A Study of The Properties of Commercial Liquid Hide Glue and Traditional Hot Hide Glue in Response to Changes in Relative Humidity and Temperature

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Abstract
Commercial liquid hide glue has been used for many years in the field of furniture conservation as a substitute for traditional hot hide glue. To maintain its liquid state and prolong its shelf life, liquid hide glue contains one or more preservatives and a gel depressant, which may significantly affect its aging characteristics. Franklin International, the primary manufacturer of liquid hide glue in the U.S., recommends it not be used for wooden objects which will be exposed to conditions where the relative humidity exceeds 70%. This research project attempts to identify the conditions under which it is advisable to use one glue rather than another through glue strength testing and evaluation of glue versus wood failure on the sample joins tested.

Introduction
This study began with a survey of the existing literature on hide glue adhesives, however, the bulk of the research consisted of measuring the strength of liquid hide glue and hot hide glue joins under varying RH and temperature conditions. The premise was that the addition of a gel depressant and/or preservative could substantially change the physical properties of cured liquid hide glue versus hot hide glue. The properties of particular concern to furniture conservators are the chemical and physical stability of the glue over time, the strength of the glue bonds, sensitivity to RH and temperature changes (especially when the glue is used to hold structural and supporting members) and reversibility.

Data on the specific physical differences between liquid hide glue and hot hide glue is relevant to the furniture conservation field, and to conservators of wood objects. There is generally a perceived trade-off between the convenience and long working time of liquid hide glue and the proven, reliable performance but longer preparation and shorter pot life of hot hide glue.

The strength of a glue can be measured in a quantitative, repeatable fashion. Standard measures of glue strength in the adhesives industry involve subjecting glue joins to either tensile or compressive force. In the United States the American Society for Testing and Materials (ASTM) provides guidelines for evaluating a wide variety of substrates and adhesives. Recommended tests for wood joins are listed in Table I (1):

TABLE I

Property Tested	Title	Test Specification #
Mechanical Strength – Shear	Method of test for strength properties in shear by compression loading	ASTM D905-49
Mechanical Strength – Tensile	Method of testing cross-lap specimens for tensile properties of adhesives	ASTM 1344-57
	Method of test for tensile properties of adhesive bonds	ASTM-897-49

A related ASTM test (ASTM D 2370-68) for elongation and tensile strength of free films of paint, varnish, lacquer and related products could provide a relevant stress/strain curve as well (2).

A discussion (3) with Mr. Hugh Evans, wood Technologist in the Applications Laboratory in the Industrial Adhesives Division at Franklin International, indicated that Franklin routinely tests wood glue strength with an Instron testing machine which measures shear strength based on the ASTM D-905 test. The tests are run at room temperature (75 degrees F.) and 150 degrees Fahrenheit. Maple (*Acer* sp.) blocks are generally used, and desired results are approximately 3000 pounds per square inch pressure and 50% wood failure. The blocks are left to sit from four to seven days after preparation, before testing. According to Mr. Evans, accelerated aging tests are rarely conducted.

ASTM D 905-89 (the 1989 version of ASTM D905-49) clearly specifies the type of wood (maple), the calculation of the proper moisture content for the maple, the method of preparation of the sample blocks, and the test conditions.

At Franklin International, once the blocks have been tested for the strength of their glue joins they are routinely examined for the degree of wood failure versus glue failure at the broken joints.

Literature Review

There is only a limited amount of current conservation-related information on the strength characteristics of hide glues. However, results from tests of other adhesives for various other conservation applications can provide insight into testing methods and the problems associated with adhesives testing. Pertinent adhesives tests and adhesives research related to animal hide glue is also available from glue industry literature.

Information on accelerated aging is also limited, however, a paper by Down published in 1984 in *Adhesives and Consolidants, IIC Preprints of the Contributions to the Paris Congress* (4) discussed the results of testing the epoxy adhesive Araldite 6010/HY951 at five elevated temperatures. The actual rate of yellowing of Araldite 6019/HY951 was found to be 31 times faster than predicted by accelerated tests so accelerated aging tests were then abandoned in favor of natural aging.

A paper by Bradley (2), also writing for the Adhesives and Consolidants Congress in 1984, provides a helpful reference as it reviews the various mechanical methods for testing adhesives on numerous different substrates. For wood, measurements made in shear and compression are recommended.

The "Adhesives Handbook" indicates which ASTM test to use when examining specific properties of various adhesives. ASTM D905-49 is recommended for shear strength testing under compression, of wood and similar materials: "Higher shear strengths are obtained than for tension load specimens due to improved distribution of stresses." (1) This handbook also has a helpful table listing resistance ratings of 89 adhesives to a variety of conditions. Animal/Fish glue has a "Good" rating for resistance to cold, aliphatic hydrocarbons, aromatic hydrocarbons, chlorinated hydrocarbons, mineral oils, greases, and shear stress. It has moderate resistance to heat; fair resistance to biodeterioration; and poor resistance to water and alcohols.

A discussion of hide glue degradation can be found in "Adhesion and Adhesives Volume 1": "In general it is both undesirable and unnecessary to heat glue solutions above 60 C. At 60 C. the viscosity and jelly strength may decrease by 0.2 – 1.0% per hour, depending on the grade and on the bacterial enzymes present. At 80 C. the degradation is about four times as great as at 60 C. … At temperatures near 40 C. thermal degradation is very slow but degradation may still be rapid if bacteria are present. (5) This book also provides information on hide glue modifying agents.

In 1973 a series of tests were conducted on a series of typical wood joins using casein, urea, animal and phenol resorcinol glues. Dry block shear tests and accelerated soaking-drying delamination tests were conducted on laminated red oak beams. The joints were conditioned at 80 degrees F. for 16 hours, but no test procedures were described. In a different test series seven types of joints were glued with 10 different adhesives and exposed for three years to a repeating cycle of four weeks at 90% RH, followed by four weeks at 30% RH Maple was used and the temperature was kept at 80 degrees F. The results showed that "In general the side grain joint resulted in the least bond strength reduction, even though two glues had practically failed completely by the time the three year period was up … These data show definitely that certain adhesives are adequate for some joint designs but inadequate for others." (6)

Research Objective

The primary objective of this study was to identify conditions under which it is more advisable to use one glue rather than another and to identify any drawbacks associated with either of the glues. This is particularly pertinent given that liquid hide glue is not recommended for conditions of display or storage where the RH regularly exceeds 70%.

To help achieve this objective, glue strengths were measured through the use of controlled compression tests for identically prepared samples (replicates) which had been kept in enclosed environments at specific RH and temperature levels.

After the joins were broken a comparison of the amount of wood failure versus glue failure was conducted to determine whether there was a significant change in the amount of wood failure between glues, and between the controlled RH and temperature levels. This type of comparison is of particular value to conservators: if a glued join undergoes stress and the glue is much stronger than the wood, it will result in failure of the wood – a very undesirable occurrence in an art object. On the other hand, if the glue is too weak it may not hold the object together properly, which could again result in undesired damages.

The percentage weight change of each block over the period of conditioning was also calculated. The change in the weight of the maple samples indicated the amount of physical effect the conditioning environment had on the blocks, and potentially on the glue joins.

Glue Block Preparation Procedures

The maple samples were prepared according to the guidelines of the ASTM D905-89 test to ensure repeatability. Preparations included conducting an oven-dry weight test to allow calculation of the moisture content of the maple. (8) Then, using the calculated moisture content figure of 8%, the specific gravity of each 11 15/16 x 2 x ¾″ block was determined. The purpose of this specific gravity measurement was to ensure that blocks intended for testing were equal to or greater than the calculated weight of blocks of equal size with a specific gravity of 0.65 and a moisture content of 8%.

After the moisture content and specific gravity was calculated, and the blocks were paired up, the liquid hide glue and hot hide glue samples were prepared following comparable procedures. The hot hide glue was brushed on hot, directly out of the glue pot, coating both gluing surfaces. Two heat lamps were used to warm the surfaces of the blocks prior to brushing on the glue. The liquid hide glue was brushed on both gluing surfaces at room temperature, directly out of the squeeze bottle container.

A new, unopened bottle of Franklin Liquid Hide glue with an expiration date of January 1991 was used for the liquid hide glue blocks. A granular hide glue from Conservation Materials, catalog number 2303-001(8) was prepared according to the recommendation of Ron Kormanek, Vice President of Milligan and Higgins, a U.S. manufacturer of hot hide glue. He advised that for gluing up maple blocks a “medium test” product is desirable, and in general the harder the wood the more dilute the glue required. (9) The following recommended procedures were followed for preparation of the hot hide glue:

1. Measure one part glue to two parts water by weight.
2. Add the glue to the cold water.
3. Let the glue swell.
4. Put the glue mixture in a double boiler and heat to approximately 104 degrees F.
5. Use at 140 degrees F.

After the glue was applied, the paired blocks were then clamped down to a maple workbench using two large five-inch jaw bar clamps for each pair of 11 15/16 x 2 x ¾″ blocks, which, based on calculations by Bruce Hoadley (10), provide approximately 550 lbs. of pressure each. Before clamping a pine block of approximately the same dimension was placed on top of each pair to distribute the pressure. The clamps were left in place for 24 hours.

After the clamps were removed the glued pairs were cut to the proper offset size of 2 x 1 ¾ x ¾″ using a table saw equipped with a ¼″ dado blade. The final result was 40 test blocks with a ¼″ offset in the grain direction.

The 40 blocks were then numbered, weighed on an Ohaus GT 4800 digital laboratory scale which recorded to the nearest 0.001 gram, and randomly assigned to controlled environments using a random number table. The blocks were periodically reweighed on the same scale, initially on daily basis, and then every two or three days as the degree of weight change slowed. All weights were recorded to allow tracking of the weight changes over time.

Three different relative humidity values – 32%, 50%, and 84% — and one elevated temperature – 150 degrees Fahrenheit – were chosen for conditioning for the following reasons:

- 50% RH is the level recommended for museums with collections of mixed materials (11), and it is approximately the RH at which the Winterthur Furniture Conservation Lab is maintained. This RH can also be maintained by the use of a dessicator jar and magnesium nitrate saturated salts available from Fisher Scientific. The ten blocks conditioned at 50% RH for this test were kept in an undisturbed area of the Winterthur Furniture Conservation Lab. A humidity indicator card made by Multiform Dessicants Inc. was kept with the blocks and indicated that the RH remained at approximately 50% for the duration of the test.

- 32% RH is below the recommended RH for collections containing wooden objects, yet is a realistic level for heated museums and historic houses during the winter heating season (11).

32% RH can be maintained by the use of a dessicator jar and calcium chloride hexahydrate saturated salts purchased from Fisher Scientific (12). A humidity indicator card kept with the blocks in this environment showed the humidity remained approximately 32%.

- 84% RH is above the recommended RH for collections containing wooden objects, yet is a realistic level for museums and historic houses in many geographic areas in the United States during the summer months. This RH level can be maintained by the use of a dessicator jar and potassium bromide saturated salts purchased from Sigma Chemical Company (12). A humidity indicator card kept with the blocks in this environment showed the RH remained at approximately 84%.

- No information was found on reliable accelerated aging for wood and glue joins, but Franklin International conducts its compression testing on wood samples which have been kept at 150 degrees F. for 4 to 7 days to test glue strength after prolonged heating (3). Use of this 150° F. temperature for testing provides comparative data. In addition it is a realistic climate for furniture stored in an attic space in an uninsulated historic house during a hot summer.

A total of 20 samples of each glue type was tested, as shown in Table II:

TABLE II

	Room Temp			150 degrees F.
	32% RH	50% RH	84% RH	0% RH
Liquid Hide Glue	5	5	5	5
Hot Hide Glue	5	5	5	5

The samples remained in their conditioning environments for 36 days before being removed for testing. At the end of the conditioning period all the blocks had stabilized in weight except the blocks in the 84% RH environment: a few of the blocks in this high RH environment still appeared to be gaining weight very slowly.

Shear Test Procedures

After being removed from the conditioned environments, each test sample was weighed again and the final weight was recorded. The ten blocks from each set were then tightly wrapped together in five layers of polyethylene and taped closed. The blocks were transported in their packages to Franklin International in Columbus, Ohio for testing. Because of the necessity of traveling to conduct the shear test the blocks were out of their conditioning environments 19 hours before testing was conducted.

Donald Grooms, the lab technician in the Applications Laboratory of the Industrial Adhesives Division of Franklin International, operated the Instron model 1125 (13) for the shear test. This is the machine used for all the shear testing conducted by the Applications Laboratory, and it is in operation on a daily basis.

The values for the shear test were recorded by the Instron testing machine in total pounds of pressure at the point at which the glue joint broke. This value was then divided by the area of the join in square inches to obtain pounds-force of pressure per square inch (7).

The surface of the broken joins were then examined to determine the percentage of wood failure using a gridded transparent ruler. Each square of the grid which covered an area of wood failure was counted, and the total number of squares containing wood failure were then divided by the total number of gridded squares (352) on the ruler. Every broken join (a total of 40) was measured using this method, which provided a close estimation of the amount of wood failure in each join.

Evaluation of the Results

All error was minimized as much as possible in running the compression tests: there was no change in machine operation between the first to the fortieth sample so the order in which the samples were tested did not affect the results; and the same technician ran all the test samples.

Appendix A contains the raw data for the shear test, the percentage of wood failure and the percentage weight change for each block in each conditioning environment.

Statistical analysis was conducted to determine whether each glue type or environment affect he three outcome variables (shear strength, percentage of wood failure and percentage weight change). Analysis of Variance (ANOVA) with BMDP program 2V was the statistical measure used: the null hypothesis was that all group means are equal.

The resulting analysis showed that the most overwhelming factor affecting glue strength in this test was environment. (relative humidity and heat), rather than glue type. There is a statistically significant difference between the environmental conditions, with a p value of less than 0.01 – in other words, the probability of obtaining these results through chance alone is less than 1%. (15). The high RH condition of 84% and the high temperature of 150 degrees F. were shown to significant reduce glue strength as measured in the shear test. The type of glue used is comparatively less significant, in part because of the interaction with the environment, although hot hide glue was shown to be less sensitive to environmental changes than liquid hide glue with a p value of less than of 0.01 (15).

In predicting the percentage of wood failure of the join, environment is again the most significant factor, with a p value of 0.01 (15). At room temperature and 50% RH the wood fails more often than the glue under shear testing. At 150 degrees F. the opposite is true, the glue fails more often than the wood.

The results of the analysis of the weight change in the wood agree with what is intuitively evident: the environment is the significant factor in determining weight change (with a p value of 0.01). The glue type has no significant effect on the amount of weight gained or lost by the wood blocks (the p value is 0.15) (15).

It is also helpful to study the seams and standard deviations for each group of blocks under each variable condition. That information is shown in Table III. The data in Table III is also presented in graph form in Appendix B.

TABLE III

Variable	Grouping	Mean	Standard Deviation
			Liquid Hide Glue
Shear	32% RH	3833.2	922.0
Strength	50% RH	4173.6	293.0
PSI	84% RH	1143.2	229.4
	150 F.	1403.2	433.5
			Hot Hide Glue
Shear	32% RH	3720.0	267.4
Strength	50% RH	3640.4	624.8
PSI	84% RH	2636.6	315.5
	150 F.	2356.8	562.6
			Liquid Hide Glue
% Wood	32% RH	29.8	27.2
Failure	50% RH	62.0	34.8
	84% RH	2.0	2.0
	150 F.	35.2	24.0
			Hot Hide Glue
% Wood	32% RH	24.0	36.3
Failure	50% RH	59.8	33.9
	84% RH	13.7	14.1
	150 F.	22.0	25.7
			Liquid Hide Glue
% Weight	32% RH	0.03	0.03
Change	50% RH	1.03	0.12
	84% RH	6.09	0.20
	150 F.	-7.29	0.10
			Hot Hide Glue
% Weight	32% RH	-0.07	0.12
Change	50% RH	0.88	0.14
	84% RH	6.15	0.70
	150 F.	-7.62	0.09

Note: There were five replicates in each set of variable conditions.

A result of interest to conservators is the difference in mean PSI between liquid hide glue at 50% RH and the mean PSI of the liquid hide glue blocks conditioned at extreme temperature and relative humidity. The liquid hide glue mean PSI of 4173 at 50% RH indicates a very strong glue bond, but the strength drops off sharply at 84% RH (1143 PSI) and 150 degrees F. (1403 PSI). While the standard deviations around these means are relatively large, these results still indicate that liquid hide glue lost more than two thirds of its strength under extreme environmental conditions.

In contrast, hot hide glue had a lower shear strength of 3640 PSI at 50% RH, which dropped down to 2636 PSI at 84% and 2357 at 150 degrees F. Thus, in this test, hot hide glue lost approximately one third of its strength under extreme conditions.

An intriguing comparison can be made for percent wood failure at 84% RH between the two hide glues. A 2% wood failure value at this high humidity indicate that the hide glue join tends to fail completely under shear pressure – a finding consistent with Franklin Industries' caution not to use liquid hide glue if the object will be exposed to high RH conditions. The hot hide glue blocks tested had a 13.7% mean wood failure at 84% RH. The wood failure results in combination with the shear strength test indicate that marked glue degradation occurs at high RH, and that liquid hide glue is more greatly affected than hot hide glue.

Conclusion

The results of this testing reinforce the importance of maintaining a controlled environment for the display and storage of wood objects. The most critical factor in the strength and stability of the 20 liquid hide glue and 20 hot hide glue joins was the environment.

Based purely on strength characteristics this testing indicates that liquid hide glue is the glue of choice for repairing a join which will undergo significant stress, such as the structural join of a chair in regular use. But, more importantly, that decision must also take into consideration the environmental conditions. Under normal conditions of 50% RH and room temperature liquid hide glue provides the strongest bond. However, hot hide glue proved to be the more stable of the two glues under extreme conditions of high heat or high humidity, and thus would be the more desirable choice if fluctuating environmental conditions are anticipated.

It is also important to consider whether a very strong bond is desirable, especially if it is coupled with a higher percentage of possible glue failure. In instances where the glued area will not be subjected to excessive stress, the slightly lower strength, lower percentage wood failure hot hide glue is more appropriate.

Future Areas for Research

At the time of publication the last step of this research had not been completed. An assessment of the degree of glue penetration into the maple is planned. The method will entail randomly cutting small sections from two areas of each broken join, for a total of 80 samples. These samples will be cast in clear polyester resin and the degree of penetration of the glue into the wood will be measured using the calibrated ocular in the Nikon Labophot Episcopic microscope owned by the Winterthur Furniture Conservation Laboratory. The results of this last step may provide one indication of the degree of reversibility of each glue. It is predicted that the more deeply a glue penetrates into the wood, the more difficult it will be to remove.

Because this initial research indicates that significant changes in the hide glue occur at extremes of heat and RH, future research into hide glues might involve using a greater number of controlled environments, such as 50%, 60%, 70% and 80%, to determine if there is a point at which glue strength drops off dramatically or whether the change is gradual. Other variables to incorporate into testing are high heat in combination with controlled humidity conditions. An added factor to consider in these tests is the use of RH recorders which are more accurate than the humidity indicator cards.

The hot hide glue used in this testing was fresh. Yet in real life many conservators use glue that may be several (or more) days old. Another aspect of future testing could be a comparison of the strength characteristics of fresh hot hide glue versus aged hot hide glue. And testing could also incorporate hot hide glues of differing gram strengths.

An additional area of possible future study could involve the identification of the proprietary materials in liquid hide glue through the use of a variety of analytical equipment. One step has already been taken in that direction: X-Ray Fluorescence Analysis (XRF) was performed by Dr. George Reilly, Head, Scientific Research, Winterthur Museum, on two samples of liquid hide glue (14). Two sources were used for the analysis; a Cadmium 109 source and an Americium 241 source. Both sources revealed the presence of zinc in measurable quantities in the sample of fresh Franklin liquid hide glue, while the old sample (taken from a previously unopened can more than 45 years old) had no inorganic material present. Further research could be conducted to determine the function of zinc in liquid hide glue – it may be present in a salt form to act as a gel dispersant; it may function as a preservative; or it may act as a “drier.” Zinc is just one example of additives which could significantly affect the strength and aging properties of liquid hide glue.

Acknowledgments
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A special measure of appreciation is due to Hugh Evans, Wood Technologist, and Donald Grooms, Technician, in the Applications Laboratory, Industrial Adhesives Division, Franklin International. Their willingness to make the testing machine available, as well as offering their time to run the shear tests, meant that this project could be completed accurately and to the ASTM D905 standards.

ENDNOTES

1. Shields, J., "Adhesives Handbook," compiled by SIRA for the Ministry of Technology, London: Butterworths, 1970, p. 277.

2. Bradley, Susan, *Adhesives and Consolidants, IIC Preprints of the Contributions to the Paris Congress* (2-8 September 1984)

3. Evans, Hugh, Wood Technologist, Applications Laboratory, Industrial Adhesives Division, Franklin International, personal communication, 1989.

4. Down, Jane L., *Adhesives and Consolidants, IIC Preprints of the Contributions to the Paris Congress* (2-8 September 1984), p. 18-20.

5. Houwink, R. and G. Salomon, *Adhesion and Adhesives Volume 1*, Amsterdam London New York: Elsevier Publishing Company, 1965, p. 155; 158.

6. Selbo, M.L., *Adhesives Age*, October 1973, p. 38.

7. *ASTM D905-89*, American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19130

8. A conversation between Gregory Landrey and a representative of Conservation Materials revealed that the gram strength of the hot hide glue granules sold through Conservation Materials is not known, although they believe it to be a medium test product. Personal communication, Gregory Landrey, 1989.

9. Kormanek, Ron, Vice President, Milligan and Higgins division of Hudson Industries, personal communication, 2-22-90

10. Hoadley, Bruce, *Fine Woodworking*, Volume 2, No. 1, Summer 1977, p. 48

11. Thomson, Garry, *The Museum Environment 2nd Edition,* London: Butterworths, c. 1986, p. 88

12. Thomson, Garry, *The Museum Environment 2nd Edition,* London: Butterworths, c. 1986, p. 113
    Note: to prepare the saturated calcium chloride hexahydrate salt a total of 374.5 grams of CaCl.6H2O was mechanically stirred into 100 ml. of water. After all the salt had dissolved the solution looked cloudy and viscous. The solution was placed in the bottom of a glass dessicator jar and within 24 hours large salt crystals had formed along the lower sides of the jar – a clear indication that the solution was saturated. A slightly modified procedure was followed for the potassium bromide saturated salt solution with a total of 500 grams of KBr stirred into 1000 ml. of water at low heat.

13. "Guide to Advanced Materials Testing," Instron Corporation, c. 1987, p. 42
    Specifications for Model 1125: "Floor Model Universal Testing Instrument with 20,000 lbs. or 10,000 kg. or 100kN capacity and speed range 0.002 to 20 in/min. or 0.05 to 500 mm/min. or 0.0002 to 40 in/min or 0.05 to 1000 mm/min."

"The 1120 series instruments provide unmatched accuracy through a unique combination of solid-state strain gage load weighing, closed loop digital drive and rigid load frame. As a result, load weighing accuracy is + 0.5% of indicated load or + 0.25% of the range in use, whichever is greater, for all standard load ranges."

14. Analysis conducted November 7, 1989 in the Analytical Lab at the Winterthur Museum, Winterthur, Delaware.

15. Reedy, Terry and Chandra Reedy, "Statistical Analysis on Art Conservation," Marina del Ray: Getty Conservation Institute, 1988, p. 39: "The probability of getting a ration at least as far from zero as that observed (given chance alone) is called the *p value*. It is standard practice, but not mandatory, to reject the hypothesis when the p value is less than either 0.05 (one chance in 20) or 0.01 (one chance in 100), depending upon how conservative one wants to be."

APPENDIX A
Wood Block Test Data
Twenty Hot Hide Glue Blocks and Twenty Liquid Hide Glue Blocks

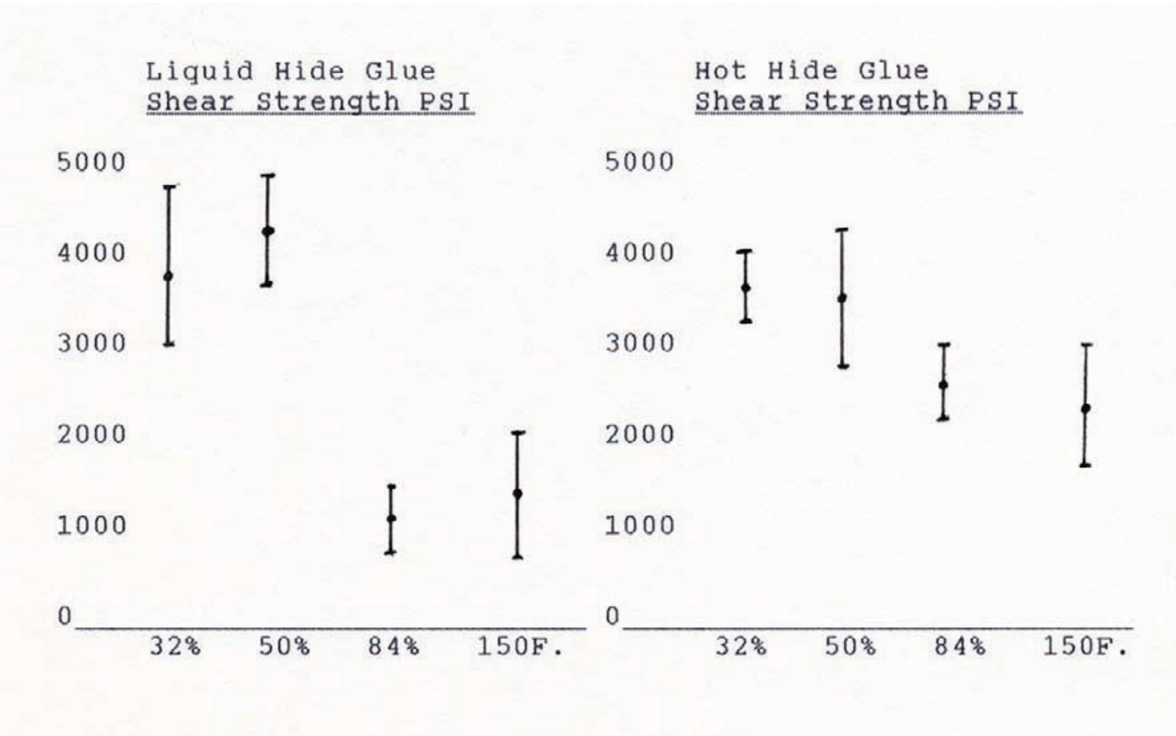
	Shear Point PSI	% Wood Failure	% Weight Change
Liquid Hide Glue/50% RH			
	4000	82.9	1.03
	4467	92.6	1.19
	4467	24.1	0.98
	3800	24.1	0.87
	4134	86.4	1.08
Hot Hide Glue/50% RH			
	3467	11.0	0.74
	3067	82.1	1.01
	4267	54.3	1.05
	3067	100	0.83
	4334	51.7	0.77
Liquid Hide Glue/32% RH			
	4633	63	-0.01
	4400	30.1	0.02
	2333	0	0.04
	3600	6.0	0.04
	4200	50	0.07
Hot Hide Glue/32% RH			
	3567	12.5	0.04
	3333	3.7	0.02
	3933	4.0	-0.06
	3967	88.6	-0.27
	3800	11.1	-0.06

APPENDIX A

	Shear Point PSI	% Wood Failure	% Weight Change
Liquid Hide Glue/150 degrees F.			
	833	9.1	-7.39
	1633	47.1	-7.34
	1167	50.0	-7.13
	1967	9.6	-7.33
	1417	60.0	-7.28
Hot Hide Glue/150 degrees F.			
	1967	0	-7.66
	2234	5.1	-7.54
	2383	4.8	-7.73
	3300	50.0	-7.67
	1900	50.0	-7.49
Liquid Hide Glue/84% RH			
	1516	4.5	6.07
	900	0	6.15
	1067	3.4	6.39
	1167	2.0	6.00
	1066	0	5.84
Hot Hide Glue/84% RH			
	2467	4.8	5.4
	2333	9.6	5.63
	2433	1.1	6.14
	2917	36.9	7.19
	3033	16.2	6.4

APPENDIX B

Graphs of Means and Standard Deviations Based on the Data in Table III



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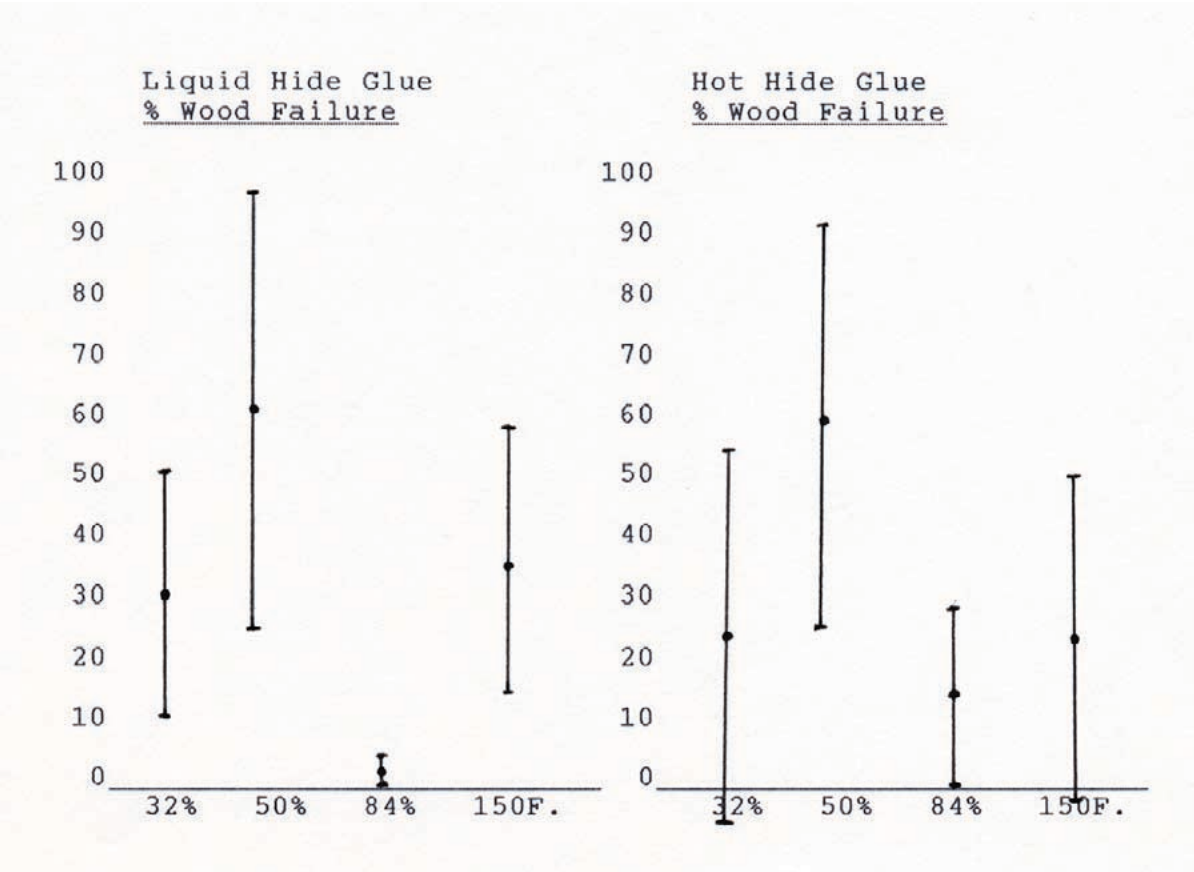

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