Staved construction in furniture

Craig McArt

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STAVED CONSTRUCTION IN FURNITURE

BY

CRAIG J. McART

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THESIS

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William Keyser
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The idea of staved construction in furniture design is an original concept. Principles have been borrowed from the old arts of cooperage and ship building and applied to a different end. The furniture that has been produced in this project is volumetric, striving for complete unity in form. It functions within a concept of light weight utility. The appearance of the forms finds no basis in any established style. The sculptural symmetry, in fact, might suggest a new esthetic for modern interiors. Certainly, it is a complete break from the square, slab type of furniture now in vogue under the nomen of "international style".

Until recently, furniture designers pretty much limited their efforts to solutions within the area of traditional joinery. Now, many are using different materials; metal, fiberglas, and plastics of various kinds to realize new design possibilities. Some, apparently revering the quality of warmth which wood holds over the stark coldness associated with these other materials, have forsaken traditional joinery to explore laminating and molding processes in accomplishing some fine designs. The famous Eames chair is one. Greta Jalk has been proceeding along these lines recently, and her prize winning chair in the Daily Mail contest is another good example. Wood is by no means on the way out as a material for progressive furniture designers. Continued concern and experimentation in wood technology will enable designers to realize new ways of using wood structurally. There is no reason why wood should be limited to a visual applique as the recent
trend might seem to indicate. Wood is a valuable and abundant resource in many countries, and is worthy by its properties of the designer's continued consideration.

Two arts of woodcraft that flourished until not too long ago, ship building and cooperage, have been made obsolete by new materials and methods. They, however, developed technologically in their own right to a high degree before becoming obscure.

It occurred that furniture might be built using some of the principles of these "lost" arts. A visit to perhaps the last practicing cooper in the East and to the New York Public Library produced a wealth of information on cooperers and cooperage, the art of barrel making. When man constructed the first crude barrel, unwittingly or not, he applied one of the strongest building principles of modern engineering, i.e., the principle of the double arch. It is impressive that for its weight, the barrel is the strongest vessel that can be made. By studying the methods, tools, and machinery employed by the cooperers, who, prior to the industrial revolution, were considered among the most skilled of craftsmen, it was possible to form some ideas of applying available shop machinery.

At the invitation of Bill Luders, several visits were paid to the Luders Shipyards in Stamford, Connecticut, which in the spring of 1964 had produced the most expensive 12-meter racing yacht yet designed, the American Eagle. Here one could appreciate the sheer beauty born out of the quest for speed where no cost was spared in attaining the fastest racing hull possible. A distinct delight was viewing a finished hull
of varnished mahogany planks, perfectly fit to form a statement of beauty in form as a promise of function. The fitting of the planks about the skeletal ribs demands uncanny skill and craftsmanship. Today there are only a few old masters of the art of planking left in this country.

Couldn't these principles of construction be used in creating a new type of furniture? The advantages of strength, lightness, economy of material, and aesthetic appeal were significant virtues of the processes. These certainly were worth pursuing. The final criteria could be met only by unresolved conjecture. Would such a departure from traditional joinery provide any valid advantages?

The forms that would evolve from this kind of construction could be quite exciting, visually. They could capture the surface quality of the racing hulls that are so admired. The staved, shell forms would be built with an absolute minimum of material and, likewise, a minimum of waste. They would in no way be superfluous.

A great deal of time and effort went into exploring ideas on paper for methods and systems by which such forms could be constructed. Several seemed to hold promise, but as they all involved what might be termed "unorthodox shop procedures", they would have to be tried and proven. The final question of the strength and durability of the product just could not be assessed without first a prototype.

Arthur Pulos, design professor at Syracuse University, had offered as advice a framework or philosophy of practice which he considered vital to any craft. He warned that the craftsman of today must explore new methods and use the materials and technology of today in order to make a worthwhile contribution. He maintained that this had always
been the position of the craftsman throughout history, but that recently there seemed to be more importance placed on doing things the old way. The result is that outmoded design is reversed solely for its handworked quality of execution. Pullos, a fine silversmith aside from his practice of industrial design, has formed a philosophy which must be regarded as healthy for the future of the crafts movement. Perhaps a craftsman needs to be more than a craftsman. He needs also to be a comprehensive designer if he is to exert an influence. Paolo Soleri has stated that the craftsman in order to succeed must "express the material, must bring out everything which is possible in terms of the material, while for an architect, the material is meaningless, a medium for something which goes beyond the material."¹ It seems that the successful craftsman must have some "architect" in him to go beyond his material. Only by so doing will he realize what might be possible in the material.

The involvement with the concepts of the project proceeded in this framework of philosophy. The first prototype shell testing the systems and geometry worked out in sketches proved a success. The simple "football" shape which was produced indicated that more sophisticated designs would, indeed, be possible. With each succeeding experiment problems were presented and problems were solved.

In the end, four pieces of furniture were produced as practical examples of the technique. The various experiments which led to the final result as well as the research involved in the study will be covered in the following exposition section.

EXPOSITION

Shipbuilding Research

Many procedures used in shipbuilding were found applicable to
the project. The following information was gathered from a Navy
Department publication: Wood: A Manual for its Use as a Shipbuilding
Material.

I Bending of Wood.

Many members of wood ships, such as frames and planks can
be satisfactorily bent. Where severe bends are necessary, only
hard-woods can be used. Oak, elm, ash, hickory and beech have
long been used as bending stock. The grain of the wood should not
exceed a slope of 1 in 15, and knots and burls should be avoided.
Generally, it is preferred to make the bend with the bark side
acting as the tension face.

Most shipbuilders prefer green stock for bending, but wood
can be bent at moisture content values ranging from the green
condition to 12 percent. Green wood is free from surface checks,
heats more quickly, and requires only heating to prepare it for
bending. The optimum moisture content for bending purposes is prob-
ably in the vicinity of the fiber saturation point, 30 percent
moisture content.

When wood is both wet and hot, its plasticity is increased.
The usual practice is to steam the wood at atmospheric pressure
in a steam box, using wet steam, or to submerge it in boiling water.
About one hour of steaming or soaking time per inch of thickness
is a good guide.

Once the wood has been softened, it should be bent as quickly as possible to minimize heat and moisture loss. Mild bends can be made over frames or forms without using a strap. One end is fastened in place, and the blank is then pulled against the form and clamped at intervals. Sometimes it is necessary to clamp only at the ends. Severe bends require the use of a strap with end blocks to hold the wood rigidly while it is being bent. They compress the inner, or concave, section of the piece and prevent the outer, or convex, section from stretching. In making severe bends, the essential feature of the whole operation is the maintenance of strap tension and end pressure during the formation of the bend. The reversed lever principle is one of the most effective ways of controlling pressure and strap tension.

To fix the bend permanently, the wood must be cooled and dried under restraint. If the piece is removed from the form, it should be joined with a stay lath across its ends until it becomes seasoned.

II Laminating.

As many as 2,200 laminated members are used in a ship. They include keels, stems, frames, stringers, deck beams, garboards, etc. Boards are joined together with long scarf joints to produce any desired length. They are then laminated in jigs of various kinds depending on the size. Resorcinol and Phenol-Resorcinol glues are used because they are not affected by water. These glues require heat for a period of time to cure. White oak is the preferred species for laminating frames of large vessels.
III Planking.

Hull planking forms the shell of a wood ship. The purpose of planking is to produce strength and rigidity and to keep water out of the ship. It generally is the main strength member of the vessel. The more seams in the shell of a vessel, the less swelling and shrinking occurs on any one seam; hence, narrow planking is to be preferred. Planks are cut to shape and finished as far as possible before they are installed on the vessel. They are shaped according to a predetermined series of dimensions which ensures their proper taper throughout their length, the proper outgaging of the calking edges, and the hollowing of the inboard face if the particular strake happens to come at the turn of the bilge. Care is always taken to insure that planking work proceeds simultaneously at the same rate on both sides of the vessel.

Most planks must be bent into position to follow the curved surface of the hull. This often calls for preliminary steaming or boiling of the plank. After steaming, the plank is hurried to the vessel and put in place quickly while it is still hot. It is clamped into the frames to which it is to be fastened, and progressively shoved into position against the planking already installed by means of wedges, clamps, or screws. It is then fastened permanently in place.

Planks are fastened to each frame with ship spikes, nails, drift bolts, through bolts, or a combination of these. Where the thickness of the planking permits, the heads of the fastenings are driven into a counterbored hole deep enough to receive a wooden
bung, which should be of the same wood as the plank and so placed that its grain parallels that of the plank in order to ensure its swelling and shrinking in the same manner as the plank.

White oak is preferred for planking because it excels in resistance to impact, in bending strength, in the ease in which it can be bent, and in its ability to hold fastenings.
Cooperage is the art of making barrels, a craft that is over 2,000 years old. In the beginning this was entirely a hand operation demanding a high degree of craftsmen's skill. Then, with the age of mechanization, came the development of machines to replace the tedious procedures of the cooper's craft. From the standpoint of this thesis, however, the methods of the early cooperers, passed on from generation to generation through a demanding apprentice system, bear special interest.

One man, Rudolph Noble of Naples, New York, still carries on this craft today by these same hand methods. He learned his skills as an apprentice in Germany, and practices this trade now by servicing wineries and breweries which still have some of the old wooden casks. Mr. Noble explained that no new casks can be made because the supply of white oak has been exhausted in the free world, and no other wood is satisfactory. His work, then, is limited to repairing or rebuilding casks already in service. Mr. Noble was very helpful in explaining how these casks and smaller barrels were laid out and constructed. He was able to show many of the special hand tools of the cooper from his own shop.

Basically, there are two types of barrels: Slack barrels which may be used to hold dry materials such as apples or nails, and tight barrels which are used to hold liquids as does a whiskey barrel.

The slats of wood which form the barrel are called staves. In order of their use: oak, elm, pine, maple, sycamore, gum, beech, and
basswood were used for the staves. The tight staves had to be quarter-sawed because the medullary ray had to be brought parallel to the surface of the stave.

The following step by step procedure used by the coopers in constructing a barrel by hand has resulted from combining information from Mr. Noble and two written sources: The Cooperage Handbook by Fred P. Hankerson and The Coopers: Company and Craft by George Elkington.

1. First the staves had to be "dressed" in order to give them the proper shape. The desired curve and edge bevel was achieved with a jointer. The cup shape was given to each stave by working both sides with a cooper's adze and a type of draw knife called a fro.

2. When all the staves were dressed, they were placed around a circle formed by a metal hoop resting on the floor, the final stave being trimmed to fit. This was called "raising the cask".

3. "Trussing and bending" was done by dropping a large hoop over the middle of the raised cask and then steaming the staves for an average of twenty minutes at a temperature of 200 to 210 degrees Fahrenheit. After the steaming, the staves were pulled in with a windlass so that hoops of iron could be driven on with sledges.

4. To "set the bend" the entire barrel was fired at a temperature of 450 to 500 degrees for fifteen minutes. This operation set the bend so that there was not more than ten percent springback when the hoops above the bilge were removed.

5. Chimes or bevels were cut on the ends of the staves with an adze, making the extreme edge of the bevel level, and forming the
the grooves into which the heads were fitted. The croze is the tool that cuts the grooves as it rides on the chimes.

6. The chime hoops being fitted on at both ends, the trussing hoops were knocked off, and the barrel was completed.
PRINCIPLES

The principles used in this thesis project to make staved furniture are related closely to the findings of the preceding research. This section shall be an attempt to illustrate the principles of construction and their application in this case to the craftsman's facilities.

First of all, no matter how complex the profile of a staved form may be, providing it has a circular cross section, that section will look similar to this:

![End view of staved form](image)

In this view it can be seen that each stave has a constant angle bevel determined by dividing 360 degrees by the number of staves to be used in the form.

If pieces of wood are formed to a curve by either bending or laminating, this constant angle bevel can be achieved by cutting the pieces perpendicularly to their cross section orientation at the proper angle.

![End view with angle determination](image)

Angle determined by \( \frac{360}{\text{no. of staves}} \)
In perspective the cuts would look like this:

The angle may either be cut by sawing,

or by jointing:

The staves are positioned for gluing by snapping them between two end blocks. As the distance between the end blocks is adjusted, the staves can be made to pull together evenly. This adjustment can be made in a vise, by moving the tail stock of a lathe, or by tightening a tie rod through the center.
To provide extra clamping pressure, band clamps (1), radiator hose clamps (2), and plywood circles can be used (3).
EXPERIMENTS

Experiment #1 - Producing a Staved "Football" Shape.

Procedure
1. Mahogany staves were cut to \( \frac{1}{4} \)" thickness.
2. Staves were soaked and pre-bent by band clamping them in multiples about a garbage can.
3. Cutting jig was made for use on the jointer.
4. Each stave was clamped in the jig with the center line of the plank even with the bottom surface of the jig.
5. The jointer fence was set at 11 \( \frac{1}{4} \) degrees, and each stave run through until the jig butted the top of the fence, and no further cut could be taken.
6. Each stave was then inverted in the jig, using the same center line alignment, and jointed again.
7. By trial and error, circular grooves were cut in the end clamping blocks until the right diameter was found to provide a tight fit for the staves.
8. One of the end blocks was mounted on a vise jaw so that it could be moved in and out in respect to the other fixed end block.
9. Hide glue was applied to the edges of all the staves, and they were sprung between the end blocks.
10. When the end blocks were moved slightly farther apart, the staves came together, and with two band...
clamps fastened around the girth, produced pressure on all the jointed areas.

11. When the glue had set, the shape was finished smooth with a spoke shave and sandpaper.

12. This shape was used to make a hanging spotlight.

The inside was painted white, and the exterior oiled.

Notes: 1. The staves might better be bent by first submerging them in boiling water for about a half hour, and then springing them to the desired curve.

2. The diameter of the piece is limited by the width of the jointer.

3. Hide glue was used because of its long working time. It is not a desirable choice, however, because of its weakness under heat.

4. The alignment of the staves during glueing needed to be improved.
Hanging spotlight from a staved "football" shape
Experiment #2. Repeat of #1.

Procedure 1. Same as in #1 except for the following:

A. Staves were cut of white oak.

B. Staves were not pre-bent this time.

C. Wood tabs were glued on each stave so as to overlap the adjoining stave and thereby insure close alignment.

D. The final shape was turned on the lathe instead of by spoke-shaving.

Notes: 1. Since the staves were not pre-bent, they depended upon the glue joints to oppose the force of each stave's tendency to straighten out, and thereby explode the shape. The hide glue proved unable to hold this force after a week or two.
Experiment #3. To Produce a Staved "Horn" Shape.

Procedure
1. Staves were cut of mahogany to 3/16" thickness.
2. Staves were formed on the jointer without pre-bending.
3. Grooves for the end blocks were cut on the lathe, the large end block being left on the head stock face plate, and the small block riding on the tail stock.
4. Wooden tabs were glued to each stave for alignment.
5. Using hide glue the staves were fit together right on the lathe and clamped.
6. The shape was turned to a very thin shell.
7. The shell was removed from the lathe and the inside was coated with fiberglass to provide strength.

Notes:
1. Downward pressure on this type of shape (opposed to the "Football" shape) tends to compress the joint, thereby producing a strong resistance.
2. After a few weeks some cracks appeared. The contraction of the wood was not matched by the fiberglass backing.
Experiment #1. To Produce a Laminated, Staved Stool.

Procedure 1. Slats were cut from 1/8" poplar to be used for the lamination.

2. The staves were formed by laminating three slats of poplar with Titebond glue between two matching forms.

3. The staves were shaped on a jointer.

4. Twenty staves were glued into pairs using Titebond glue.

5. They were then assembled on the lathe using Titebond and clamped.

6. The Form was turned on the lathe.

7. Sixteen pie-shaped pieces of poplar were cut for the base with a taper jig.

8. These pieces were glued together and then turned on the lathe.

9. The shell was fastened to the base by a large plug and bonded with polyester resin.

10. The upholstery was accomplished with eight segments of vinyl sewed together with a button in the middle. This was tacked over 2" foam.

11. The wood was finished with "Satin Zar".

Notes: 1. Flitches can be ordered cut to 1/8" thickness.

2. The segmented base reduces warpage.
Laminated staved stool
Experiment  #5. Producing a Staved Bar Stool.

Procedure 1. Slats were cut from 1/8" poplar.

2. The staves were formed by laminating three slats of poplar with Titebond glue.

3. The staves were shaped on a jointer.

4. Alignment tabs of wood were glued to each of the 24 staves.

5. They were then assembled on the lathe using Titebond glue and clamped.

6. The form was turned on the lathe.

7. The top angle was cut with a sabre saw.

8. The shape was sanded and given a couple sealer coats of Zar.

9. After the top edge was covered with plastic tape, a canvas sling was taped into position for the seat.

10. The canvas was then coated with polyester resin, making it rigid.

11. For strength two additional layers of polyester and burlap were applied.

12. The seat was removed and the excess material trimmed off on the band saw.

13. The seat was upholstered with vinyl over 1 1/2" foam, and fastened to the stool by means of a treaded rod and nut.
Staved bar stool
Bar stool in clamps on the lathe
Turning the bar stool on the lathe
Experiment #6. Producing Two Staved Casual Chairs.

Procedure

1. Slats were cut from 1/8" poplar.

2. The staves were formed by laminating four slats of poplar against a form with Titebond glue.

3. The 24 staves were shaped with a hand-held circular saw mounted horizontally on a sliding platform. The staves were clamped to the form so that their center lines were even with the top of the form. The form, in turn, was tilted at 7 1/2 degrees to the surface on which the platform saw was to slide. Using a hollow ground blade, a smooth cut with the proper bevel was achieved by sliding the saw platform along the length of the stave.

4. Since the form was of too large a diameter to be assembled on the lathe, two end blocks were joined by means of a threaded tie rod. By tightening nuts at the ends of the rod, pressure could be applied through the center of the shape to be glued. Cylinders of rubber at each end of the rod encircled by heavy rubber bands helped to hold the staves in place during assembly.

5. Titebond glue was used for the assembly. All the staves were aligned between the end blocks and pressure was applied through the tie rod, by two band
clamps around the girth, by radiator hose bands at each end, and by two plywood circles clamped across the middle.

6. The form was smoothed by spokeshave and sandpaper.

7. A sabre saw was used to cut the form so as to produce two identical halves.

8. Bases were formed by gluing wedges of poplar together forming a disc which was turned on the lathe.

9. The bases were joined to the chair forms with oak dowels and polyester resin.

10. The chairs were sanded and filled with Zar wood filler.

11. A bucket seat of cardboard was taped into each chair. Layers of burlap and polyester resin were applied over the cardboard until they produced the necessary strength.

12. The seats were removed and the excess material trimmed off on the bandsaw.

13. The chairs were finished with Satin Zar.

14. The seats were upholstered with vinyl over 2" foam, and fastened to the chairs by means of a threaded rod and a nut.
Two staved casual chairs
Glueing the slats for the chairs

Forming the lamination (I)

Forming the lamination (II)
Cutting the staves for the chairs
Assembling the staves for the chairs
Chair form in clamps
Cutting the chair forms with sabre saw
CONCLUSION

The results of this thesis project have, for the most part, been successful. The principles which were conceived in theory were proved in practice. The pieces of furniture which were produced indicate that very pleasing and exciting shapes may evolve from applications of this technique. The pieces are structurally sound and uncomplicated, and relate well to each other.

Most of the qualifications are concerned with the perfection of the technique. At this point there are two drawbacks which would be discouraging to the craftsman. The first is the time involved in laminating enough staves to make a complete form. The second is the difficulty in obtaining a perfectly cut stave.

If a single form is used in making the stave laminations, one is limited to producing two staves per day. Even at this rate, the spring-back in each stave is noticeably greater than if the lamination is given a full day to set on the form. Two attempts were made to improve this situation.

By using an electronic glue welder which sets glue in a matter of seconds with high frequency current, it was hoped that a speedy system could be worked out. When this method was tried, however, the clamps used to hold the lamination to the form got in the way of the welder. Also, the effective penetration of the welder through the edge of the lamination was limited by its design. It seems likely that if an electrode could be placed at each parallel edge of the lamination, as could be done in an industrial operation, the current would flow
directly through the glue area and produce an excellent, instant bond.

The other attempt to improve on the situation was an investigation of a new wood plasticization process developed by Conrad Schuerch of the State University College of Forestry at Syracuse, New York. The process, which was reported in the *Forest Products Journal* Volume XIV seemed to hold promise of being an ideal solution. The process involved the temporary plasticization of strips of wood by subjecting them to ammonia. This had the effect of loosening the bond of lignin between the cells of the wood so that they could slide against each other.

"This technique permits one to mold or form wood much as one can manipulate and form damp leather. Thereafter, the plasticizing agent can be removed and the wood regains its usual mechanical properties and retains the new form that has been impressed. The most remarkable feature of this new technique is the fact that wood can be distorted into complex shapes without clamping. For exact control of shape, restraint is needed for a short period, but there is no tendency for the wood, once significantly bent, to spring back to its original form." ¹

Dr. Schuerch was visited and was found to be very interested in the possibility of adapting his process to the problem of this thesis. Arrangements were made to use the lab facilities at Syracuse with the supervision of a graduate chemist who had assisted in the discovery. This was only to be disappointed shortly thereafter by a breakdown of some of the lab machinery. Since this machinery was not to be replaced, Dr. Schuerch was forced to cancel my project.

By such a process as this, as in steam bending, the staves would have the additional advantage of being homogeneous, and so, would not reveal different grain patterns or wood color as occurs when a lamination is exposed in the finishing of a piece.

The second qualification concerned the difficulty of obtaining perfectly cut staves. While the jointer method of shaping the staves produced perfect staves, the method was limited by the width of the jointer, and was, besides, a rather tedious and time consuming operation. The method employing the circular saw has the advantage of being quick and unlimited in the size of the stave it can cut.

The difficulty has occurred in clamping the stave to the form so that it may be held positively while the cut is being made. In cutting the staves for the occasional chairs, they were clamped to the form so that the center line of the stave followed the top edge of the form. This meant that half of the stave projected unclamped above the form for a free saw cut. It seems that a more accurate cut might be achieved by cutting the staves while clamped entirely on the form, and allowing the saw cut to protrude into the form itself.

Poplar was used for the project because of its immediate availability in eighth inch thickness, and because it was a more economical wood to risk in perfecting the technique. Although the poplar has an exciting appearance of its own, different woods will produce richer looking forms. Flitches of all woods may be obtained in the eighth inch thickness.

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