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Improved Methods of Plywood Carcass Construction

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IMPROVED METHODS OF PLYWOOD CARCASS CONSTRUCTION

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PROPOSAL

The purpose of this thesis is to devise plywood joining techniques superior to those in use today. I hope to add to the body of knowledge surrounding plywood as a major element in furniture carcass construction. I intend to make sample plywood carcass joints, test them in the Engineering Department's strength of materials lab, and use the information to build plywood furniture.

DEDICATION

This thesis is dedicated to you; to anyone who takes the time to pull if off the shelf and read it.

When I began my graduate studies at the Rochester Institute of Technology, there was little work being done with flat panel plywood; probably because plywood has developed a bad name. In the 40's and 50's it was looked on as a cheap substitute for real (solid) wood. The very word veneer itself still carries with it the connotation of cheap, counterfeit or structurally unsound, mostly due to industry's tendency to balance quality against profit, with the scales almost invariably tipped to the side of the dollar. The result in many instances was that plywood's reputation was deserved. The mention of plywood still brings to many minds the picture of failing glue and delaminating veneers; literally wood that is falling apart. The advances in adhesive technology brought on by World War II and putting a man on the moon should have laid this vision to rest.

I would like to quote from M. L. Selbo's Adhesive Bonding of Wood (p. 16, Drake, N. Y., 78; originally published by the Department of Agriculture as Technical Bulletin No. 1512).

> The durability of moderately alkaline phenol resin, resorcinol resin and phenol-resorcinol resin adhesives is essentially similar. When these glues are properly used, they are capable of producing joints that are about as durable as the wood itself under various severe service conditions studied. Properly made joints will withstand, without significant delamination or loss in strength, prolonged exposures to cold and hot water, to alternate soaking and drying, to temperatures up to those that seriously damage the wood, to high relative humidities where many untreated species decay, and to outdoor weathering without protection from the elements.
>
> The joints between lumber laminations or plies of plywood made with these adhesives will not separate when exposed to fire. The glues are not weakened by fungi, bacteria or other micro-organisms and are avoided by termites. These adhesives, however, do not offer any significant protection to the adjacent wood. Consequently, wood products glued with these adhesives should be considered no more decay or insect resistant than solid woods of the same species.

Even the most avid solid wood craftsman finds himself using plywood on flat panels where movement and mass to strength ratios are important, especially if only one surface is seen, e.g. drawer bottoms and cabinet backs, not so much because plywood is less expensive (which it is), but because in these applications it is structurally superior to solid

wood.

Artists and craftsmen share a tendency to command material, i.e. to have the capability of exercising as much control as possible. For the woodworker this would be using wood which he has felled, milled and dried himself. This is certainly the most gratifying way of working, and the only way of exercising any control over the grain pattern. When using plywood, this is not the case. The craftsman is more or less forced to take the material as it is. Even if he veneers his own plywood, he must take the veneer as it is. This loss of control (dependency on industry) simply discourages most craftsmen and prevents them from utilizing the material with the same passion and insight they are willing to devote to solid wood (and familiar processes). I imagine that we would see more hand-crafted plywood furniture if craftsmen had joining techniques equal in strength to those of solid wood.

Plywood presents craftsmen with many other problems. Among these are:

1. With the inception of stacked plywood, the flatness of the manufactured product remains

in the finished piece of furniture.

2. The quality of the material varies greatly with the manufacturer.

3. Deep interior defects in core stock cannot be detected until they produce unwanted results.

4. If panels are not stored flat, they will gradually warp.

5. Interior plywood accidently exposed to exterior conditions is quickly rendered useless.

6. Although plywood is manufactured as a material of uniform thickness, changes in humidity affect the edges before the center, usually producing a panel domed like a bar of soap, i.e. slightly thicker in the middle.

7. Plywood furniture is difficult for a craftsman to market because of plywood's bastard child reputation.

If plywood can be thought of as a material on its own merits and not as a substitute for "real wood", then several advantages become apparent:

1. Working with it is less time consuming because the material comes ready-to-use in a wide range of sizes and thicknesses.

2. Checking, splitting, honeycombing, warping

and surface defects so common in solid wood are eliminated.

3. The strength of plywood is only mildly affected by grain direction while solid wood is relatively strong with the grain and much weaker across the grain.

4. Changing humidity only mildly affects plywood.

5. Because plywood is a manufactured material and not a processed commodity, it is readily available, i.e. you can usually just go out and purchase it at any lumber yard.

6. The use of plywood actually conserves our wood supply. There is more waste in converting a log into lumber and then into furniture (certainly case goods) than if plywood were the intermediate step.

7. Veneers can be matched to produce striking results.

8. The beauty of a wood in a given tree can be seen by more people.

9. Plywood construction, even in high quality furniture is less costly.

While planning my early graduate work at RIT, I was approached with a commission for ten large (4 ft. x 8 ft.) wall mounted, glass front plywood display cases. Because of the difficulty of making strong plywood partition joints, there was some question in my mind as to how many partitions it would take to support a 150 lb. safety plate glass front. The only information I could find on short notice (from industry) was that it was reasonable to expect a plywood dado to support 100 lbs. per inch. But I suspected these figures. I was certainly dealing with measurements made under laboratory conditions and the very way the test was structured (distributing the load uniformly along the length of the joint) seemed meaningless when applied to my design problem of supporting the glass front. I concluded that these figures were biased by industry to insure the highest possible result.

I decided to make some tests of my own. I made four test samples from 3/4" nine ply fir core luan plywood; two dados (one nailed with six penny cement coated box nails and the other with six 3/8" dowels on opposing 20 degree angles); and two sliding dovetails (one 3/8" deep and one 5/8" deep). I wanted

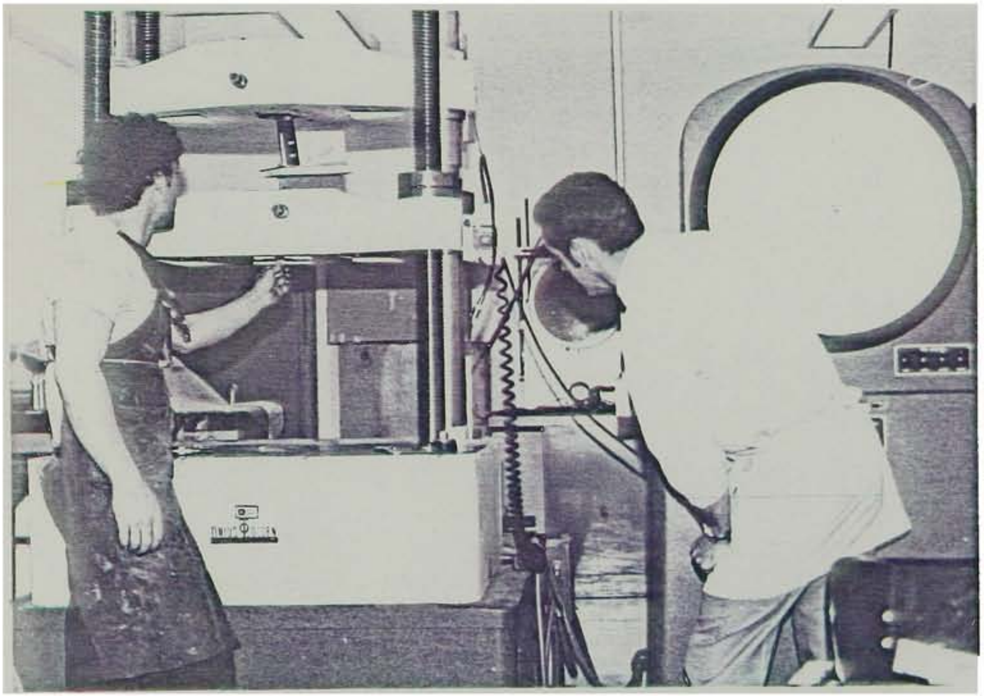
to experiment under conditions that would approximate the stresses encountered by plywood carcasses. Therefore, I designed a test that would rip a 12" long dado apart from the outside edge (Fig. 1 & 2).

With one coat of Franklin titebond yellow glue on each surface, the nailed dado held 208 lbs. before it snapped. The 3/8" deep dovetail held 250 lbs., the 5/8" deep dovetail held 299 lbs. and the 3/8" dowels were strongest at 331 lbs.

I was intrigued to find that the dowels were stronger than the dovetails, so I tried many other mechanical solutions. Among these were: different angles of dovetails, bigger dowels, glue blocks, double rabbits, locking joints, end kerfs, and finally a 3" mending plate (a steel strap with four 3" number eight wood screws on opposing 20^{o} angles). I also tried kerfing and v-grooving to give the upright tooth (something for the glue to grip).

I tested sixteen samples and found most of the results around 300 lbs. However, some were very interesting. If appearance is no problem, i.e. when the carcass is only seen from the inside, the mending plate was strongest at 762 lbs. Although the dowels would show on the outside of the carcass, they could

SEPARATION TEST



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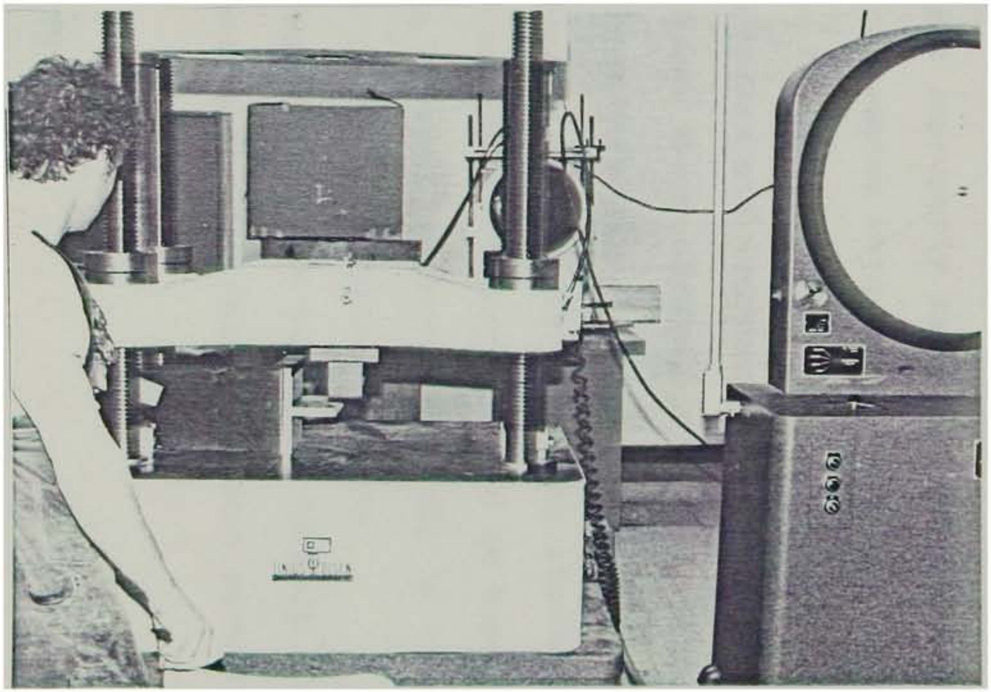
make a nice detail and are very strong. The outside can be kept unbroken by using short (1/4" deep) band saw kerfs in the end of the upright. The end kerfs appeared to be stronger than dovetails.

As long as I was testing joints, I thought some investigation of glue line thickness would be reasonable. I made three more samples: one with the dado so tight that I had to drive it home with a hammer, one snug, and the other quite loose (.016"). I was very surprised to find the loose dado over 100 lbs. stronger than the tightest one. Because it is desirable to test varying glue thickness without having glue squeeze out of the dado (this could lead to assembly problems), I made seventeen samples, keeping the dado constant and varying the thickness of the upright by cutting shoulders slightly less than the depth of the dado on each side of the upright. I didn't want to increase the strength of the joint in one direction and weaken it in another. I therefore made fourteen additional samples to test for rigidity, i.e. pushing laterally on the upright (Fig. 3 & 4).

The glue line varied a great deal (from .005" to .154") but the result did not really vary that

RIGIDITY TEST



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much (from 367 lbs. to 240 lbs). After re-evaluating the experiment, I decided that it had been structured poorly. When the glue line was increased, the glued area of the joint decreased.

I made eight more samples. This time I varied the width of the dado. I wanted to repeat the original test, so I tried to cut dados that fell into the broad categories of tight, medium and loose. I also tested a butt joint (no dado). In the separation half of the experiment, the medium dado (loose by .010") was strongest. However, in rigidity, the tight dado was strongest, but the medium sample was clamped improperly and could not be tested. Eight more samples were made, this time in oak plywood. The medium dado (.011") was strongest in both separation and rigidity.

Although these findings are very crude and are far from complete, I can see a definite indication that allowance for optium glue line thickness (under .03" for Franklin titebond) should be considered when designing plywood joinery, certainly if tensile strength is the only consideration.

By optimizing the following factors, it would be reasonable to hope that a carcass partition set

into a 3/4" by 12" dado could support over a 1000 pound load on its outside edge without resorting to metal hardware:

1. Glue type, its method of application and thickness
2. Depth of dado
3. Size, spacing and angle of dowels
4. Size, spacing and angle of end-kerfs
5. Plywood construction (lumber core, uniform laminate or hardwood inner ply)

My experimenting with plywood had given me a respect for the material and some intuitive response to a few jointing techniques. So, when another commission came along for an oak plywood stereo cabinet, I eagerly accepted it. I wanted to explore the possibilities of creating strong carcass corner joints in plywood case goods. It seemed to me that a bending technique would yield the strongest joint because the material is not first separated and then rejoined. I tried thinning, a bending process where enough material is removed in the area of the bend to allow the plywood to bend without breaking, i.e. reducing the stock thickness enough to make

it flexible. The removed material must be replaced, however, with a shaped glue block corresponding to the curve of the bend.

I thinned a piece of 3/4" oak plywood to 3/32", wet it, bent it 90° and inserted a piece of 3/4" quarter round fir moulding. This produced a rounded corner about 7/8" in radius. A 7/8" radius was as tight as I wanted to risk. For longer radii, thinning creates problems due to the logistics of removing such large amounts of wood and replacing it with a large glue block. It is possible that very large glue blocks, 2" or more in radius, might swell enough with changes in humidity to crack the veneer.

I began experimenting with kerf bending (sometimes called "kerf curving"). In this process a number of deep side by side cuts are made in the back of a panel giving the face flexibility. After several attempts I found that seven kerfs 1/8" wide by 41/64" deep, spaced 3/16" apart produced a 1 1/4" radius bend.

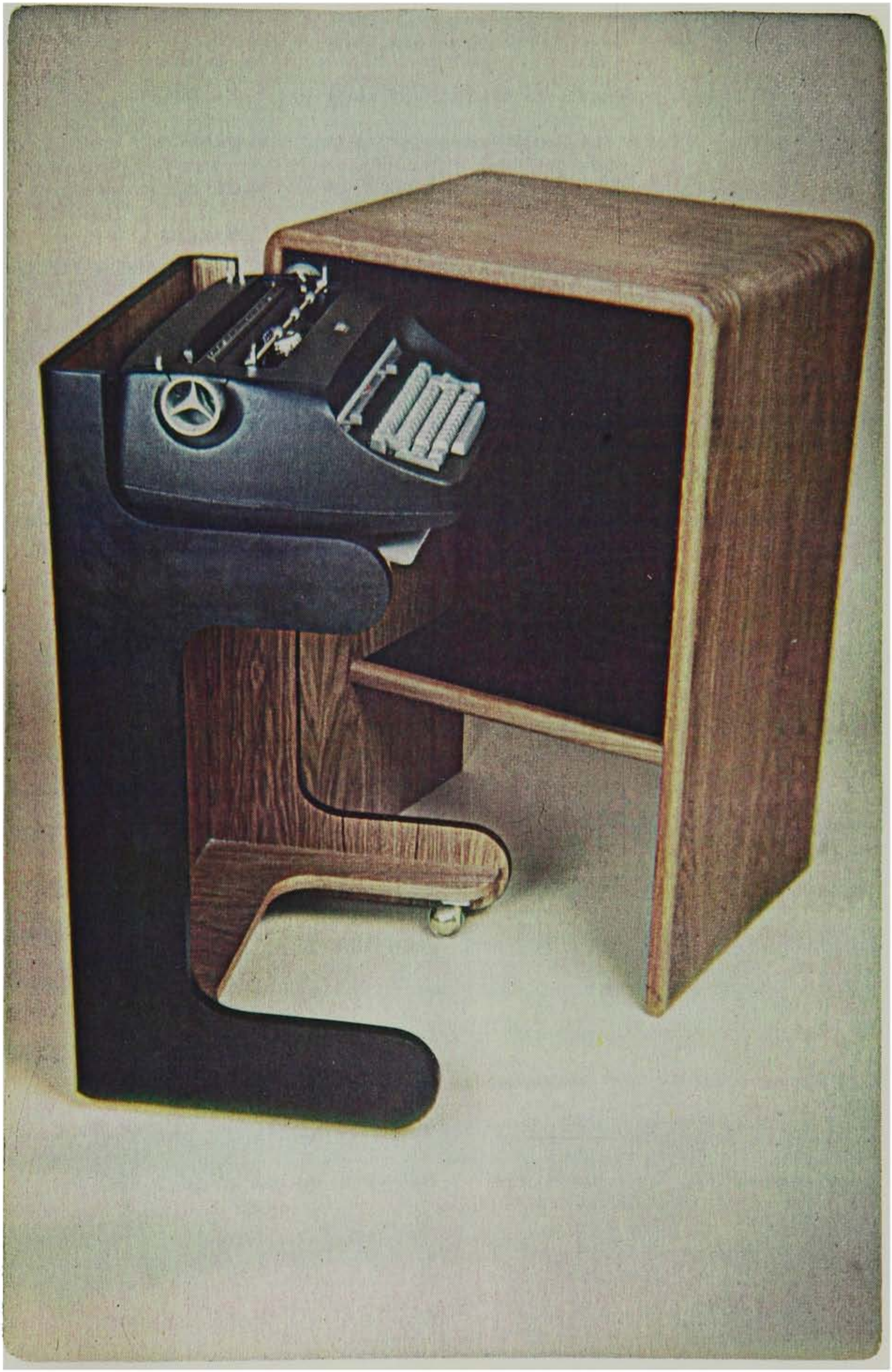
I tried cutting trapazoid wedges to fit in the kerfs after the panel was bent. They turned out to be difficult to insert. I tried extending

yellow and white glue with sawdust, planer shavings and a combination of dust and shavings and packing it into the kerfs before bending. It was readily apparent when evaluating the results that I was trying to strengthen the bend in successive sections (a chain, which of course, broke at its weakest link). Next I tried reinforcing the bend with a shaped glue block, but because the inside of a kerf bend is facetted, the glue block reinforced joint was not very strong. I then tried a strip of canvas soaked in yellow glue because it would conform to the facets. I was amazed to find that the canvas and glue reinforced bend would support my weight (180 lbs.)

I wanted to use what I had learned in one piece of furniture. So, in the oak plywood stereo commission, I thinned the carcass corners to 7/8" radius and kerf bent the counter edge to produce a 2" radius (Fig. 5).

I was then offered a commission to design and build a portable typing stand that would conceal the typewriter when not in use (Fig. 6 & 7).

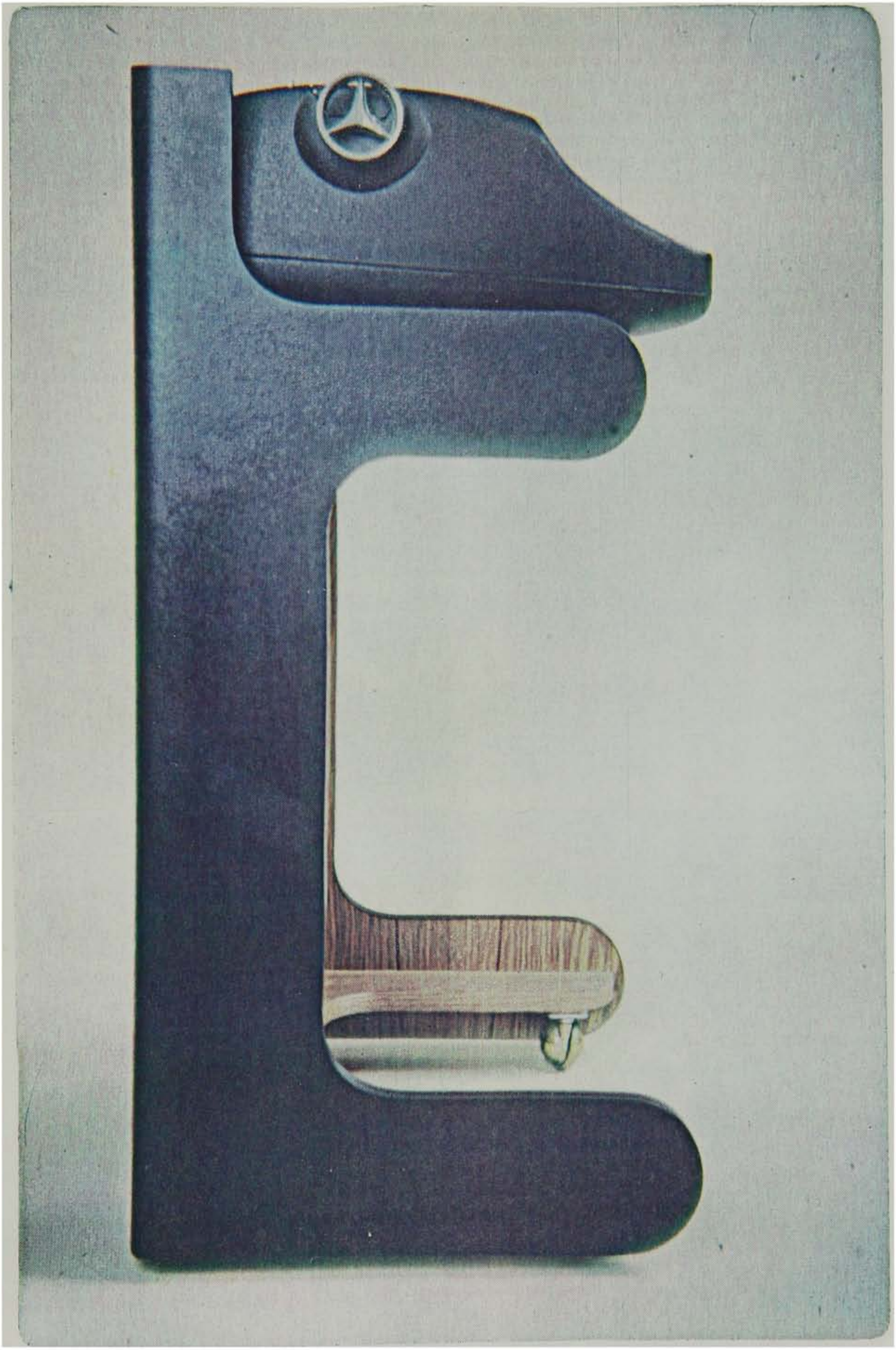
I liked the soft line that kerf bending produced in the stereo cabinet's counter. I wanted to stay



with it, but I also wanted to develop bending techniques for other materials to use in conjunction with kerf bent plywood, to give me more design options. I began experimenting with bending formica. I used a strip heater and bent a piece of 1/16" formica 20" long. Although the bend was not completely successful, the results were encouraging.

After experimenting with the three thicknesses of formica and various temperature ranges, I was able to produce two consecutive 1" radius, 36" long bends in 1/20" heat formable formica by raising it rapidly (10 sec.) to 300° F. (Fig. 8). To cover the edges, I used 1/32" vertical grade formica which will conform to rather tight radii (2") in thin strips without heat forming (Fig. 9).

Since the pedestal, which conceals the typewriter when not in use, is open to the front, it was necessary to skin the inside. This required kerf bending an inside corner. In this process the kerfs open instead of close when the panel is bent. Kerf bending an inside corner is always more difficult than the outside corner because the radius is smaller and it seems to be easier to stretch the face veneer fibers in an outside corner bend than it is to

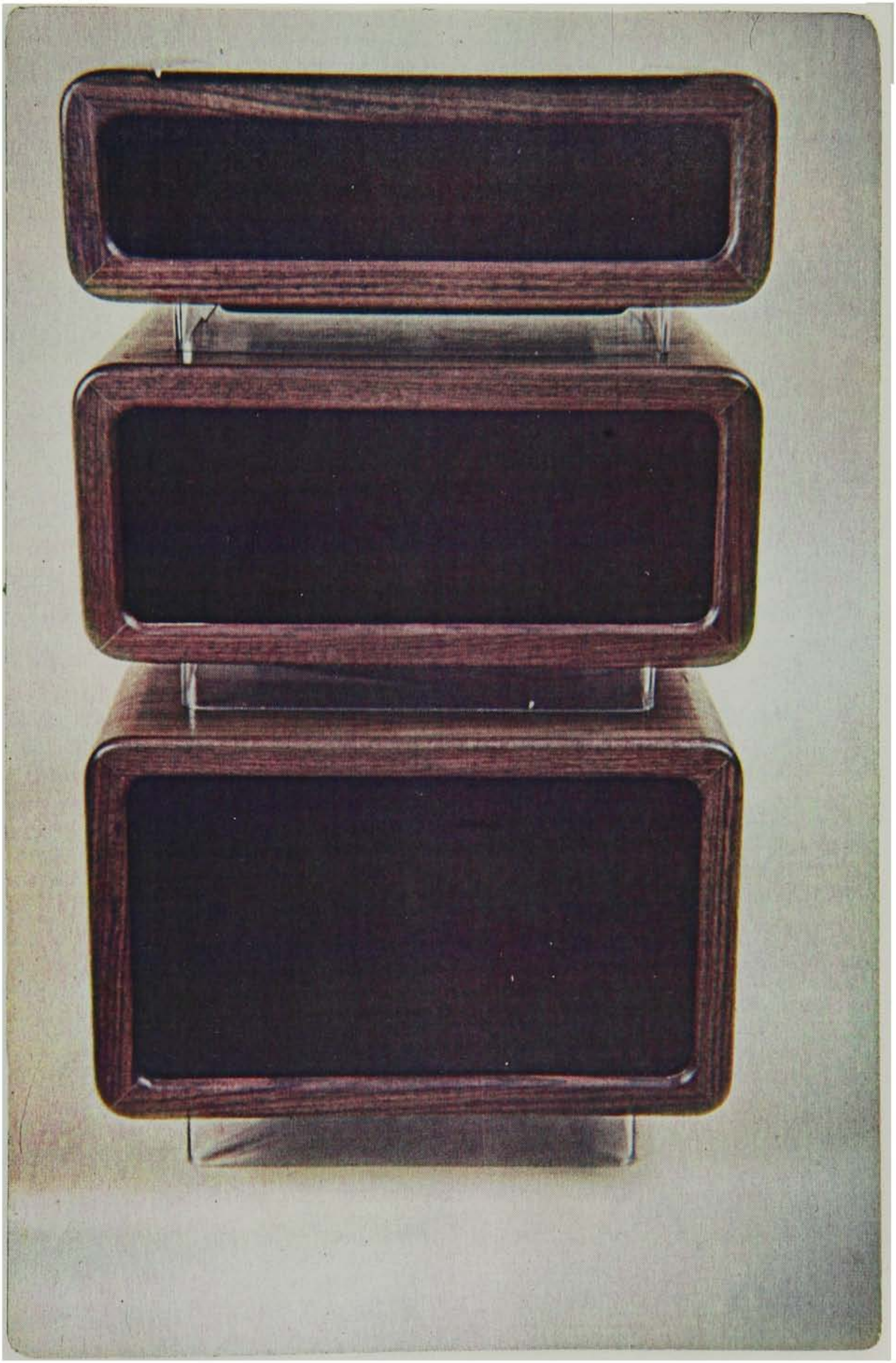


compress them in an inside corner bend. Cutting the kerf slightly deeper seemed to help.

At roughly the same time I was working on the typing stand, I was given a problem in my Environmental Design minor to design a stereo cabinet. Naturally, I kerf bent it. This time I used walnut plywood. Since walnut plywood is relatively expensive, I designed the cabinet from one-half a sheet (4' x 4'). Experimenting further with other materials, I used smoked plexiglass fronts with clear plexiglass spacers between the turntable, amplifier and cassette player modules (Fig. 10 & 11).

I was pleased with the appearance of the walnut stereo modules, so I decided to do another walnut stereo, this time to include speakers, record storage and cassette storage. I used one sheet of walnut plywood and 1/4" black styrene fronts and spacers. To take kerf bending a step further, I used it as a purely visual element. I "golden-sectioned" the side of every module with one kerf (Fig. 12, 13 & 14).

I tried a few more tests, kerfing on a changing angle to create a partial cone. I rolled an edge 270 degrees. The results were surprising. I should

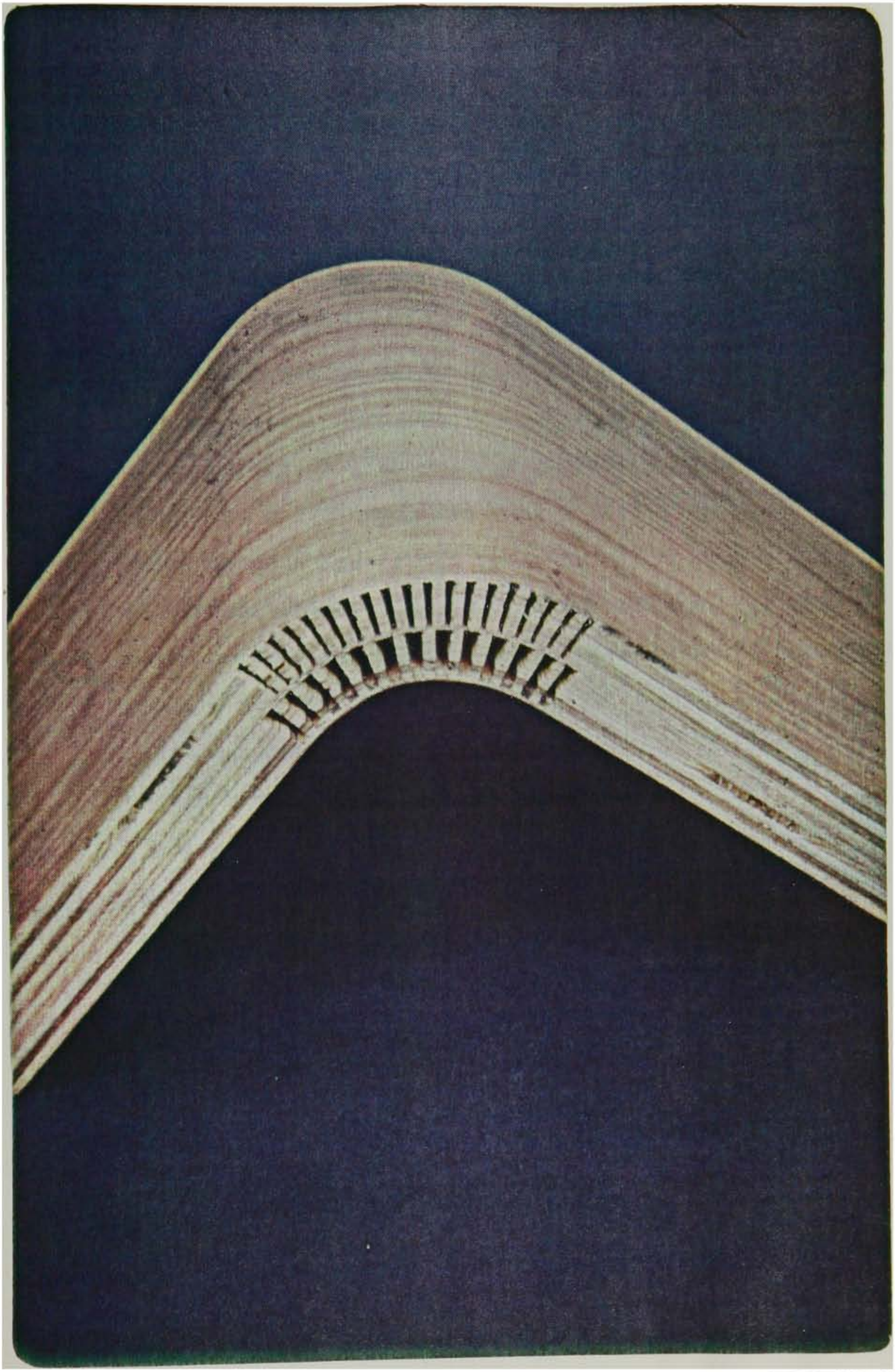


have rolled the counter's edge 180 degrees on the first oak stereo cabinet. I also experimented with a fiberglass reinforced bend. The result was an extremely strong corner, much stronger than canvas soaked in yellow glue.

This fiberglass reinforced corner was strong enough to stand by itself, i.e. a broken loop with no front, back or bottom. I used it for a coffee table. I ripped a sheet of oak plywood kerf bent one-half with an inside bend, held it in place, layed up ten ounce fiberglass cloth with a special epoxy developed for the boat building industry and sandwiched it in between the other outside kerf bent half (Fig. 15, 16, & 17).

If the kerfs are not deep enough the panel will break when bending. If the kerfs are too deep, they will show through, an unhappy event called telegraphing. Oak appears to resist telegraphing more than walnut. It seems that woods which steam bend well are more likely to suffer from this problem.

My previous kerf bent modular pieces seemed to have a machine made look, or a coldness due to the flatness of the fronts and the fact that they were plastic. So I tried to eliminate this in my last



piece, a modular armoire. I used kerf bent inside and out, fiberglass reinforced walnut plywood carcass, and a compound curved, vacuum formed, Brazillian rosewood veneered front.

I wanted the grain and the curves of the front to match throughout the three modules, so the vacuum form mold had to be as large as the front (36" x 78"). After several attempts, I was successful in molding four layers of 1/8" Italian bending poplar which produced a 1/2" compound curved panel veneered with book matched Brazillian rosewood. The top module, a sweater chest, was lined in upholstery leather with an aromatic cedar veneered partition. The center module housed a shelf, six leather lined, self-closing drawers and two shallow jewelry drawers that would remain open. All sections were of uniform laminate Baltic birch. A light comes on when the mirror backed doors are opened. Opening the doors also exposes the kerfs in the carcass corners. I filled them with black epoxy (epoxy mixed with carbon black). The bottom module had three deep drawers on full extension (150 lb.) drawer slides (Fig. 18 & 19). The carcasses were 24" deep; the deepest kerf bent carcass I had tried.

The longer the bend, the more important the accuracy of the cut. A piece of plywood 24" wide could vary in thickness .020", one edge coming from the thick center of a sheet. This variation in thickness, when transferred to the bottom of the kerf, can cause severe telegraphing. It was necessary to design a jig to support a skill saw passing over the panel. In this way, the depth of cut could be controlled regardless of the panel's thickness. I also found that by making the saw blade wobble (tilted on its axis of rotation), producing a wider and more flat bottom kerf, telegraphing could be virtually eliminated.

Some telegraphing may be inherent in cutting flat bottom kerfs, but it can be controlled to the extent that it can only be detected by a trained eye, and then only on close inspection.

In conclusion, kerf bending affords the home craftsman or small shop owner an economic way of bending wood, because it is not necessary to build a mold. The panel can be kerfed, bent, fiberglassed, and simply held in place while the fiberglass hardens. It is often impractical to build a mold which will be used only once.

I hope to develop lighter and stronger plywood carcasses by increasing the amount of fiberglass and decreasing the thickness of the plywood, i.e. 1/8" of fiberglass sandwiched between two layers of kerf bent 1/4" plywood.

My future research will be aimed at combining the strength and durability of fiberglass with the beauty and serviceability of plywood.