% ethylene glycol

Within each treatment group the panels were tested. Each solution was applied to the flat of the test panel by hand with a small paint brush to ensure maximum absorption. The panels dried at room temperature for three days prior to bonding the PATTI studs.

In summary, the PATTI applies an aligned and controlled force, applied by pneumatic pressure, to an aluminum cylinder (called the 'stud') attached to the surface being tested, until reaching a maximum force or failure. The PATTI provides a gauge that translates the pneumatic force into pounds per square inch of force. The attachment of the stud is controlled to ensure strict conformity between samples. The stud, about _" in diameter, is etched with WEST SYSTEM(R) 860 two step etching solution prior to bonding, then bonded to the surface being tested with the requisite epoxy, and allowed to cure appropriately. In this instance, WEST SYSTEM(R> 105/206 was used as the bonding agent, and allowed to cure at room temperature for two days prior to testing.

**Test Results**

Test results for the samples are presented as the average value of the three samples within each treatment group. The data present both the pounds per square inch (p.s.i.) of force applied at failure, and the percent of wood failure within the area of bonding (at increments of 5%). These measures provide both a quantitative measurement for comparison and a qualitative sense of the integrity of the bond.

| | Solution applied | Adhesion p.s.i. at failure | % Wood failure |
|---|---|---|---|
| White Oak | | | |
| 1. | Control | 1625 | 68 |
| 2. | 75% e. glycol/25% s. borate | 579 | 10 |
| 3. | 50% (75% / 25%)/50% water | 1285 | 48 |
| 4. | 50% e. glycol/50% water | 1774 | 80 |
| 5. | 100% e. glycol | 1380 | 38 |
| White Pine | | | |
| 1. | Control | 661 | 100 |
| 2. | 75% e. glycol/25% s. borate | 511 | 100 |
| 3. | 50% (75% / 25%) /50% water | 620 | 100 |
| 4. | 50% e. glycol /50% water | 701 | 100 |
| 5. | 100% e. glycol | 756 | 100 |

**Discussion and Conclusions**

The results presented herein cannot be viewed as definitive, but do provide good illustration of certain areas where the ethylene glycol and or sodium borate may be appropriately used. This test examined only white oak and white pine, and while indicative of the results that may be found in other woods, one cannot extrapolate with confidence from these results to other woods.

Certain results also do not lend themselves to an intuitive explanation. For example, many plausible reasons could be presented for increased adhesion under certain test solutions, but none can be validated based on the results presented herein.

We have no explanation for why the 75% ethylene glycol/25% sodium borate solution results in such diminished adhesion, on both the soft and hard wood. A better understanding of this phenomenon requires further testing, with particular attention to the testing of various sodium borate solutions alone and in combination with ethylene glycol. It may be that the sodium borate leaves a residue that affects adhesion, but this interpretation is speculative.

Further testing of the 75%/25% solution would be of value, given that some recommend the use of these two chemical additives in common to attain greater penetration of the wood treated (due to the effect of the ethylene glycol) and longer lasting preservative qualities (due to the effect of the sodium borate). Indeed, certain proprietary products tout the benefits of this combination of preservatives.

Even in the absence of statistical analysis, it is clear that application of the 75% ethylene glycol/25% sodium borate solution results in a significant loss of adhesion. This is especially true with the white oak substrate, where the loss of adhesion is sufficient to jeopardize bonding for structural purposes. The minimal wood failure with the 75%/25% solution and white oak substrate

also calls into question the applicability of this combination even for applications limited to coatings.

With any but the 75%/25% solution and white oak, one may safely use WEST SYSTEM 105/206 for coating applications. On white oak treated with the 50% e. glycol/50% water solution, one may safely use WEST SYSTEM 105/206 for bonding applications.

The situation with respect to the white pine is less definitive. The loss of adhesion under the 75%/25% solution is less dramatic than with the white oak, and the white pine still shows 100% wood failure. Even so, in structural bonding applications one would be wise to adopt a conservative approach and avoid using the 75%/25% solution. With any of the solutions and white pine, one may safely use WEST SYSTEM 105/206 for coating. With any but the 75%/25% solution and white pine, one may safely use WEST SYSTEM 105/206 for bonding applications.

Given the differing bonding and solution absorbing characteristics of various wood substrates, it is unwise to extrapolate from these results to other woods. Those interested in using sodium borate or ethylene glycol solutions as preservatives in combination with other woods are advised to test samples with the solution to be used.

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