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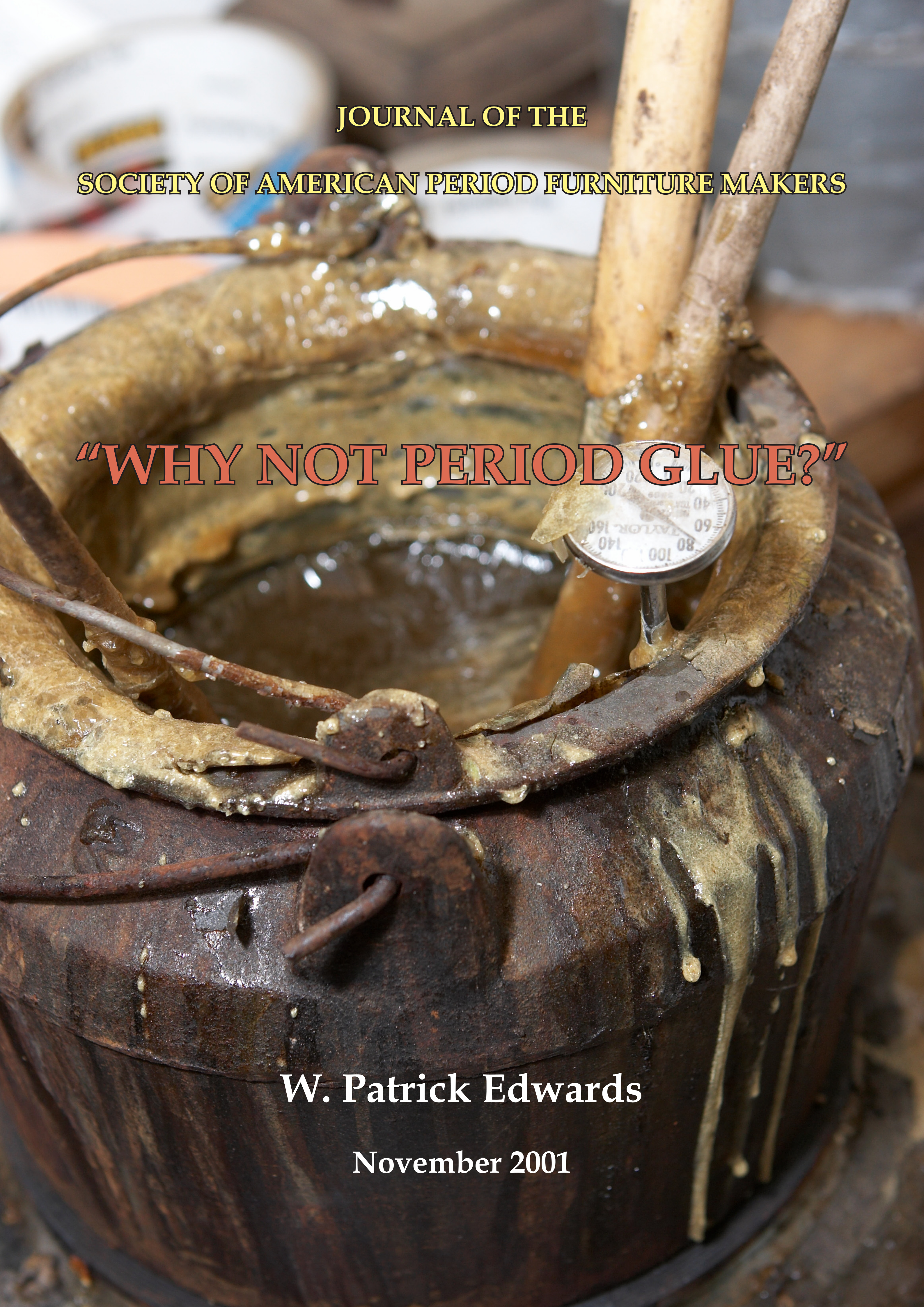

"WHY NOT PERIOD GLUE?"

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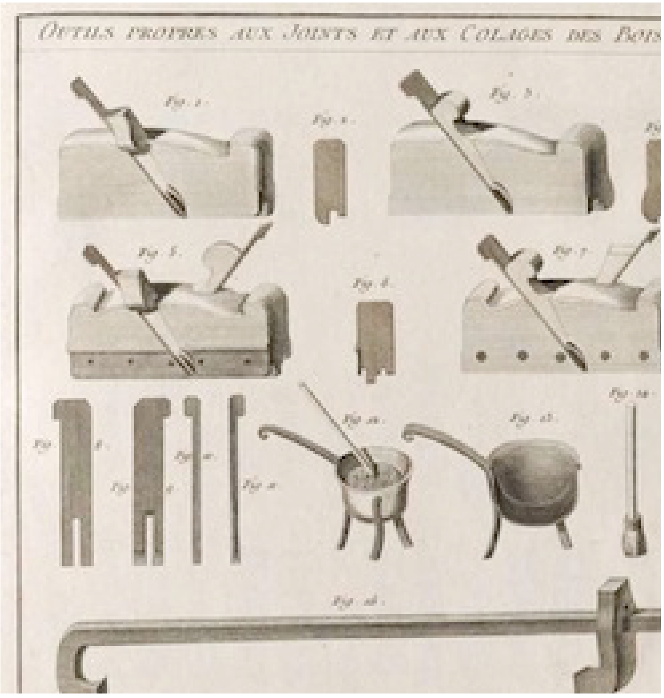
Period furniture makers today have a variety of traditional and modern adhesives available, and it is sometimes difficult to choose the perfect glue for the job. However, a careful examination of the working characteristics of these glues makes it evident that the best choice is traditional animal protein hydrolyzed collagen glue, known simply as "hot glue." This paper will present many of the facts and some of the fiction surrounding the most commonly used furniture glue in history.

HISTORY OF COLLAGEN GLUE



Glue pot among other tools
L'art Du Menuisier - Roubo, Plate 18 - 1769

The use of animal collagen glue by man has been traced back over 8000 years, with the discovery of artifacts in caves near the Dead Sea which contain this material as an adhesive. Egyptians used collagen glues 4000 years ago. Historical records indicate large specialized glue factories were established in Europe at the end of the 17th century and America at the beginning of the 19th century. Hot glue was used by furniture makers exclusively until the start of the 20th century, when the development of synthetic glues began to change the market for this product. American furniture makers were some of the first to abandon the use of animal glues in favor of these new synthetic products, while in England and Europe the use of traditional glues continued until well after the second World War. Today, traditional animal glues are generally used in America by antique restorers, museum conservators and musical instrument makers and restorers.

ANIMAL AND VEGETABLE GLUE

There are two basic types of natural adhesives which are commonly used: animal and vegetable. A wide variety of vegetable glues are derived from starches, gums, cellulose, bitumen and natural rubber, and have specialized applications. Animal glues are derived from casein (a milk protein used in paint), blood albumen (used in plywood), and collagen (used in woodworking). All of these adhesive products are organic in nature and non toxic to humans.

Arabic Gum or Acacia gum

CHEMICAL MAKEUP OF ANIMAL GLUE AND FISH GLUE

Animal glues are adhesives which are essentially high polymer proteins derived from hydrolyzed collagen. **Footnote 1** These organic colloids are comprised of complex proteins found in animal hides, connective tissues and bones. This protein has two elements that define its characteristics: chondrin, which gives it adhesive strength, and gluten, which gives it gel strength (gelatin). **Footnote 2**

These glues are made using a rather simple process, which hasn't changed much over the ages. The raw material is first conditioned in a water solution with lime (calcium hydroxide). Then the pH value is adjusted by adding a dilute mineral acid and rinsed in water. **Footnote 3** Then the process of cooking begins, and while the material is cooked the water/protein solution is extracted and filtered. The protein which is collected by the filters is dried and ground up as a final product. The resulting glue is then tested as to viscosity (fluidity) and gel strength (stiffness of gel formation), and graded on a scale from 50 to 512. **Footnote 4** Lower grades dry slower and are more flexible and higher grades dry faster and harder. Glue chip glass is made using hide glue with a 135 gram strength, which allows the glue to actually tear off the surface of the glass as it sets. Woodworkers can choose between 164, 192, and 251 gram strengths, which have slightly different working characteristics. 192 gram strength is the most popular, and allows hammer veneering, "rubbed" joints, and adequate working times when the wood is preheated to 95 degrees.

Animal hide and bone glues set in a two part process which first begins by cooling from 145 degrees to room temperature, and then completely drying by evaporation during the next 12 to 24 hours. This allows the traditional woodworker to use this glue to his advantage, since hammer veneering and "rubbed" joints both require a glue with a rapid initial grab as it cools. In addition, the strong initial hold of these glues allows clamps to be removed and reused on another job while the first project dries overnight.

Bone Glue in Pearls

Protein glues form a chemical (molecular) bond as well as a mechanical bond. This means that fresh animal glue will reactivate and chemically bond to previous animal glue surfaces, as well as forming a strong mechanical bond with wood surfaces and other natural fibers. Hide glue sticks to surfaces by an electrochemical attraction, or "specific adhesion." It is one of the few truly reversible glues, which can be changed from liquid to solid and back again with the addition or subtraction of heat and moisture.

MODIFICATION OF ANIMAL GLUES

An example of urea modified Liquid Hide Glue.
W. Patrick Edwards' Old Brown Glue.

Hydrolyzed collagen glues are easily modified with a wide variety of additives. It can be formulated with all water soluble materials, such as sorbitol, glycols, sugars, syrups, metal salts and sulfonated oils. Efforts to make it more water proof have involved using 1% aluminum sulfate, alum (aluminum potassium sulfate), tannins and formaldehyde fumes. KCl (salt) and potash prevent brittleness and crazing over time. A 5% glycerin additive makes the glue flexible enough for canvas backing on tambours. Adding 5-10% or more by weight of urea extends the gel time, and also increases flexibility, producing a liquid hide glue at room temperature. All of these additives reduce the actual strength of the glue somewhat, but the final result is still an adhesive which is stronger than the wood surface. All protein glues contain some preservatives and foam control agents, which do not affect their working characteristics.

TRADITIONAL USE/TECHNIQUES

All pre industrial woodworking processes which required adhesives were designed to maximize the working characteristics of animal collagen glues. In the 18th century, shop stoves and open fires were used to preheat the wood surfaces, and during the 19th century furniture factories used specially heated rooms to allow more assembly time. The rapid setting action of the hot glue as it cooled was used to great advantage when hammer veneering, as it allowed the worker to lay veneers directly onto the final surface, cutting the joints as the work progressed. The simple technique of "rubbing" in glue blocks was used universally from cabinetmakers to clock makers, and allowed rapid and solid construction without nails, screws or clamps. Glue was modified with additives to allow the veneering of turned columns, which became a popular form of furniture decoration, and requires a reversible glue to accomplish. Shaped, heated cauls were constructed which

Different types of Veneer Hammers.

allowed veneering crotch mahogany on simple OG moldings, and, by the mid 19th century, shaped cross grain veneer rosewood moldings appeared. When large areas of veneer had to be laid by hand, all hands in the shop would work together to hammer veneer it in place before it cooled. By the end of the century, large factories used heated, hydraulic presses to veneer large areas more easily, and with less labor.

Toothing plane blades

When veneers were first sawn by specialized workers before 1800, the thickness was uneven and the surface rough. A toothing plane was created, which used a toothed iron, set at a scraping angle, to further reduce the veneers in thickness and make the surface more even to glue. At the same time these toothing planes were used to prepare the surface of the groundwork for the veneer, and, if the surface was flat with no defects, the evidence of even toothing marks was said to prove the "truth" of the work. This meant it was ready for the application of veneer, since the hot glue would eventually pull the veneer down into any depressions that might exist on the groundwork and show up in the finish later. As veneers were mechanically sawn after 1800, the use of the toothing plane was no longer required to prepare the veneers, but it continued in use for preparing the groundwork. As well as showing the "truth" of the work, it was used to increase the surface area of the glue joint, as well as provide a stronger mechanical bond with dense woods. After the introduction of sliced veneers, and the final transformation of the industrial revolution changed the way furniture was produced, the toothing plane and its use became obsolete.

There are a variety of traditional animal glue applications that continue to be used by modern craftsmen. Rabbit skin glue is necessary for laying gold leaf properly. Instrument makers and restorers have a wide variety of applications that depend on animal glues. For example, the fact that these glues can be colored and mixed with many components allows the addition of plaster of paris to glue for laying ivory keys. Marquetry workers add different colors to the glue to restore Boulle tortoise shell and make mastic. Fish glue has properties which make it perfect for exotic materials, such as tortoise shell, horn, leather, shark skin, cloth and metals. **Footnote 5** Fish glue is a liquid glue with strong cold tack grip, and its use to glue brass, pewter and copper in Boulle marquetry is further strengthened when the metal is first rubbed with a fresh clove of garlic. Animal bone and hide glues are used individually and mixed together for all types of woodworking. Diluted glues are used for veneer sizing and flattening, as well as for sizing end grain and porous woods before sanding.

PROBLEMS WITH SYNTHETIC GLUES

There are several problems associated with synthetic glues which make them unattractive to furniture makers. These problems are often overlooked in favor of the generally perceived “easy to use” features that make a ready to use product handy around the shop. One of the most overlooked problems is the most obvious: lack of reversibility. Most furniture makers today do not consider the future problems synthetic glues create when it comes time to repair their creations. However, all furniture is subject to use and damage, and all furniture needs to be repairable if it is to survive the generations. Synthetic glues cure by a catalytic conversion from one chemical to another, and are irreversible. This means to take apart furniture made with synthetic glues requires destructive intervention and physical removal of all glue prior to repair.

Modern glues have a mechanical bond only, and require tight fitting joints and even clamping. They do not bond to themselves, and set up unevenly, remaining wet in one area of the joint while setting dry in another. These glues seal the wood surface and prevent stains and finishes from penetrating evenly. They are difficult to sand and remove from the surface when set. One of the greatest problems is the lack of resistance to sheer forces, which allow the wood to “creep” along the glue joint. This “creep” allows veneer joints to open up, and solid wood joints to move over time as wood movement occurs relative to humidity and temperature fluctuations, as well as wood shrinkage due to aging.

A more serious consideration when using synthetic glues is the toxic nature of the solvents which are included in their formulation. This represents, in some cases, immediate health concerns for the wood worker who might be constantly exposed to these solvents on a daily basis, and requires informed decision making as to what kinds of protection are required for their safe use.

WORKING WITH PROTEIN GLUE

Working with traditional animal glues is a simple process. The glue in dry form has a unlimited shelf life, stored in a dry container and kept away from heat. To prepare the glue for use, just add cold water and let sit overnight. It is not really important how much water you add, as long as it completely covers the glue. If you mix by weight, use 1.8 parts of water to 1 part of glue. If you mix by volume, just cover the dry glue with more water than glue. Once all the water has been absorbed, put the gelled glue into a double boiler and cook it on a low heat. A variety of materials can be used for the double boiler, such as copper, iron enamel, glass, stainless steel or aluminum. Use a stainless steel meat thermometer to monitor the glue temperature. Keep it constantly at 145 degrees F (60 degrees C), and add more water as needed to replace that lost to evaporation. A foil cover can be kept loosely over the top of the glue pot while cooking to reduce evaporation. A good quality round bristle brush is best as an applicator.

Traditional woodworkers used subjective tests to monitor the hot glue as it cooked. The odor should be pleasant if the glue is good, and smell bad if the glue is overheated or has been damaged by mold. The viscosity is measured by lifting the glue brush about a foot over the pot and letting the glue drip back down. It should be thin and liquid, with no lumps. You can test the strength by putting a small amount of hot glue between your finger and thumb, and rubbing together until it cools. The strength is then measured by pulling the finger and thumb apart several inches and looking at the protein strands which appear like spider webs. The longer the strands the stronger the glue. The color of protein glue when freshly cooked is light amber and it continues to darken as it is cooked. As long as it is not overheated it remains quite strong. If the glue temperature reaches 212 degrees it is ruined. If there is mold in the glue it can be very hard to see, but the glue will remain lumpy at operating temperature, and should be discarded. The glue pot and brushes must then be cleaned by boiling in water before a fresh batch is made.
Footnote 6

Video from www.woodtrek.com
Hide (& Animal Protein) Glues: Background, Selection and How to Prepare

THE IMPORTANCE OF REVERSIBILITY

Animal protein glues are the only easily reversible glues available to woodworkers. All modern synthetic glues convert from one chemical form to another by using a catalyst. Once converted these synthetic glues are difficult or impossible to undo. Since protein glues react to heat and moisture, they can be easily converted from liquid to solid and back again, even after a century or more of time. **Footnote 7**

This is a primary reason why these glues have continuously been used in the restoration field. The existing original glue can be softened or cleaned with warm water, and the new application of hot hide glue will completely bond with the previous glue. For example, if you want to repair a rush seat chair, or any joint that can’t be fully taken apart, you can drill a small hole into the joint, inject some warm water and then some hot glue using a syringe. Injecting alcohol or vinegar into an old glue joint will dry out the glue and make it more brittle, which can make it easier to take apart. Steam can also be applied to veneers which make it possible to remove and repair these surfaces.

Glue reversibility is essential when working with veneers, inlay and marquetry surfaces. It is necessary to be able to glue and unglue veneers while building a pattern on the surface. Protein glues allow easy repair and replacement of damaged veneers, by using heat and moisture. The glues are easy to clean off the surface, either with water or sanding, and are not affected by stains, solvents and finishes. Thinned animal glue mixed with sawdust makes a good mastic for marquetry.

Picture from the article on glue rehydration : "Current Trends in Conservation of Marquetry Surfaces"
W. Patrick Edwards, 1997

A technique used in conservation of marquetry surfaces for several years demonstrates the advantage of traditional animal protein glue. Since antique veneer and marquetry surfaces in poor condition often have losses in finish, missing elements, loose areas, and cracks, the original animal glue dries out and looses its grip. This original layer of protein glue, often centuries old, can be rejuvenated by a simple process. The surface is first made wet with distilled water and paper towels. Plastic is placed over the towels to keep the water in. Constant observation is necessary to determine when the veneer, mastic and marquetry elements begin to lift. The surface is then immediately dried off and covered with a traditional animal glue modified by urea to make it stay liquid longer. This modified glue is worked into all the cracks and under any loose veneer. Once the glue is rubbed into the surface, it is covered with a thin sheet of Lexan plastic. A heated aluminum plate is then tightly pressed over the Lexan plastic and left in place 24 hours. Once the marquetry is removed from the press and the plastic is removed, the surface glue can be cleaned up with cold water. The new glue "re activates" the old glue, through the veneer and mastic, and restores the grip of the original glue without any damage to the surface. **Footnote 8**

CONCLUSION

In our efforts to research and understand the furniture of the past, we are obliged to recreate the process used by pre industrial cabinet makers. This implies a knowledge of the types of tools and methods used, as well as the materials selected and the reasoning behind their selection. One of the most important elements of all aspects of furniture making is the selection of adhesives. If we strive to recreate the period furniture as faithfully as possible in the world today, we must adopt the hot glue pot as a permanent fixture in the wood shop. It is every bit as important to the process as the selection of tools and wood.

REFERENCES AND SOURCES

Jay Utzig, Milligan and Higgins, www.Milligan1868.com
Craig Brougher 816-254-1693, www.player-care.com/hide_q-a.html
Frank Ford, www.frets.com
Hubbard harpsichord, www.hubharp.com
Eugene Thorndahl, Bjorn Industries, North Carolina, 704-364-1186, www.bjorn.net
W. Patrick Edwards, www.wpatrickedwards.com
Old Brown Glue, www.oldbrownglue.com
http://en.wikipedia.org/wiki/Animal_glue
Hide (& Animal Protein) Glues: Background, Selection and How to Prepare : Video
W. Patrick Edwards informative log : www.wpatrickedwards.blogspot.com

FOOTNOTES:

1. Product Information pamphlet, Milligan & Higgins, (p.2)
"Animal glue is a protein derived from collagen...described as hydrolyzed collagen with the following formula:

C102 H149 O38 N31(COLLAGEN) + H2O------------->C102 H151 039 N31 (ANIMAL GLUE PROTEIN)

The approximate chemical composition of glue protein is as follows:
carbon, 51.3%; hydrogen, 6.4%; oxygen, 24.1%; nitrogen, 18.2%."

2. Bookbinding and the Conservation of Books, Stanford Internet site
"An adhesive consisting of organic colloids of a complex protein structure obtained from animal materials such as bones and hides in meat packing and tanning industries. Glue contains two groups of proteins: chondrin, which accounts for its adhesive strength, and gluten, which contributes jelling strength. Animal glue is a protein derived from the simple hydrolysis of collagen, which is the principle protein constituent of animal hide, connective tissue and bones."

3. Ibid
"Hide and bone glues make up the two major types of animal glue. Hide glue, which is by far the superior of the two, yields a fairly neutral pH in solution, usually in the range of 6.5 to 7.4, although wider variations are possible. Bone glue is generally acidic, having pH values of 5.8 to 6.3. A glue having a high acidity absorbs less water and tends to set more slowly than a glue having low acidity."

4. Product Information pamphlet, Milligan & Higgins, (p.6)
M&G "The gel (or jelly) strength of a glue is determined with the Bloom gelometer. It is the measure of the rigidity of a gel formed by a 12.5% glue solution at 10 degrees C ...The Bloom unit is a measure of the force (weight in grams) required to depress a 0.5 inch diameter plunger 4 mm into the surface of the gelled sample."

5. The Restoration of Old Wood Furniture Marquetry: Protein Glues, Their Analysis, Upgrading and Rehydration"
M.C. Triboulot, N. Boucher, et al, "Holzforschung und Holzverwertung" Nr. 3/1996, (p.63)
"Fish glue, contrary to the collagen based gelatins, appears to be particularly rich in the amino acid phenylalanine...proteins secreted by marine organisms to adhere to submerged rocks are particularly rich in phenolic groups to increase the resistance of the protein to the action of the water."

6. Test for quality of glue
Test: 1 oz glue (2 tablespoons) in 1 lb water (about 1 pint) let sit 12 hours. pour off surface water and weigh glue gel. 5 times the original weight or more is excellent. Solidity and coherency of the mass indicates the strength.

7. Product Information pamphlet, Milligan & Higgins, (p.2)
"Animal glues are soluble only in water. They are insoluble in oils, greases, alcohols, and other organic solvents. When placed in cold water, the glue particles absorb water and swell to form a spongy gel. When heated the particles dissolve to form a solution. When the solution is cooled the glue forms an elastic gel. This property is thermally reversible, and upon application of heat the gel liquefies. The gelling or melting point of an animal glue solution will vary from below room temperatures to over 120 degrees F, depending upon glue grade, concentration, and the presence of modifiers."

8. The Restoration of Old Wood Furniture marquetry:
Protein glues, their analysis, upgrading and rehydration"
M.C. Triboulot, N. Boucher, et al, "Holzforschung und Holzverwertung" Nr. 4/1996, (p.61)
"Protein glues solidify by dehydration, that is the loss of water to the environment (wood, air). However, a certain amount of water remains bound to the solid adhesive. Over many years or under drastic temperatures or lack of moisture in the air even this water is to a high extent lost and the glue becomes very brittle and weak and loses both adhesion and cohesion. Thus rehydration, the reestablishment of this water, becomes necessary to reverse the state of the glue to one of both good adhesion and good cohesion."
Note: For a more complete discussion of this procedure, see "Postprints of the Wooden Artifacts Group", American Institute for Conservation, San Diego conference, June 1997, paper presented by W. Patrick Edwards, "Current Trends in Conservation of Marquetry Surfaces", (p. 27)