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The Shrinking and Swelling of Wood and Its Effect on Furniture

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Introduction

The dimensional changes that accompany the shrinking and swelling of wood are major sources of both visual and structural problems in furniture. Shrinking and swelling occur as the wood changes moisture content in response to daily as well as seasonal changes in the relative humidity of the atmosphere, i.e., when the air is humid, wood adsorbs moisture and swells; when the air is dry, wood loses moisture and shrinks. Various finishes and treatments may be used to slow this process, but, in general, they do not stop it. Likewise, air drying and kiln drying the wood do not prevent the wood from subsequently gaining or losing moisture. Thus, wood that is kiln dried to 6 percent moisture content and stored in a dry shed outdoors in a temperate climate such as that found in Indiana will regain moisture until it eventually reaches about 12 percent moisture content. Under the same conditions in a tropical climate, the wood will come to a moisture content of about 16 percent.

EMC vs Relative Humidity

With time, the moisture content of wood will always come into equilibrium with the relative humidity of the air surrounding it. This moisture content is referred to as the equilibrium moisture content (emc) of the wood. It follows that for each level of relative humidity of the air, there is a corresponding equilibrium moisture content of the wood. This relationship is illustrated by the sorption curve presented in Figure 1 in which emc is plotted as a function of relative humidity. This curve may be used to predict the moisture content of wood in service at any relative humidity. Thus, wood that is exposed to a relative humidity of 30 percent will eventually come to an emc of about 6 percent. Similarly, wood exposed to a relative humidity of 75 percent will come to an emc of about 14 percent.

The emc's of wood composites tend to be somewhat less than those of

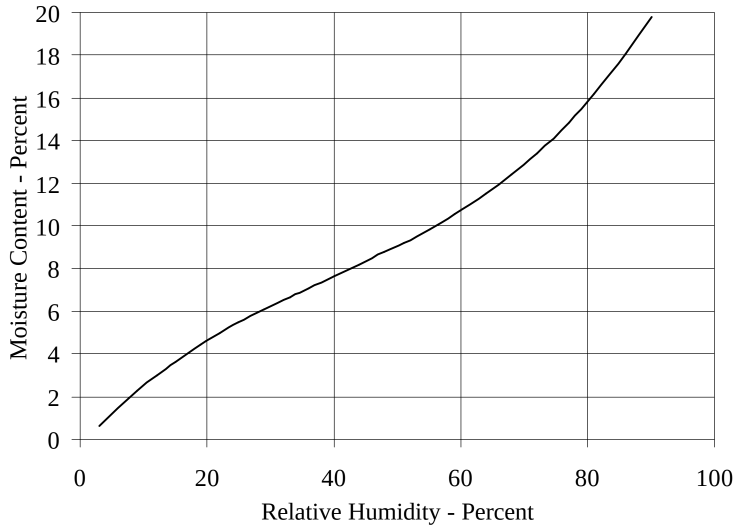

Figure 1. Equilibrium moisture content versus relative humidity for solid wood at 70° F.

solid wood. Values for softwood plywood, particleboard, oil-treated hardboard, and high-pressure laminate are given in Figure 2.

Equilibrium moisture content values are sufficiently similar for most of

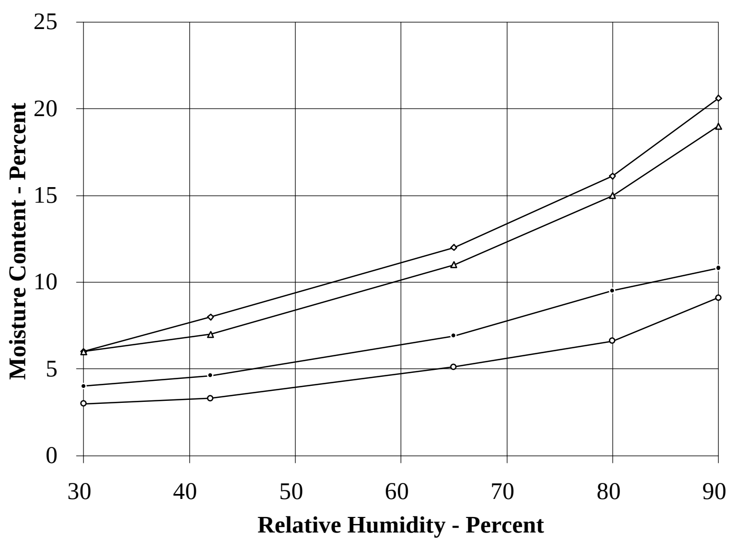

Figure 2. Equilibrium moisture content of selected wood composites.

the commonly used woods that one set of values can be used for all species. Emc values are affected by temperature, however, so that different sets of values have been determined for a wide range of temperatures. These values are important in high temperature drying, but the values given for an average daily temperature are appropriate for most emc determinations.

EMC'S by Region

Since the climate of the US is quite varied, the moisture content of wood in service varies from region to region in accordance with differences in temperature and humidity. The climate, for example, tends to be somewhat hot and humid in the southern coastal states and cold and dry - at least in the winter months - in the north and, in particular, in the north central states. As a result of these differences, the moisture content of furniture used in the southern coastal states such as Florida, southern California, and Mississippi must be expected to attain relatively high equilibrium moisture contents of at least 12 percent at sometime during the year, whereas furniture used in the northern states in cities such as Chicago must be expected to attain relatively low emc's of 5 percent or less. Similarly, furniture used in the dry Sun Belt states of the southwest must also be expected to attain very low emc's. A comprehensive view of the average moisture contents to be expected in various regions of the country is provided by Figure 3.

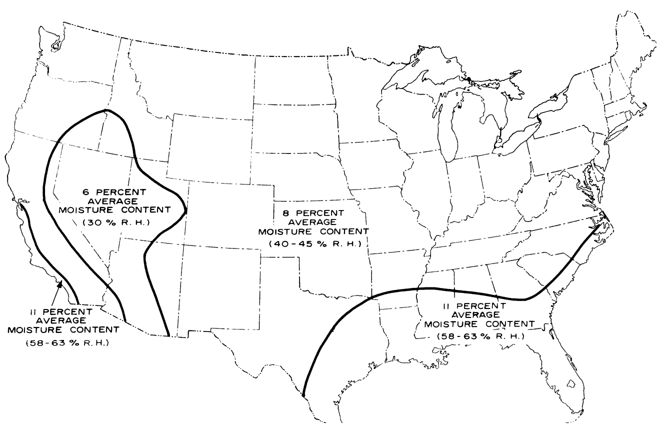

Figure 3. Average equilibrium moisture contents in various regions of the United States.

Moisture content changes of only a few percent are sufficient to cause significant shrinking and swelling of wood. In the case of sugar maple, for example, a change of 6 percent in moisture content may result in a dimensional change in a furniture part of about 2-1/2 percent.

In general, the amount of shrinking and swelling which takes place is directly proportional to moisture content changes in the wood. Wood shrinks and swells the greatest amount in the tangential direction, about half as much in the radial direction, and about 0.1% to 0.2% in the longitudinal direction, Figure 4. Because of its small magnitude, shrinkage in the longitudinal direction is usually ignored in most design problems.

Shrinking and Swelling in Relation To Grain Direction

The amounts of shrinkage which various species undergo as they are dried from the green to oven-dry condition may be found from the shrinkage coefficients (SC) given in Appendix III. Sugar maple, for example shrinks 9.5 percent in the tangential direction as it goes from the green to the oven dry condition and 4.9 percent in the radial direction - as defined in Figure 4. Differences in shrinkage between species may be significant. In contrast to sugar maple, mahogany shrinks 5.0% and 3.6% in the tangential and radial directions, respectively.

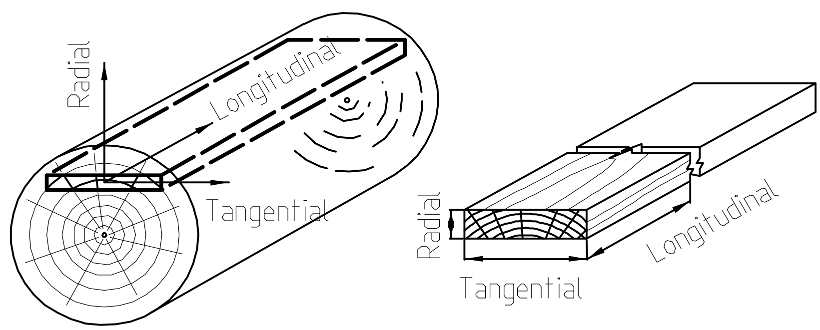

Figure 4. Diagram illustrating the radial, tangential, and longitudinal directions both in a log and in a board cut from it.

It is this difference between shrinking in the radial and tangential directions that causes splits to develop in the ends of logs and disks cut from logs, Figure 5. As a log dries, it shrinks more in circumference than the corresponding shrinkage in diameter will allow. To compensate for this phenomenon, a split develops, usually along a ray, in order to preserve the integrity of the expression relating the circumference of a circle to its diameter, i.e., Circumference = 3.14 x Diameter. This differential shrinkage along the radial and tangential axes also explains the characteristic shrinkage and distortion of flats, squares, and rounds, Figure 6, as a function of the direction of the annual growth rings.

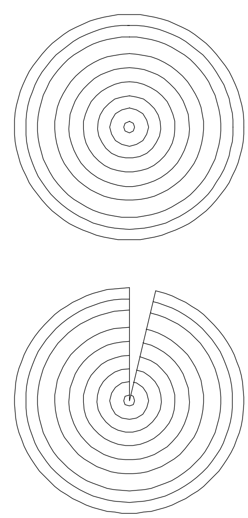

Figure 5. Differences in shrinking along the radial and tangential axes cause splits in the ends of logs.

Fiber Saturation Point

In general, shrinkage does not occur in wood until the moisture content drops below what is termed the “fiber saturation point” (fsp). Specifically, the fiber saturation point is defined as that moisture content at which all of the liquid water, essentially sap, has been removed from the cell cavities but the cell walls are still saturated with adsorbed water. For most woods, the fsp is taken as 30 percent moisture content. Significant differences do occur, however.

Woods with high extractive contents, in particular, tend to have lower fsp's. These differences can be seen in Table 1 where the fsp's for a few selected woods with both low and high extractive contents are presented. As can be seen, the fsp for rosewood, which has a high extractive content, is much lower than for Sitka spruce, which has a very low extractive content.

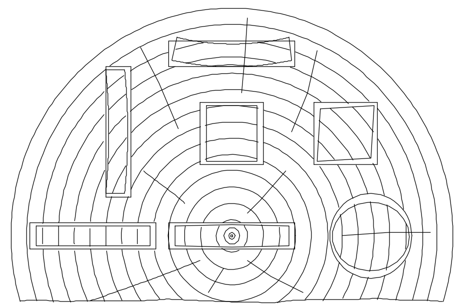

Figure 6. Shrinkage and distortion of flats, squares, and rounds as affected by annual growth rings.

Quantitative Amounts of Shrinkage

The amount of shrinking or swelling which takes place as a product undergoes a change in moisture content may be calculated by means of the expression

$$\Delta W = W[(SC)/100] \cdot \Delta mc / 30$$

where:

ΔW = change in width of a product; e.g., a board.

W = original width of a product.

Δmc = change in moisture content of a product - if a board dries from 12% to 8% moisture content, then it has a change in moisture content, Δmc, of 4%.

SC = the appropriate shrinkage coefficient given in Appendix III.

Moisture content changes of only a few percent are sufficient to cause significant shrinking and swelling of wood. In the case of the 32-inch wide sugar maple table top, for example, a change of 6 percent in moisture content results in a change in width, ΔW, of

$\Delta W = 32 \cdot (9.9/100) \cdot 6/30 = 0.63$ in.

Failure to appreciate that changes of this magnitude occur in service may lead to serious problems if the furniture is not designed to accommodate them.

Species	FSP- %
Southern yellow pine	29
Sitka spruce	28
Western redcedar	18
Redwood	22
Teak	18
Rosewood	15

Table 1. Fiber saturation points of selected woods.

Some shrinkage and swelling of wood must always be anticipated. It is important, therefore, that furniture be designed to accommodate dimensional changes of the wood. Furthermore, the need for moisture control and elimination of moisture-related dimensional stability problems increases as the price of the furniture increases. Small splits and checks that may be tolerated in low to medium price furniture are totally unacceptable in high quality furniture.

Problems Caused By Shrinkage and Swelling

Some of the most important problems related to the shrinking of wood are simply visual. Of particular importance, shrinking of wood causes joints to open and mating parts to fit together poorly. This is a serious problem with miter joints in case doors, for example, which present an especially poor appearance when they do not fit together properly, Figure 7. It is also a common problem and is particularly objectionable in corner miter joints on tables since they are so easily seen.

Improper moisture content is also responsible for many gluing problems, both with respect to initial gluing of the wood and also with respect to the development of internal stresses in glued parts which result

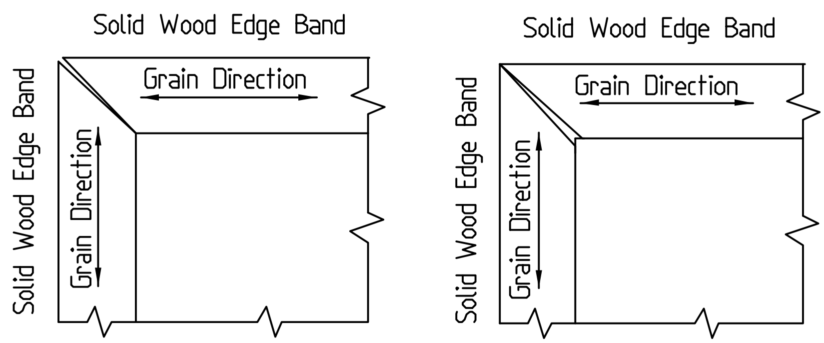

Figure 7. When wood swells, miter joints open as shown on the left. When wood shrinks, miter joints open as shown on the right.

from differential shrinkage and swelling of the parts glued together. Internal stresses of this nature frequently cause solid wood seats to split apart, for example, in early American type chairs.

Shrinkage of wood also causes appearance problems with parts such as L-shaped butt joints that initially fit flush with one another but later distort in service as the "butt" member shrinks across the grain, Figure 8. This action causes the finish to “craze” along the glue line and also breaks the smooth finish across the two parts joined together.

Shrinkage of the wood is also responsible for the development of unsightly splits in essentially all types of furniture. Solid wood table tops often develop unsightly splits in their ends, Figure 9. Not only is the split objectionable, but it also exposes "white wood" which is particularly objectionable with dark finishes.

Shrinkage or swelling of wooden parts after manufacture is also a major cause of the poor fit commonly observed between holes bored into solid wood parts such as chair seats and the ends of the back posts and spindles which fit into them. Figure 10 illustrates the changes that take place in the shape of a hole and the end of a dowel or turned pin end as the

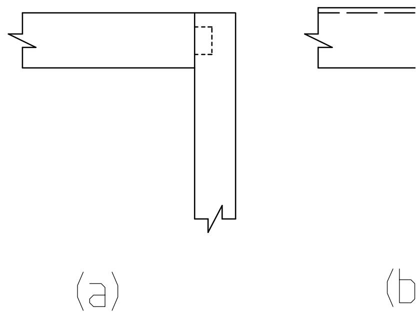

Figure 8. When wood swells, L-shapec
When wood shrinks, the joints appear as in (c).

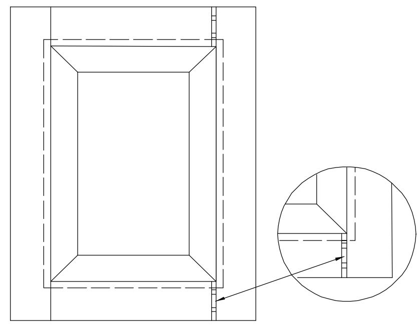

Figure 11. Swelling of the raised panel caused the joints of the frame to fracture. Ss031296.mpg.

wood shrinks and swells. Often, the clearances between the ends of the parts and the holes into which they fit are so great that it is impossible to obtain an acceptable glue bond between them. As a result, furniture constructed with such joints tends to be weak.

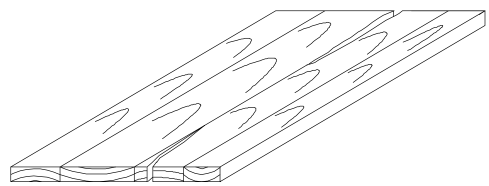

Figure 9. Unsightly splits develop in the ends of tables when the end grain dries too rapidly. Ss111296.mpg.

Excessive swelling of the center panel in solid wood raised panel doors may cause the joints of the frame to fracture as shown in Figure 11. This damage is not only unsightly, but it also seriously weakens the doorframe.

Veneer which was laid up at too high a moisture content on dry particleboard or medium density fiberboard panels will subsequently dry in service and develop surface checks which will cause the surface finish to crack, Figure 12. A related problem occurs in laminated chair backs that are inherently prone to checking -- formation of checks in dark-colored backs exposes "white wood" that is readily noticeable and creates a poor

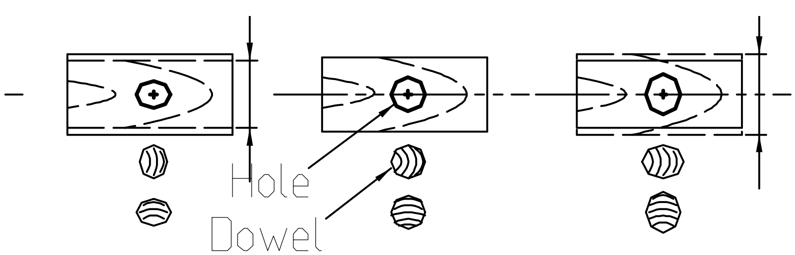

Figure 10. When wood shrinks, joints become elliptical in shape as shown on the left. When wood swells, holes become elliptical as shown on the right. Dowels change shape according to grain direction.

image.

Shrinking and swelling of wood is also responsible for sunken glue lines. When glue is first applied to the edges of the boards in a panel, the panel appears in the condition shown in Figure 13a. As water is adsorbed from the adhesive into the wood, the wood begins to swell as shown in Figure 13b. If the panel is then sanded to remove these swollen lines, it will at first assume a smooth appearance. As the glue line area dries, however, the wood along the glue line will shrink, and the panel will take on the appearance shown in Figure 13c.

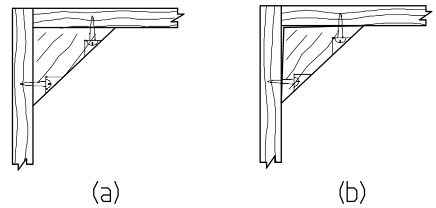

Figure 14. Shrinking can cause corner blocks to fit poorly. Ss112696.mpg

Shrinking of wood can also cause corner blocks to fit poorly. In the corner joints shown in Figure 14a, the corner block fits tightly against the two rails it joints together. Should the block dry in service and shrink, however, only the ends of the block will contact the sides of the rails, Figure 14b. As a result, the glue bond between the faces of the block and the sides of the rails will be broken

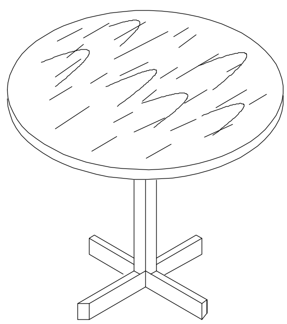

Figure 12. Drying of veneer surface causes checks to develop.

Swelling of particleboard cores can cause solid wood edge bands to split on tables as shown in Figure 15. This problem can arise when tables manufactured in a dry climate are shipped to a humid climate or used in a very humid atmosphere. A table manufactured in December in Indiana, for example, and shipped to the Bahamas might experience such problems.

As wood shrinks, any fasteners embedded in it will tend to loosen as shown in Figure 16. The tip of the fastener will tend to maintain its position - in this case along the center line of the wood - as the surface of the wood in effect shrinks toward the center. As a result, the length of the fastener protruding from the wood increases. Joints loosen as a result of the action as shown in the lower illustration in Figure 16.

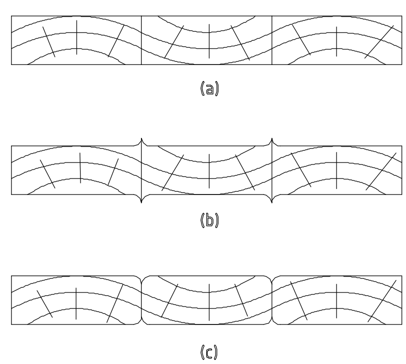

Figure 13. Shrunken glue lines result when a panel is planed before the glue lines are allowed to dry and shrink to original size. ss011497.mpg

Table legs that are attached to the support rails with anchor bolts or lag screws loosen in service for the same reason. As the leg dries, it shrinks and becomes smaller, Figure 17. The amount of the anchor bolt protruding from the side increases accordingly. Since the anchor bolt no longer holds the sides of the legs firmly against the ends of the rails in the "pocket" formed by the two rails, the leg becomes loose and wobbly.

Reducing Shrinkage and Swelling Problems

Four factors account for most of the shrinking and swelling problems seen in furniture.

• The wood was not dried to the proper uniform moisture content before manufacture which subsequently lead to excessive shrinkage,

• The construction of the furniture is such that the wood is mechanically restrained from shrinking and swelling

• Excessive drying takes place through the ends of the members.

• A design was used that accents visual differences in shrinking and swelling in members oriented perpendicular to one another rather than minimizing them.

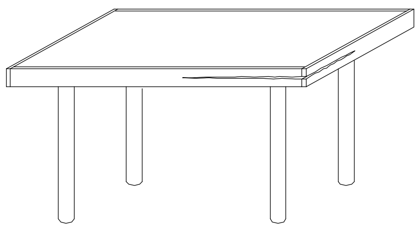

Figure 15. When a particleboard core swells, it can cause a solid wood band to split. Ss112496

Numerous problems arise because the furniture is constructed from wood that has been improperly conditioned prior to manufacture; i.e., the wood is at the wrong moisture content at the time of manufacture. To reduce problems related to the initial moisture content of the wood, the wood should be dried to a moisture content level consistent with its final service environment. It should then be stored and manufactured under atmospheric conditions that will maintain this level. Then, even though the wood will continue to shrink and swell in service as the seasons change, the effects will be minimized.

It is, of course, impossible to always know the conditions in which the furniture will be used. Lacking better information, many manufacturers in the U.S. prefer to dry wood to about 6 percent moisture content since fewer problems appear to arise from over-drying as opposed to under-drying - presumably, subsequent swelling of the wood causes joints to close tightly, whereas shrinking of the wood causes joints to open. Lacking more precise knowledge, the conservative *"2 percent rule"* can be applied; i.e., allow for 2 percent movement of the wood in service. This amount of

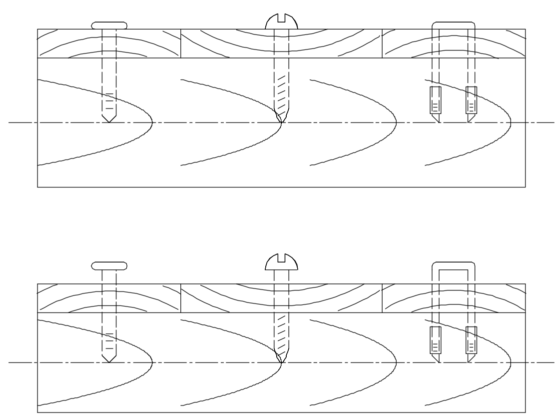

Figure 16. Loosening of nail, screw, and staple resulting from shrinking.

movement corresponds to a moisture content change of about 8 percent - for a moisture content change of 4 to 12 percent, for example. This should be adequate for almost any area of the United States.

The moisture content of the lumber must be regularly sampled to ensure that it is maintained at desired levels. A calibrated moisture meter provides the most convenient way of determining moisture content before

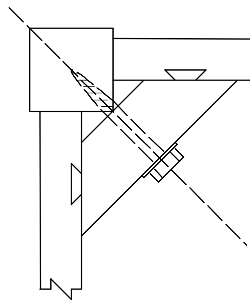

Figure 17. As a table le
from the leg loosens as s

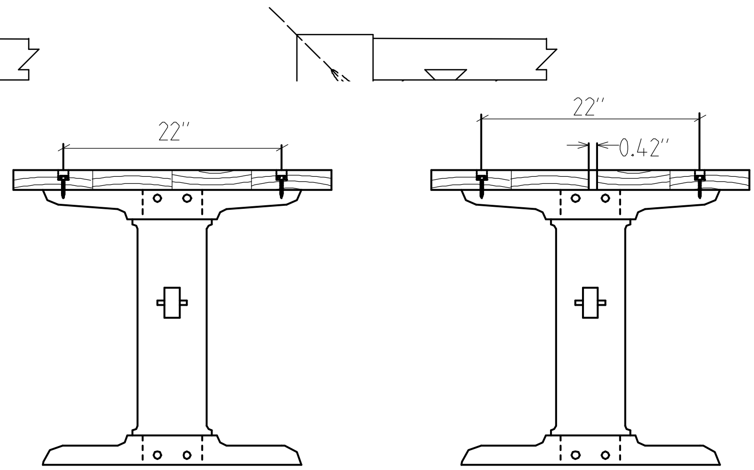

Figure 18. When a solid wood top is anchored to its support rail as shown, splits are likely to develop if the top dries during service.

it is machined into parts.

It is particularly important that wood not be hindered from shrinking across the grain since serious splitting problems occur when the furniture is constructed in such a way that the wood is mechanically restrained from expanding and contracting in service. Shrinkage and swelling of wood cannot be prevented mechanically - only the rate of shrinking and swelling can be slowed through the use of coatings. Wood is very strong along the grain (longitudinal direction), but it has limited strength across the grain (tangential and radial directions). *Thus, furniture must always be designed so that the wood is free to expand and contract across the grain.* The importance of this principle is demonstrated in Figure 18. In this figure, a solid wood sugar maple top is shown attached to the support rails at points 22 inches apart by means of lag screws embedded in the top. Based on the data given in Appendix III, if the wood were to dry from 12 to 6 percent, the top would shrink 0.42 inches between the points of attachment to the rail. The rail itself, on the other hand, would shrink a negligible amount in this direction. In effect, the rail hinders the top from shrinking, but it cannot prevent it. As a result, a 0.42 inch-wide split will develop in the end of the top.

Parts will also tend to develop end-splits if conditions are such that they dry too rapidly through end surfaces. Thus, stored parts may develop end-splits if the temperature in the factory increases excessively over a weekend (and the relative humidity decreases accordingly). This problem arises because moisture loss from the end of a member is 16 to 20 times greater than from the side. Thus, as the ends of the members begin to dry, the ends try to shrink, but the core (which loses moisture at a much slower rate) prevents it. When the internal stresses developed in the end of the member exceed the inherent strength of the wood perpendicular to the grain, the wood yields and splits develop. This type of split often develops in the ends of tabletops, Figure 9, in the dry winter months of the northern climates. To prevent this type of split from developing in the factory, parts should be stored in an area where the relative humidity is maintained at the proper level. Alternatively, the ends of the members may be coated with a material that will significantly retard end drying.

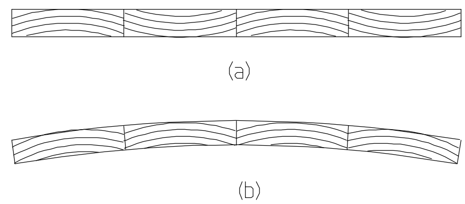

Figure 20. Boards should be laid with alternate growth ring orientation as in (a) – not as in (b). ss120496.mpg

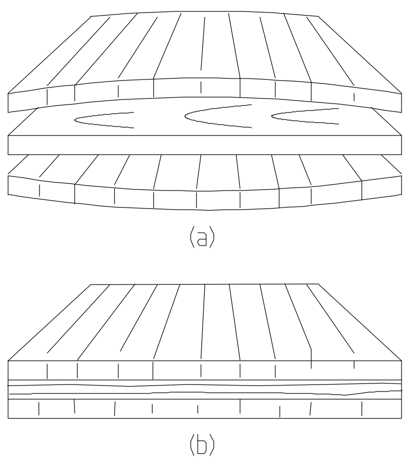

Figure 21. Panel with "balanced" construction.

Esthetic problems arise when wood shrinks or swells if the visual effects are not hidden, disguised, or minimized. Most annoying, perhaps, is "crazing" of the finish at a joint. In this case, joints that initially presented a smooth fitting appearance subsequently appear to be misfit. . Such problems generally occur in L-shaped joints where one member butts into another at right angles. A typical problem is illustrated in Figure 19 where the original smooth line between the top of the back and the top of the back post has been broken by swelling of the back.

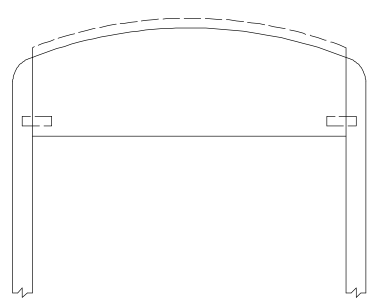

Figure 19. Swelling of the back breaks the smooth line between the top of the back and the back post.

When edge-gluing boards to fabricate panels, the boards should be laid with their growth rings alternately reversed as shown in Figure 20a. By alternately reversing the orientation of the grain, the growth ring effects shown in Figure 6 are averaged so that bowing of the panel as shown in Figure 20b is avoided.

It is also important that "balanced" construction be used when laying up panels or laminating veneer or high pressure laminates to tabletops. Balanced panel construction is illustrated in Figure 21. In this construction, the top and bottom plies are laid up with the grain running in one direction while the grain of the center ply runs crossways to these faces. Any shrinkage or swelling which takes place in the face ply will be offset by a corresponding amount of shrinking or swelling in the bottom ply, and, as a result, the panel will remain flat.

Tabletops should also have balanced construction. This is illustrated in Figure 22 where the veneer or laminate applied to the top surface of the table top is balanced by the comparable backer sheet applied to the underside of the top.

Specific Examples

In the section that follows, a number of specific problems related to shrinkage and swelling are presented and discussed. For convenience, the furniture discussed is presented by functional category.

Tables

Solid Wood Table Tops

Problems with solid wood tabletops arise from the differential shrinkage of the top across as opposed to along the grain. Shrinkage or swelling along the grain will be near zero; shrinkage or swelling across the grain, however, may be substantial.

Splitting in the ends of solid wood tabletops, Figure 23, is a phenomenon that is most frequently seen with "antique" tables which have been stored in an unheated area but are subsequently brought into a centrally heated home. Moisture content of the tops stored in unheated areas is likely to be 12 percent or more. As soon as these tops are brought into a heated home, they immediately begin to dry out. Since moisture movement is much more rapid from end grain than from side grain, the ends of the table begin to dry out before the core is able to lose moisture. The ends of the top try to shrink, but the core, which retains its original dimensions, prevents this from occurring. As a result of this action, the ends of the top are subjected to tensile forces. Since wood has low resistance to tensile force across the grain, the wood yields, resulting in unsightly splits in the ends of the top.

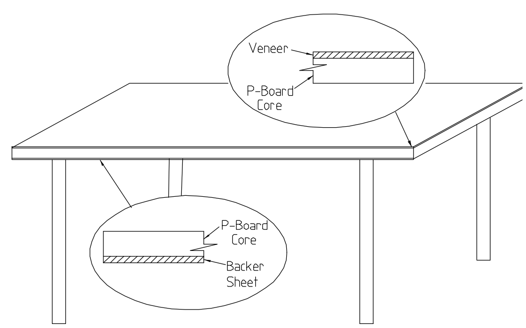

Figure 22. "Balanced top construction. The veneer on top is "balanced" by the "backer sheet" on the underside.

When tops are mechanically prevented from shrinking and swelling, splitting of the entire top can occur. This principle is illustrated in Figure 24 where a round pedestal table with a split in the top is shown. The top is supported by cross rails with the end of each rail firmly anchored to the top. Splits develop in tops supported as shown here because the top is prevented from shrinking across the grain by the cross rail which is anchored at each end to the edge of the top with screws. As the top begins to shrink across the grain, it is prevented from doing so by the cross rail. Eventually, a point is reached where the internal stresses exceed the tensile strength of the wood, and the top splits.

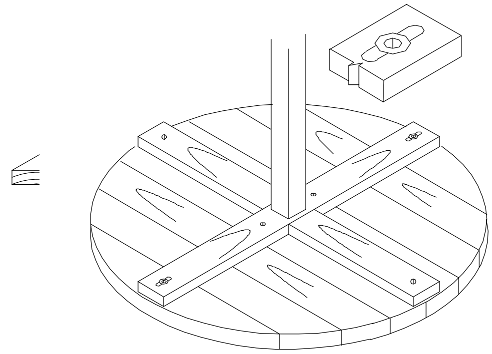

Figure 23. Splits may develop in the ends of solid wood tables if the ends dry out too rapidly.

Figure 25. Splitting can be prevented by inserting the screws through slots that allow the top to move.

This damage could have been prevented if the screws had been inserted through slots which would have allowed slip to take place between the top and the cross rail, Figure 25, without creating internal stresses in the top. The two screws located in the cross rail near the pedestal should not cause problems because only a small amount of shrinking and swelling should take place in the wood between them. These two screws can, therefore, be used both to locate the rail and to firmly attach it to the top.

Splitting in rectangular tables with solid wood tops occurs for essentially the same reason. If the rails are attached to the underside of the top with screws at the points shown in Figure 26, the end rails will prevent the top from shrinking if it begins to dry out in service. As a result, the top will split. With solid wood tops, these attachments should be made with connections that allow movement to take place between the top and the rails, i.e., with slip joints. When screws are used, they should be located in the middle portion of the end rails as shown in Figure 27. By locating the screws in this area, the amount of shrinkage that occurs between the fixed fasteners may be held to acceptable levels.

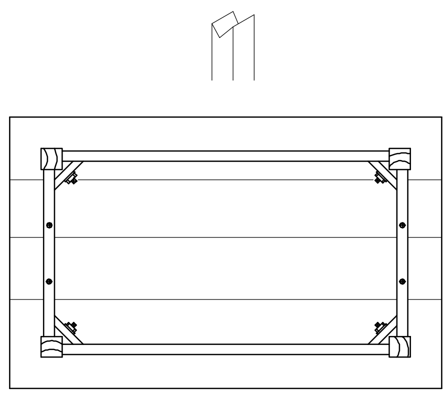

Figure 27. To allow the top to shrink and swell, screws should be located towards the centers of the end rails.

Figure 24. Splits develop in solid wood tops when they are prevented from shrinking and swelling across the grain by cross rails.

Figure 28 illustrates the bowing that can occur in front and back rails when the rails are attached to the top with screws as shown in Figure 29 as the top shrinks. This is a particularly serious problem when tops are constructed of air-dried wood and the tables are subsequently shipped to a much drier climate. Such problems tend to occur in furniture produced in Central America and the Far East where the emc's are frequently 16 percent. Bowing of up to 3/4 inches has been observed in some rails.

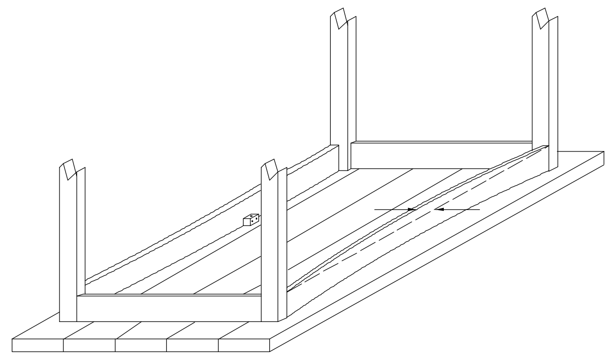

Figure 28. When front and back rails are attached to the top as show, they will bow inwardly if the top shrinks

Rails are often attached to tops by means of screws that are inserted in pocket holes drilled in the sides of the rails, Figure 30. This type of connection does not allow the top to move relative to the rail and hence is not suited for constructions in which the top must be expected to expand and contract.   Where such action must be expected, it is necessary to use connections which will allow the top to expand and contract without pulling the side rail along with it while at the same time maintaining an effective vertical connection between the rail and the top. Screwed in place wooden blocks, Figure 31, are often used to secure such connections between the rail and top. In this construction, the block should be securely screwed to the side rail, but only loosely screwed to the underside of the top. Furthermore, the hole for the screw in the top should either be oversized, or else, an actual slot can be used. In either event, the intent is to allow the top to expand and contract without forcing the rail to follow its movement.

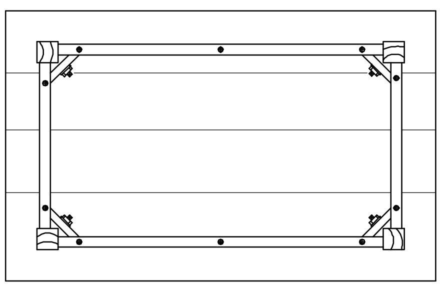

Figure 26. The screws in the end rails do not allow the top to shrink and will likely cause the end of the top to split. ta11496.mpg

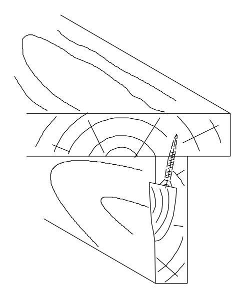

Figure 30. This screw/pocket hole connection does not allow the top to shrink and swell.

Another connector that is used to allow the top to move is a metal clip. One end of the clip is securely screwed to the underside of the top. The free end of the clip fits into a groove that is cut into the side of the rail, Figure 32. As the top shrinks and swells, the free end simply slides in the groove

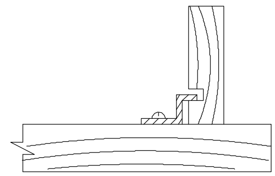

Figure 32. This metal clip assembly allows tops to shrink and swell.

Attachment of Rails to Legs

An interesting problem can arise when the side rails on tables are doweled into the sides of the legs under the condition that the legs have not been sufficiently seasoned and as a result, subsequently dry out in service, Figure 33. As the leg dries and shrinks, the depth of the hole in the leg decreases. If the dowel were inserted the full depth of the hole, i.e., if the dowel "bottomed out" in the hole, then as the leg dries, the dowel is in effect ejected from the hole. If, as is often the case, the end of the rail is glued to the side of the leg, as the dowel pushes the end of the rail away from the side of the leg, the end of the rail will try to pull the side of the leg (to which it is glued) with it. If the glue bond between the end of the rail and the side of the leg is greater than the strength of the leg perpendicular to the grain, a split will develop in the top of the leg, Figure 34.

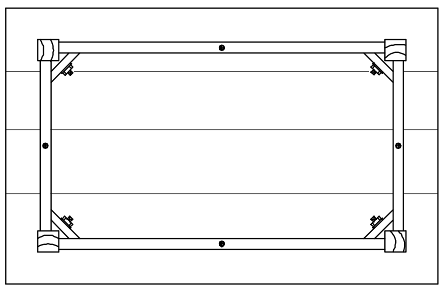

Figure 29. When the front and back rails are attached to the top with screws as shown, bowing of the rails can occur as shown in Figure 28 can occur.

Seating

Solid Wood Booth Ends in Restaurants

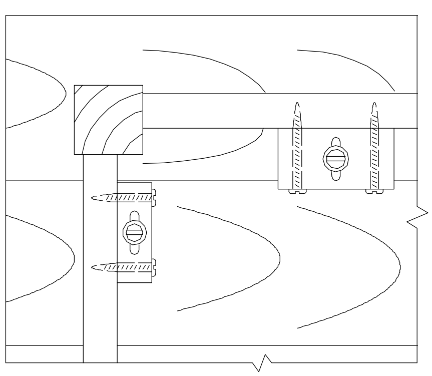

Figure 31. Attachment of rails to top with screws and slotted blocks. Ss032797

Splitting also occurs in the solid wood ends used in the booths in many

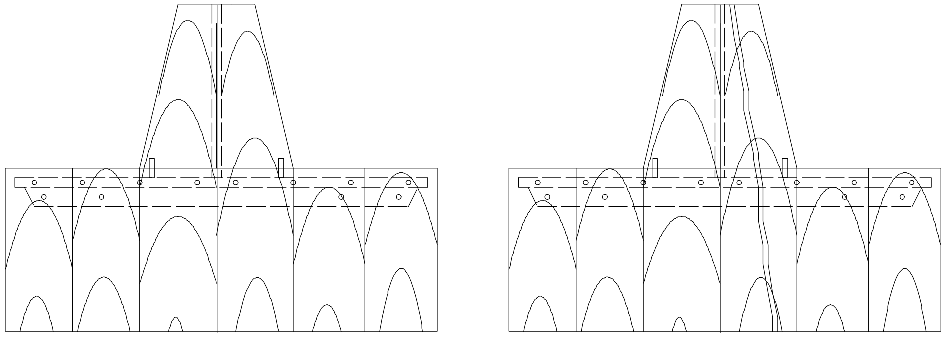

Figure 35. Solid wood restaurant booth ends may develop splits if they are anchored at their ends and not allowed to shrink.

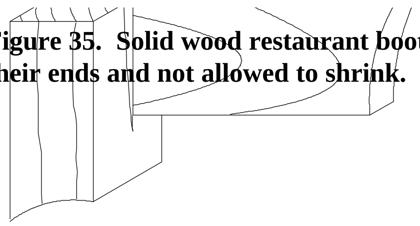

Figure 33. This damage resulted because the end of the rail was glued to the side of the leg.

restaurants, Figure 35 (l). This can occur with solid wood ends in which all of the material is vertically oriented when a seat rail is firmly attached across the width of the rail. If the rail is attached at each end (near the front edge of the seat) with connectors which do not allow for expansion and contraction, as the end attempts to shrink when the humidity drops, a split will develop along the grain, Figure 35 (r), in order to relieve the internal tensile stresses which are developed perpendicular to the grain.

A somewhat different problem can occur with the end shown in Figure 36 (left). In this end, the grain of the backrests is oriented vertically while the grain of the base portion is oriented horizontally. If the backrest is attached to the base by dowels located near each edge, internal tensile stresses will be developed in the backrest when the humidity decreases longitudinal splits subsequently develop in the backrest in order to relieve these stresses, Figure 36 (r).

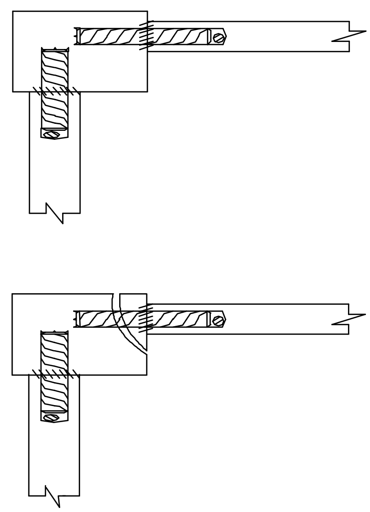

Figure 34. Bottoming of dowel in hole in leg and gluing end of rail to edge of leg cause damage seen in Figure 33.

Solid Wood Ends in Sofas

Splits can also develop in the solid wood end panels used in the end frames of some sofas if the panels are not allowed to "float." The end panel shown in Figure 37a is attached at each end to the arm and side rail with dowels. When the panel tries to shrink, it is restrained by these dowels, and as a result, a split develops along the grain, Figure 37a.

When the end panel is fastened to the frame near its edges, it will tend to shear the dowels as it shrinks, and a split will likely develop in one of the panels, Figure 37b. If it swells, it will tend to separate the end rails from the stiles, Figure 37c. To eliminate these problems, the panel should be anchored near its center, and allowed to float in grooves cut in the underside of the arm and the top of the side rail, Figure 37d.

Chairs

Visible joints in chairs should be designed so that movement of the wood occurs at points that cause the least visual impact. This principle is demonstrated in Figure 38. When the back is joined to the back post with dowels located near the bottom edge of the backrest, dimensional changes in the width of the backrest are transmitted to its top edge where they are most evident (left view). When the backrest is joined to the back post with dowels located near the top edge of the backrest, however, movement takes place along the bottom edge of the backrest where it is least evident (right view).

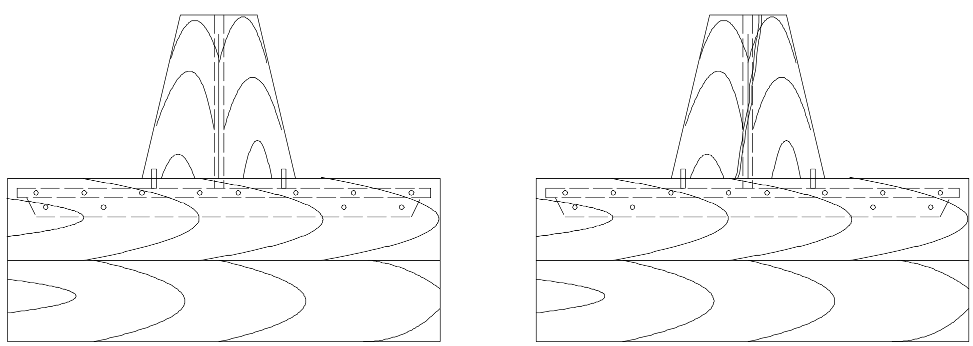

Figure 36. Splits will develop in the ends of booths constructed as shown if the bottom edge of the backrest is anchored near its outer edges.

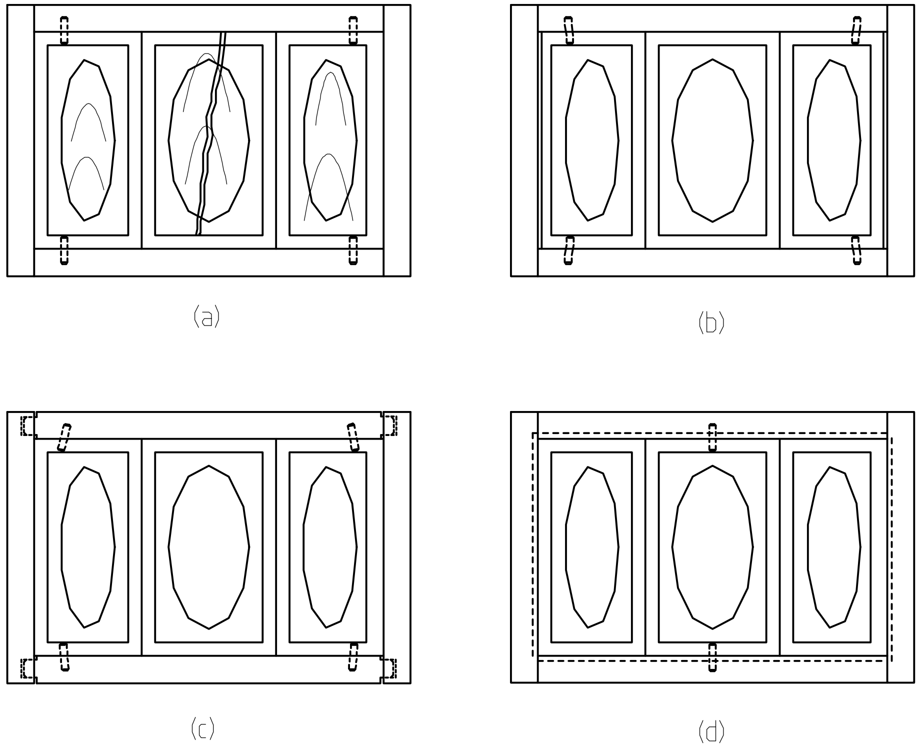

Figure 37. Solid wood ends in upholstered furniture will split as shown if not allowed to shrink and swell.

Desks

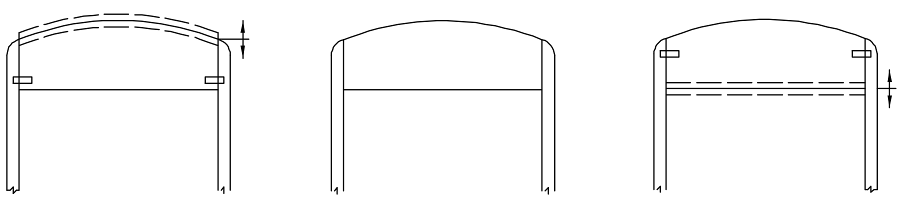

Figure 38. The unsightly effects of shrinking and swelling on the top rail to back post glue line can be minimized by the proper placement of fasteners.

Sticking drawers are one of the most common moisture related problems that occur with desks, Figure 39. The problem is that drawers that move easily in the factory often stick tightly after desks are in service for some time. The problem arises because the drawer fronts adsorb moisture and swell. The solution is straightforward--desks must be manufactured with sufficient clearance between rails and drawer fronts to allow the fronts to swell without sticking. A 10-inch wide yellow poplar drawer front, for example, could swell an eighth of an inch if the desk left the factory at 6 percent moisture content but increased to 12 percent in the field.

A more serious problem occurs with solid wood ends that are prevented from shrinking by some part of the desk frame. The end panel on the desk shown in Figure 40, for example, split because the drawer guides were rigidly attached at each end with screws to the end panel. When the end panels dried out in winter and tried to shrink, the drawer guides prevented it with the result that large splits opened in the panels. For a panel this large, the amount of shrinkage is substantial. If this panel were constructed of yellow poplar, and the distance between screw centers was 23 inches, then for a 6 percent decrease in moisture content, the panel would shrink more than a quarter of an inch between screw centers. Had the end been constructed of sweetgum, shrinkage would have been more than 3/8 inches.

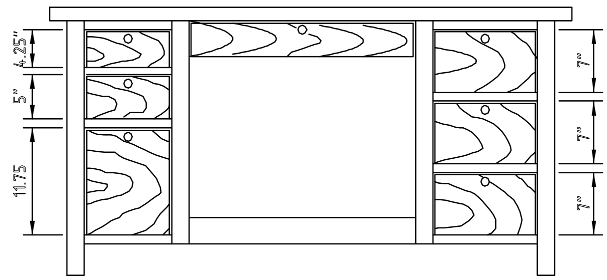

Figure 39. Desk drawers will stick with changes in climate if allowance is not made for shrinking and selling of drawer fronts

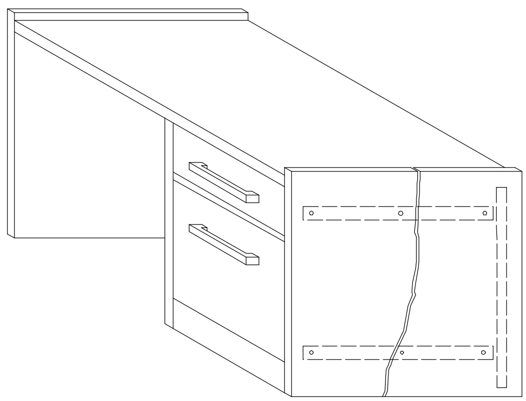

Figure 40. The screws used to attach the ends of the drawer slides to the inside of the desk did not allow the solid wood end to shrink and swell – thus causing splits.

Box Constructions

Shrinking and swelling also causes splitting to occur in the sides of box type constructions when the grain of the sides and ends are mismatched. In the toolbox construction shown in Figure 41, for example, the grain of the sides run horizontally while the grain of the ends to which the sides are attached runs vertically. If the wood dries and the sides shrink, the sides may split. It is often difficult to avoid this problem. In large chests, the grain of the sides and ends must almost necessarily match if splits are to be avoided owing to the significant width of the parts. In such chests, the bottom must be allowed to float since it will always be mismatched with either the end or the side.

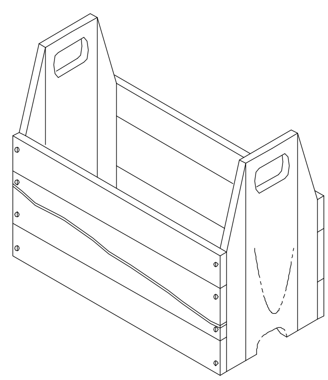

Figure 41. Box construction provides a dilemma because there is always a mismatch in the shrinking and swelling characteristics of the sides joined together.

Cabinet Doors

Raised Panels in Doors

Panels in door frames should be lightly stapled at their centers in a center position in the frame so that the panel is free to expand outward on both edges, Figure 42d. If the panel is pinned at the edges, Figure 42c, splits will likely develop as shown. In addition, adequate clearance must be provided in the frame for the panel to swell since a 16-inch wide red oak panel must be expected to swell as much as 1/4 inch for a 6 percent change in moisture content.. If this is not done, swelling of the joints may cause

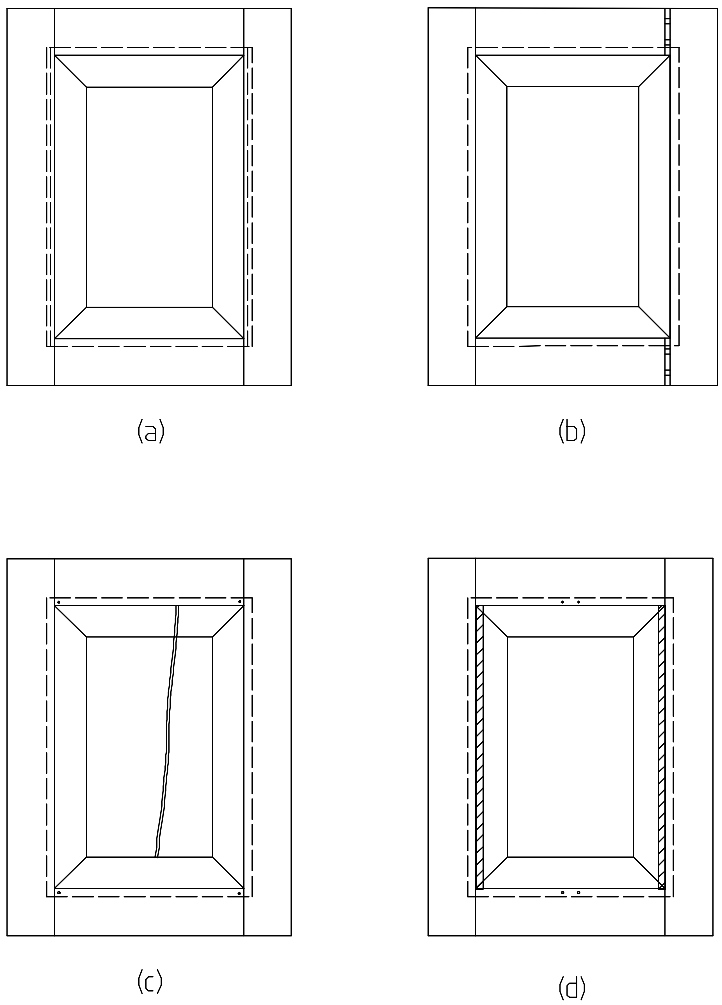

Figure 42. An allowance must be made for raised panels to swell in doorframes, or they will break the corner joints. Panels will split if pinned at the edges – they should be pinned near the center of the panel.

the joints of the frame to fracture, Figure 42b. Since the panels will also shrink, the edges of the panels should be “finished” to avoid showing “white wood,” Figure 42a.

Shrinking and swelling may cause appearance problems with both miter joints and butt joints in cabinet doors. Figure 43 illustrates the importance of the proper placement of dowels in butt joints in order to minimize the visual effects of swelling of the frame. As can be seen, the dowels should be located as close to the upper edge of the frame as possible so that in effect, the frame swells into the panel cavity.

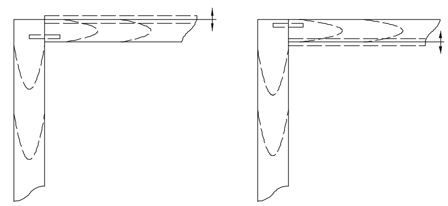

Figure 43. Proper placement of dowels minimizes the visual effect of shrinking and swelling of the top rail.

Figure 44 illustrates how shrinking and swelling affect the appearance of miter joints. As can be seen, when the rails shrink, the joints open on the inner corner; similarly, when the rails swell, the joints open on the outer corner.

Edge Bands on Solid Wood Tops

Shrinkage and swelling problems have always existed, and craftsmen

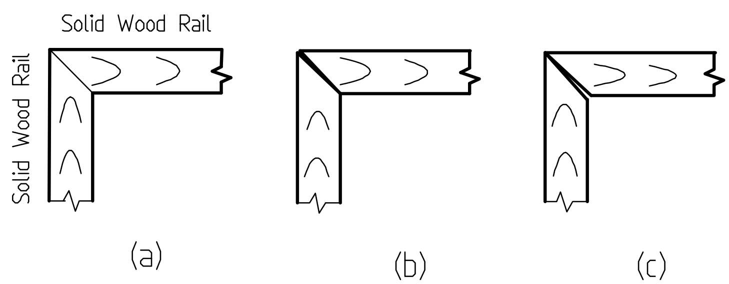

Figure 44. Effect of shrinking and swelling on miter joints.

of an earlier age dealt with them accordingly. Figure 44 shows the solid wood top of a trestle table. End caps on these tops must also allow the top to expand and contract freely. To allow the top to shrink and swell, early craftsmen machined a tenon on the end of the top that fit into a mortise

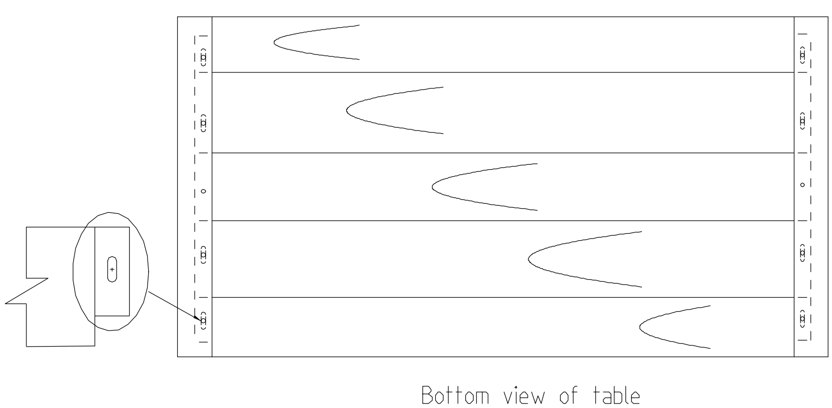

Figure 44. Attachment of end cap to top on pedestal tabletop.

machined in the side of the end cap. The cap was attached to the top with dowels that are visible only on the underside of the top. The center dowel fit snugly in a hole in the tenon that served to locate the cap with respect to the center of the top. The remaining dowels, however, fit through slots cut in the tenon. These slots allowed the dowels to slide sideways as the top expanded and contracted thereby preventing splits in the top.

Shelving

Splits may develop in the ends of solid wood shelving fitted with dividers if the shelving is manufactured at too high a moisture content, Figure 46. The dividers tend to prevent the shelves from shrinking and swelling. Hence, the screws used to attach the shelving to the divider should be located as near to the center of the assembly as possible. Alternatively, a slotted hole could be used with the rear screw to allow a slight amount of movement.

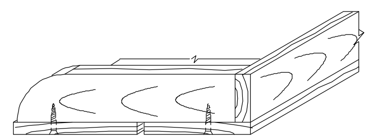

Figure 46. Splits may develop in shelving when the end of a shelf is anchored to a divider as shown.

Corner Blocks

Corner block with anchor bolt construction is widely used in both chairs and tables to attach legs to the supporting framework. Both the size and placement of corner blocks can have a significant effect on whether or not a chair or table leg will subsequently loosen in service owing to shrinking and swelling. In Figure 47a, a large corner block with dovetailed ends is shown which is anchored at a point near the corner, i.e., near the leg. If the corner block shrinks in service, the anchor bolt will loosen as shown along with the leg attached to it. Had the block been attached as shown in Figure 47b, shrinking and swelling effects would be greatly reduced since the face of the corner block would essentially maintain its position. A similar situation exists with the corner block shown in Figure 47c - it is both large in size

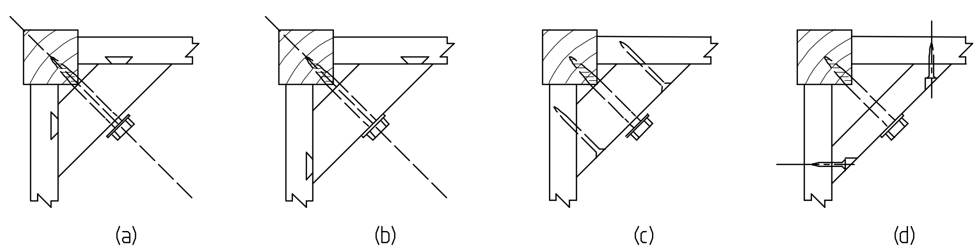

Figure 47. Designing corner block construction to avoid shrinking and swelling problems. Constructions (b) and (d) are preferred.

and anchored near the “root” of the joint. Shrinking and swelling effects could be reduced both by using a thinner corner block and by anchoring it near its outer edges as shown in Figure 47d.

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Rasmussen, Edmund F. 1961. Dry Kiln Operator's Manual. USDA Agricultural Handbook No. 188. USGPO, Wash. D.C. 197 pp.
U.S.D.A. For. Serv. Res. Note FPL-0226. 1973. Moisture Content of Wood in Use. U.S. For. Prod. Lab., Madison. 6pp. (Revision of FPL report 1655, Moisture Content of Wood in Use, E.C. Peck, 1947).

Appendix I

Moisture Content of Wood

In general, the weight of moisture contained in a piece of wood expressed as a percentage of its oven dry weight is referred to as its moisture content. Expressed mathematically

$$mc = \frac{(W_g - W_o)}{W_o} \times 100\%$$

where mc = moisture content

W_g = green weight of the wood

W_o = oven-dry weight of the wood

and oven dry weight refers to the quasi-constant weight attained by wood samples dried at 105 C° (221 F°).

The following example demonstrates the use of the above expression:

1. The green weight of a specimen of red oak is 227.0 grams. Its oven dry weight is 170.3 grams. What is its moisture content?

Ans:

W_g = green weight of the wood = 136 grams

W_o = oven dry weight of the wood = 100 grams.

Therefore,

$$mc = \frac{(227g - 170.3g)}{170.3g} \times 100\% = 33.3\%$$

i.e., the moisture content of the specimen is 33 percent.

A similar problem stated and calculated in English units would appear as follows:

2. The green weight of a specimen of red oak is 8 ounces. Its oven dry weight is 5 ounces. What is its moisture content?

Ans:

W_g = green weight of the wood = 8 oz

W_o = oven dry weight of the wood = 5 oz.

$$mc = \frac{(8oz - 5oz)}{5oz} \times 100\% = 60\%$$

i.e., the moisture content of the specimen is 60 percent.

The "oven-dry" method provides a universally accepted basis for determining the moisture content of wood, and it is, in fact, the method preferred by kiln drying operators. For most purposes, however, moisture content can be quickly determined with sufficient accuracy by means of simple hand held resistance meters.

Appendix II

Calculation of Equilibrium Moisture Content at Any Temperature and Relative Humidity

When desirable, equilibrium moisture content values may be estimated with reasonable accuracy by means of the expression

$$emc = \left[\frac{-\ln(1-f)}{4.5\times10^{-5}(T+460)} \right]^{0.638}$$

where

emc = equilibrium moisture content at stated temperature and relative humidity;

ln = natural logarithm of value contained in parentheses;

j = relative humidity expressed as a decimal; e.g., 30 percent relative humidity should be expressed as the decimal 0.30

T = temperature, °F.

As an example, the emc of wood at 40 percent relative humidity and a temperature of 72 degrees may be estimated as follows:

$$emc = \left[\frac{-\ln(1-0.4)}{4.5\times10^{-5}(72+460)} \right]^{0.638} = 7.05\%$$

Appendix III
Shrinkage Coefficients for Selected Woods
(Green to Oven Dry)

Species	Radial Shrinkage (%)	Tangential Shrinkage (%)	Species	Radial Shrinkage	Tangential Shrinkage
Alder, red	4.4	7.3	Laurel, California	2.9	8.5
Apple	5.9	10.5	Locust, black	4.6	7.2
Ash:			Madrone, Pacific	5.6	12.4
Black	5.0	7.8	Magnolia, southern	5.4	6.6
Green	4.6	7.1	Mahogany	3.6	5.0
White	4.8	7.8	Maple:		
Aspen:			Black	4.8	9.2
Bigtooth	3.3	7.9	Red	4.0	8.2
Quaking	3.5	6.7	Sugar	4.9	9.5
Basswood, American	6.6	9.3	Oak:		
Beech, American	5.1	11.0	Black	4.5	9.7
Birch:			Bur	4.4	8.8
Paper	6.3	8.6	California black	3.6	6.6
Sweet	6.5	8.5	Chestnut	5.5	9.7
Yellow	7.2	9.2	Live	6.6	9.5
Buckeye, Yellow	3.6	8.1	Oregon white	4.2	9.0
Butternut	3.4	6.4	Pin	4.3	9.5
Catalpa, northern	2.5	4.9	Northern red	4.0	8.2
Cherry, black	3.7	7.1	Scarlet	4.6	9.7
Chestnut, American	3.4	6.7	Southern red	4.5	8.7
Cottonwood, black	3.6	8.6	Swamp chestnut	5.2	10.8
Dogwood, flowering	7.4	11.8	Water	4.2	9.3
Elm:			White	5.3	9.0
American	4.2	9.5	Willow	5.0	9.6
Rock	4.8	8.1	Persimmon, common	7.9	11.2
Slippery	4.9	8.9	Sweetgum	5.2	7.6
Hackberry	4.8	8.9	Sycamore, American	5.1	7.6
Hickory:			Tupelo:		
Mockernut	7.8	11.0	Black	4.4	7.7
Pignut	7.2	11.5	Water	4.2	7.6
Shagbark	7.0	10.0	Walnut, black	5.5	7.8
Shellbark	7.6	12.6	Willow, black	2.6	8.1
Holly, American	4.8	10.0	Yellow-poplar	4.0	7.1
Hophornbeam, eastern	8.5	10.0			

	Average(%)	Standard Deviation(%)
Radial	4.966	1.367
Tangential	8.732	1.622
(Radial+Tangential)/2	6.849	1.367
Tangential/Radial	1.830	0.381
Radial/Tangential	0.569	0.381

Abstract

Shrinking and swelling of wood occur as a result of the response of the wood to changes in atmospheric humidity. The resulting dimensional changes in the wood are a major source of defects in furniture. In general, shrinking and swelling cannot be prevented. It is important, therefore, that furniture be designed so that shrinking and swelling effects are minimized. This paper discusses why shrinking and swelling occur, the amount of shrinking and swelling to be expected, and how furniture can be designed to minimize the effects. Numerous illustrations are used to demonstrate preferred construction techniques.