

Minimizing Warping of Solid Wood Panels

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Solid wood panels are manufactured from lumber by edge gluing. For some types of furniture, solid panels are preferred over veneered panels despite their inferior formstability. This bulletin explains the performance of solid panels in terms of the geometry of the shrinkage and swelling of solid wood and discusses some procedures used to minimize warping.

Shrinkage and Swelling of Solid Wood

Table 1 shows the shrinkage values in two of the three principal directions of selected commercial hardwoods. Shrinkage in the third direction, longitudinal, is not included. This is normally very small, ranging from 0.1 to 0.3 percent, when wood is dried from the green to the ovendry condition. In addition to maximal shrinkage values, Table 1 also contains the shrinkage per one percent moisture content change and the ratios of tangential to radial shrinkage. Although the figures shown in Table 1 are shrinkage values, they may be used to determine swelling by multiplying the values

in column "b" with the percent moisture content increase.

Swelling of 12-inch wide boards or panels resulting from a moisture content change of 10 percent is also indicated. A moisture content change of 10 percent would occur if wood were first conditioned to equilibrium at 33 percent relative humidity and then at 81 percent relative humidity at a temperature of 70°F. Under these conditions, a 2-foot wide panel made from flat-sawn beech boards would expand 1 inch. Due to the relatively slow moisture absorption of wood, a 10 percent moisture content change would take place only after long term exposure at the above conditions. Still this cannot be ruled out as a practical possibility.

In order to minimize the lateral swelling of solid panels, one should select quarter-sawn boards from species with low radial shrinkage or swelling values, such as teak, silver maple, lauan, mahogany and cherry. Avoid species like yellow birch, beech, walnut and red oak.

Swelling along the grain under the above conditions would be so small that it would be practically insignificant.

Distortion of Solid Wood Cross Sections

Under certain conditions, a solid board (dried and machined perfectly flat at a given moisture content) will experience a distortion of its cross section, in addition to dimensional changes, as its moisture content changes. This distortion is caused by the difference between the radial and tangential swelling or shrinkage rather than by their absolute magnitudes.

If the radial swelling were exactly equal to tangential swelling, moisture content changes would cause the dimensions of a board cross section to change without any distortion of the cross section, regardless of the orientation of the annual rings (Figure 1). A square cross section would remain a square cross section.

Since the tangential swelling of wood is always larger than its radial swelling, a square cross section will not remain square as it swells or shrinks. If the annual rings are parallel to one of the sides of the cross section, right angles will remain right angles (Figure 2). Distortions of rectangular cross sections will occur when the annual rings intersect the sides at an angle different from 90 degrees. The worst dis-

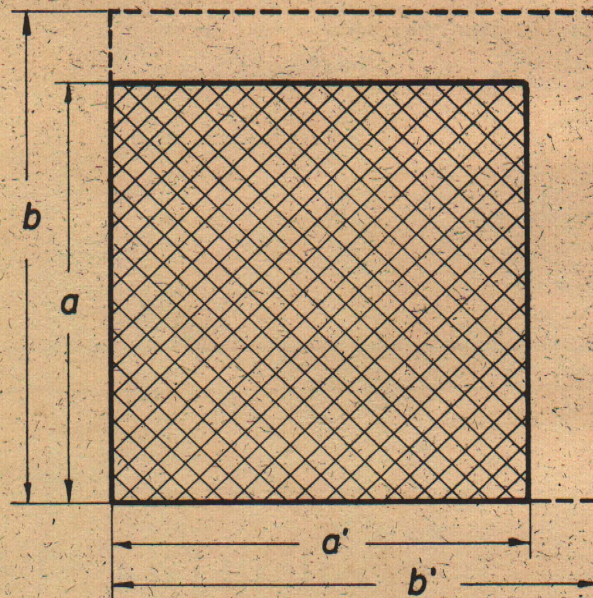


Figure 1. Swelling of square cross section when radial swelling equals tangential swelling ($a = a'$; $b = b'$). Cross section remains square regardless of orientation of annual rings.

TABLE 1. Hygroscopic shrinkage and swelling of selected commercial hardwoods.*

Species	Shrinkage values				Ratio tangential./radial	Shrinkage or swelling of 12 inch wide boards per 10% moisture content change	
	Radial		Tangential			radial	tangential
	a	b	a	b			
	green to ovendry	per 1% moisture content change	green to ovendry	per 1% moisture content change		inch	inch
	%	%	%	%		-	-
Beech, American	5.1	.20	11.0	.42	2.16	.24	.50
Birch, Yellow	7.2	.28	9.2	.35	1.28	.33	.42
Cherry, Black	3.7	.14	7.1	.27	1.92	.17	.32
Elm, American	4.2	.16	9.5	.37	2.26	.19	.44
Lauan, Red	3.3	.13	8.0	.31	2.42	.16	.37
Mahogany	3.6	.14	5.0	.19	1.39	.17	.23
Maple, Silver	3.0	.12	7.2	.28	2.40	.14	.34
Maple, Sugar	4.9	.19	9.5	.37	1.94	.23	.44
Oak, Northern Red	4.0	.15	8.2	.32	2.05	.18	.38
Oak, White	5.3	.20	9.0	.35	1.70	.24	.42
Teak	2.3	.09	4.2	.16	1.83	.11	.19
Walnut, Black	5.5	.21	7.8	.30	1.42	.25	.36
Poplar, Yellow	4.0	.15	7.1	.27	1.78	.18	.32

* Wood Handbook, Agriculture Handbook No. 72, USDA Forest Service, Washington, D.C., 1955.

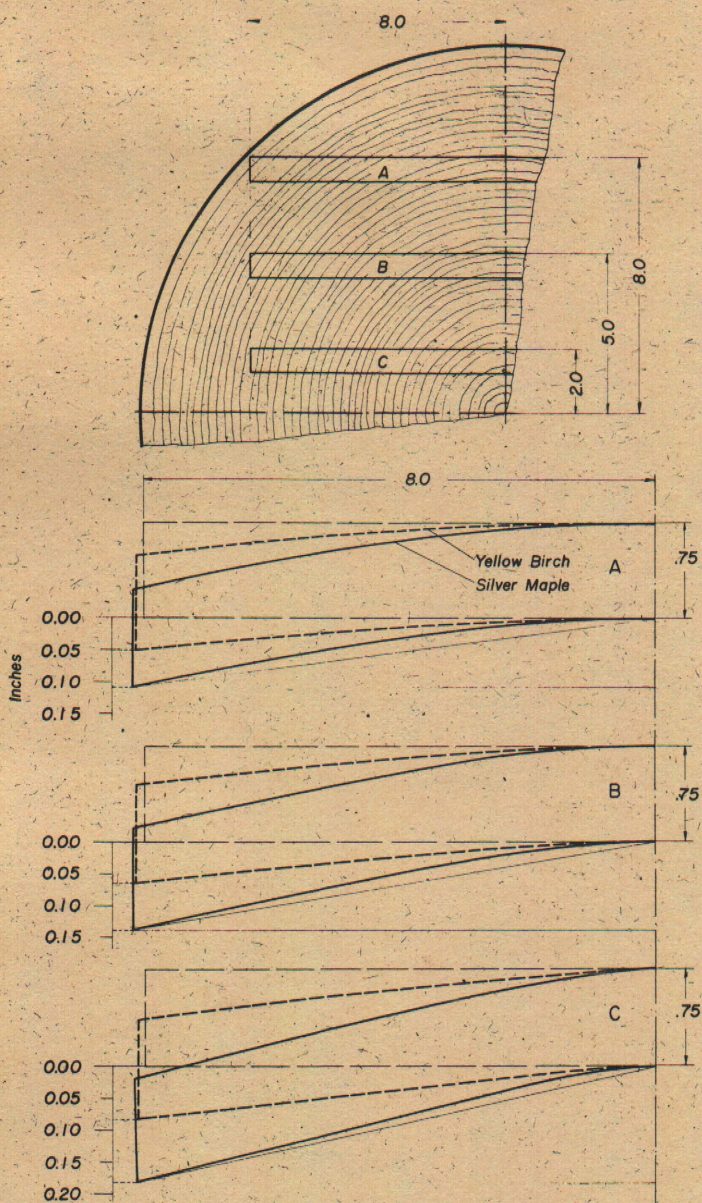


Figure 4. Distortion of solid cross sections due to 10 percent moisture content increase.

manageable and often destructive stresses. This led to a number of design principles, some of which are illustrated in the following examples.

Figure 6 shows the use of a simple cleat at the end of an edge-glued solid panel. The great stiffness of the cleat across the grain of the panel prevents the panel from warping. Glue is applied only at the center of the cleat in order to allow stress-free swelling and shrinkage of the panel across the grain.

Figure 7 shows a dovetail joint used in joining solid furniture panels. This joint prevents warping of horizontal and vertical panels, but allows stress-free lateral swelling and shrinkage.

Figure 8 illustrates the principle of the framed panel. The frame not only restrains the panel from

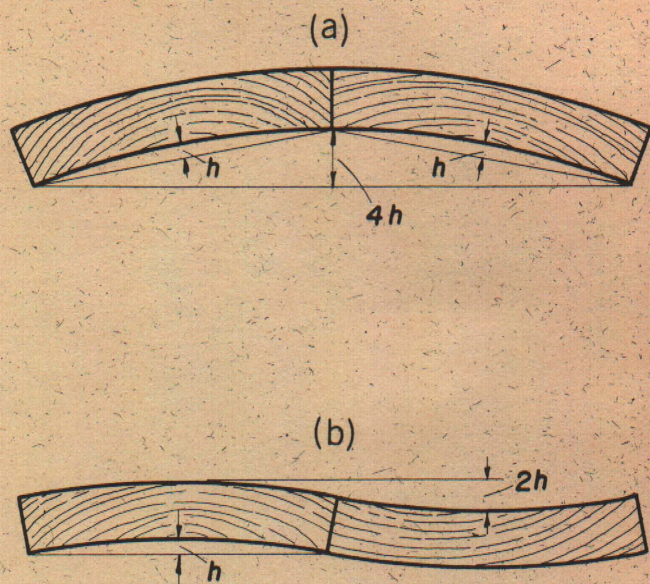


Figure 5. Warping of edge glued panels.

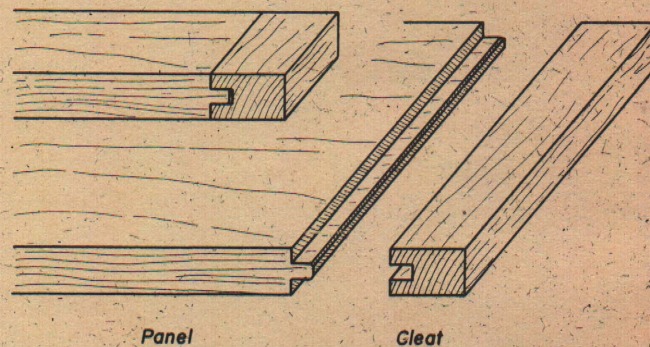


Figure 6. Cleated solid panel.

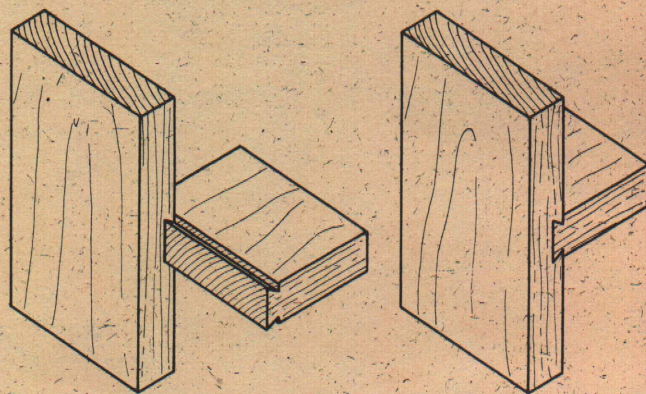


Figure 7. Dovetail joint in solid panels.

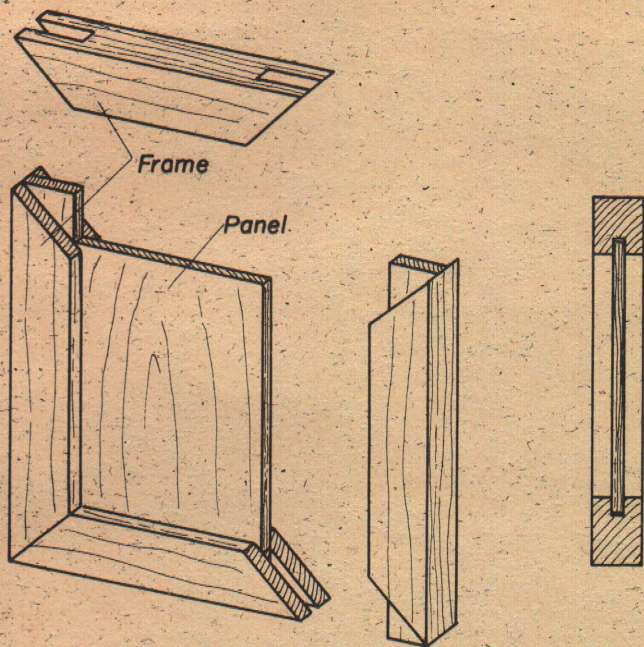


Figure 8. The framed solid panel.

warping but allows the stress-free swelling and shrinkage of the floating panel without affecting the outside dimensions of the frame.

Lumber Core Panels

The lumber core panel, a veneered construction, is a favorite furniture panel — sometimes classified as a solid panel. The solid, edge-glued core provides a smooth substrate for the veneers, which, in turn, greatly reduces the warping of the panel (Figure 9). The finished panel is extremely sensitive to unequal-thickness swelling of the lumber core strips, especially if polished to a high gloss. The potential differences in thickness swelling due to a 10 percent moisture content increase of $\frac{3}{4}$ inch core strips are illustrated in Figure 10. These differences are, of course, modified by the restraining effect of the glue lines between strips and by the veneers. Nevertheless, the human eye can discern periodic distortions of polished surfaces of only a few ten-thousands of an inch. Proper selection of the core material with regard to annual ring orientation is therefore of importance.

Another phenomenon causing deterioration of the surface quality of veneered and finished lumber core panels is the so-called 'sunken joint'. Its development is illustrated in Figure 11. During the manufacture of the lumber core by edge gluing individual strips, the moisture content of the wood immediately adjacent to the glue lines increase due to the absorption of water

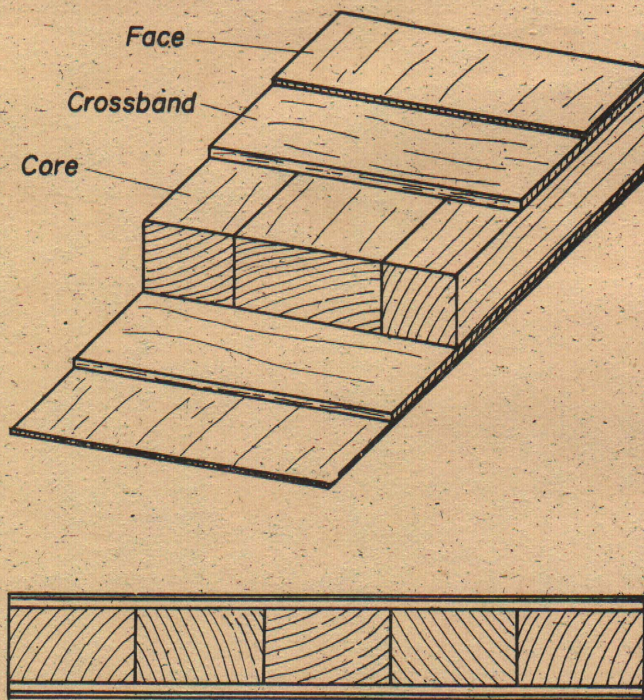


Figure 9. Construction of lumber core panel.

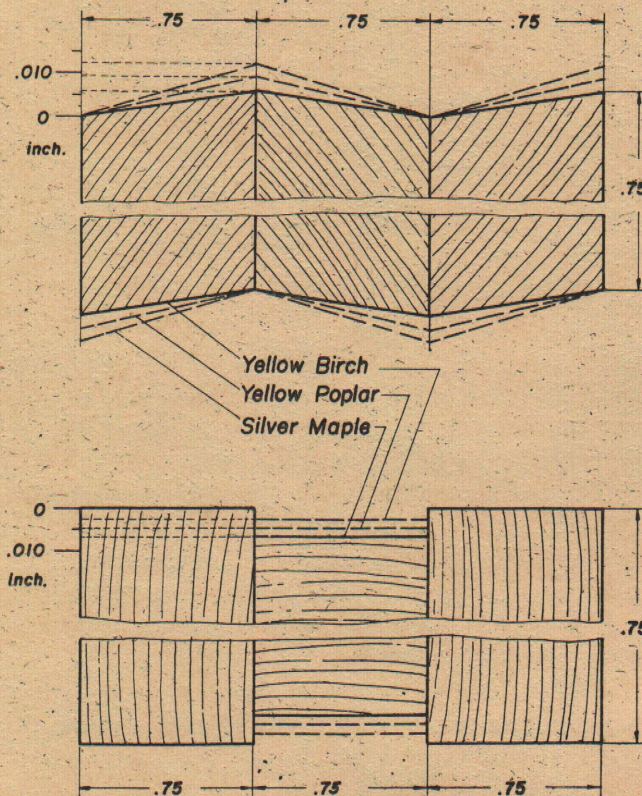


Figure 10. Differential swelling of lumber core strips due to 10 percent moisture content increase.

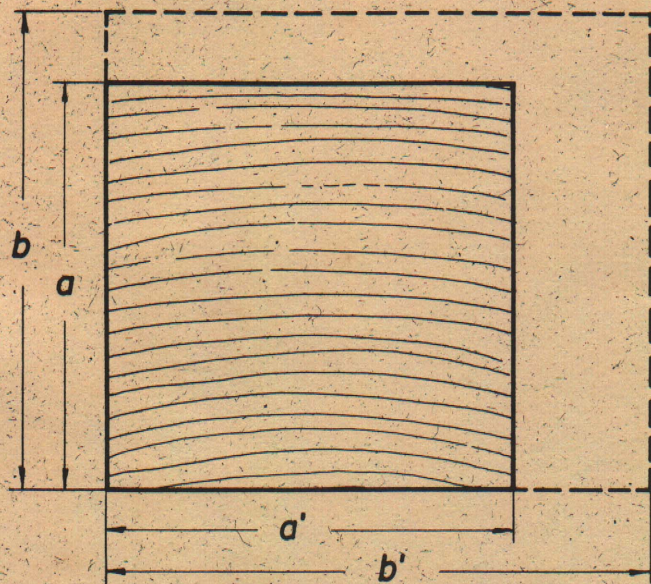


Figure 2. Swelling of square cross section when radial swelling is smaller than tangential swelling ($a = a'$; $b < b'$). Cross section remains rectangular but not square.

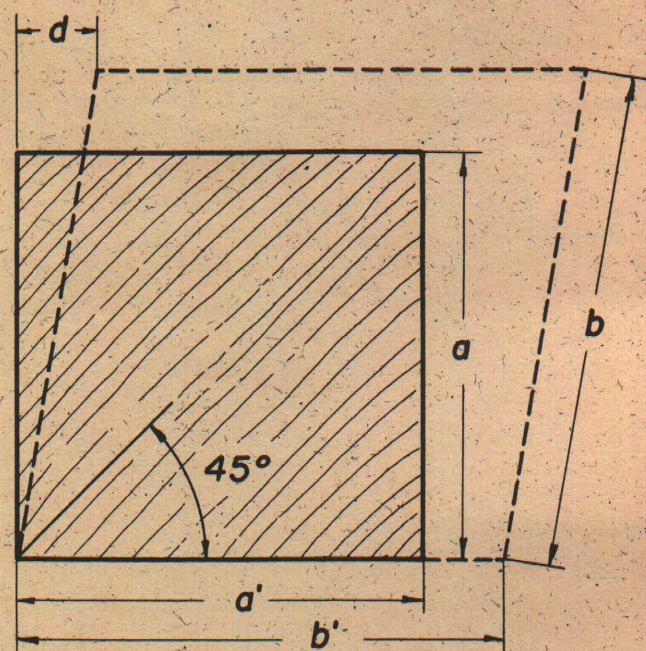


Figure 3. Swelling of square cross section when radial swelling is smaller than tangential swelling and annual rings oriented diagonally. ($a = a'$; $b = b'$). Values of "d" for square cross section with $a = \frac{3}{4}$ inch: Silver Maple, 0.012 in.; Yellow Poplar, 0.009 in.; Yellow Birch, 0.006 in.

tion occurs when that angle is 45 degrees, because then the minimal and maximal swelling or shrinkage will be in the direction of the diagonals (Figure 3).

It is this angular distortion that causes the warping of wider boards. Severity of the distortion does not depend on the magnitude of the swelling in any one direction, but on the ratio of the tangential to the radial swelling. Thus, yellow birch is relatively distortion-free (ratio = 1.28) although its swelling values in both directions are rather high. Mahogany and walnut are next in line, while silver maple, elm and beech would develop more severe distortions.

In most boards taken from round logs, the orientation of the annual rings on the cross section varies over the width of the board, depending on the location of the cross section relative to the center of the log. This change in annual ring orientation will result in a more-or-less uniform curvature of the cross section as the moisture content changes.

Figure 4 shows the distortion of three boards, dried and machined to perfectly rectangular cross sections, before being exposed to a moisture content increase of 10 percent. Note that the curvature in board "A" is rather uniform over the width of the board, while in board "C" the curvature is limited to a small part of the board close to the centerline of the log. The rest of board "C" remains almost perfectly flat. It might be concluded that flat-sawn boards always develop a moderate amount of warping, while quarter-sawn boards remain fairly flat as long as the portion of the

board containing the center of the log is removed. Yellow birch and silver maple are extreme cases. Most other commercial species would fall between the two.

Certain characteristics, like curly grain, which is common in yellow birch, cross grain or the presence of reaction wood could appreciably alter these relationships.

Edge-Glued Panels

When several boards must be edge glued for the manufacture of wider panels, close attention should be paid to the orientation of annual rings on cross sections of adjacent boards in order to minimize warping of the panel. If two boards with similar annual ring orientation are edge glued as shown (Figure 5, a), the warping of the resulting panel due to moisture content increase is not double the warp of the individual boards, but approximately four times that value. Turning the second board over (Figure 5, b) and reducing the width of the individual strips will greatly improve the formstability of the panel.

Dimensional changes and warping of solid panels have challenged wood-workers for centuries. It was recognized early that warping could generally be restrained with very moderate forces, while attempts to forcibly restrain linear swelling can result in un-

introduced with the glue. This will cause a swelling pattern as illustrated in Figure 11(b). Allowing enough time between gluing and planing of the core, will permit the moisture content to equalize again and result in a trouble free panel. However, if the edge-glued panel is planed too soon, the moisture content peaks at both sides of the glue line will still exist after planing. As this moisture content equalizes later, the sunken joints will develop and telegraph through the crossband and face veneers as shown in Figure 11(c) and 11(d).

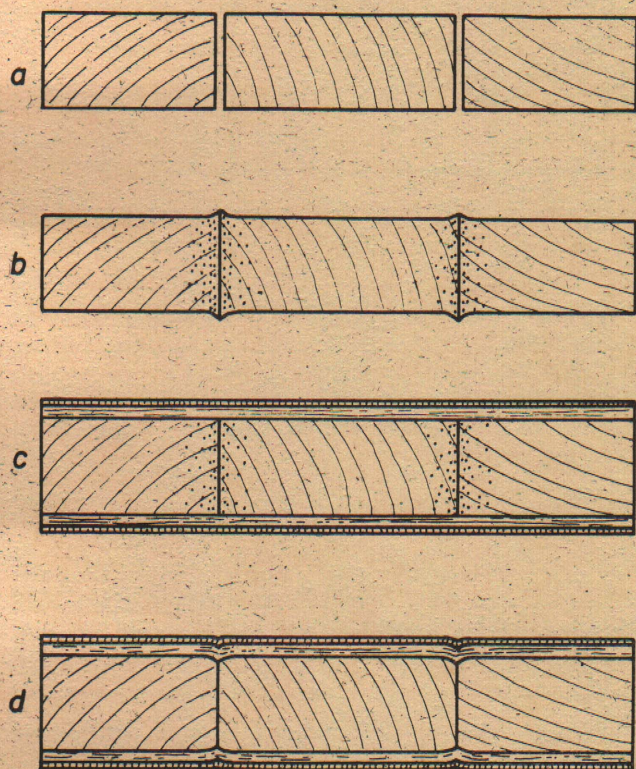


Figure 11. Development of sunken joints in lumber core panels. Dots indicate moisture absorbed from glue line.

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