Making a Plank for a Carvel-Planked Boat

This document describes how to layout and cut a plank for a Carvel planked boat. Because the shape of a boat is typically complex, fitting a plank requires making a number of precise measurements – the plank must have the correct shape in profile, it must be beveled on its edges to mate with the plank below it and above it, its inside face must be contoured to fit the curvature of the frame that it fastens to, and the outside face must be shaped to match the desired shape of the hull. In addition, the planking material itself imposes certain limitations on the shape of the plank – it can only twist and bend so much.

Although the process of "getting out a plank" is described in numerous references, these descriptions typically lack sufficient detail for the novice. The goal here is provide some of that missing detail.

We initially consider a plank that has a convex inside face, one that you would typically encounter below the turn of the bilge. Later we will examine the case of a plank above the turn in the bilge where the inside face is concave. We also consider the problems associated with nibbed planks.

Plank below the Turn in the Bilge

In Fig. 1 we show a typical frame with the garboard plank already in place. The goal is to fit a plank between the two green points in the figure. The bottom point represents the top edge of the garboard plank below. The upper point represents the top edge of the plank to be fitted. We assume that the location of this top edge has been drawn on the frames, either from the lining-off process for a new boat or from the bottom edge of the plank above for a reconstruction. The bottom edge of the new plank must be beveled to match the top edge of the garboard plank below. The top edge will be left square to the face of the plank (unless you're fitting a shutter plank). In addition, the inside face of the plank must be shaped (convex) to fit against the frame – a process called backing out or scrubbing. The outside face must also be scrubbed (concave) to conform to the desired shape of the hull.

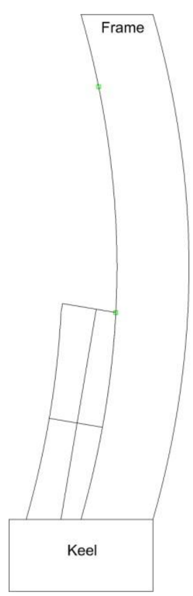

Fig. 1

Fig. 2 shows the finished plank in place.

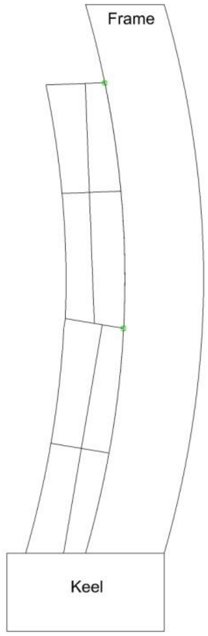

Fig. 2

The first step is to capture the shape of the plank in profile. This is done using a technique called spiling. The idea is to make a template, called a spiling batten, that roughly approximates the shape of the plank. The spiling batten is temporarily fastened to the boat where the plank will go. The spiling batten is made from flexible stock so that it easily conforms to the twists and bows required by the shape of the hull. With the spiling batten in place, we record on the batten the width of the plank at regular intervals. We also capture the details of the plank ends. The template is then removed, fastened to the planking stock, and the perimeter dimensions are transferred from the spiling batten to the stock.

In Fig. 3 below, we see an example of a plank that needed to be replaced. Fig. 4 shows the spiling batten used to capture the shape of the plank.

Fig. 3

Fig. 4

Although in principle one could trace the profile of the old plank onto the new stock, the old plank has too much twist and bow and numerous checks which would lead to inaccurate results. We can use the old plank to construct the spiling batten, however.

The batten is made from 3/16” Luan underlayment. We then trace the shape of the old plank onto the batten and then cut inside the lines by about ¼”. You want the batten as close to the finished plank dimensions for accuracy, but you need some clearance to do accurate spiling.

Fig. 5 below shows the front end of the batten, illustrating an important detail.

Fig. 5

We see that the batten was constructed in sections – the front piece is spliced to the main part by using a small overlapping piece that is hot-melt glued in place. Unlike the rest of the batten, the front piece is an accurate template cut exactly to the shape of the finished plank. Using a template is often done in areas having intricate detail or being too small for accurate spiling. It’s quite easy to construct small templates like this by simple trial and error. Once the template is cut to shape, it is tacked in place on the boat (see the small finishing nails in Fig. 5). Other templates could be constructed in a similar fashion. The rest of the spiling batten is then tacked into position and the splices hot-melt glued into place. This locks all the templates into proper registration.

When positioning the batten on the hull, it’s important that the batten defines a fair surface – no edge set. Any edge set in the batten will lead to edge set in the plank, which is undesirable. Also, it’s very important not to introduce excessive twist in the batten. Keep in mind that whatever you’re asking the batten to do will also be required of the plank, which is much thicker and therefore considerably less flexible. Hopefully, when the boat was lined-off for the planking that consideration was given to minimizing twist. Even if this is true, planks with nib ends can introduce severe twist if precautions are not taken (discussed at the end of this document).

With the spiling batten in place, trace the location of the frames onto the back face of the spiling batten. (Later you will transfer this data to the front of the batten.) Next, transfer the plank dimensions to the spiling batten at regular intervals - typically at the frame locations and at other locations where more detail is needed. A variety of tools exist for doing this, but after experimenting with these methods, I’m now convinced that the spiling compass is best. Fig. 6 illustrates the use of the spiling compass when capturing the bottom edge of the plank. The spiling batten in this case makes contact with the frame on top but lies away from the frame at the bottom. Although we could force the batten to contact the frame above and below, it is sometimes better to allow gaps such as this to avoid too much twist in the plank (see my discussion of planks with nib ends at the end of this document).

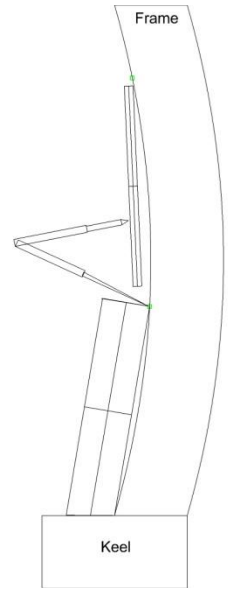

Fig. 6

As you can see in the figure, you need a compass with a point that can get right at the frame/plank intersection. In some cases you need to capture a point between frames, in which case the plank edge has no backing. In that case, use a temporarily backing block behind the plank to create a corner for the compass point.

Using the compass, scribe an arc on the spiling batten. The arc should swing through 90 degrees if possible. Scribe an arc at every station location both for the bottom edge and top edge of the plank (Fig. 7).

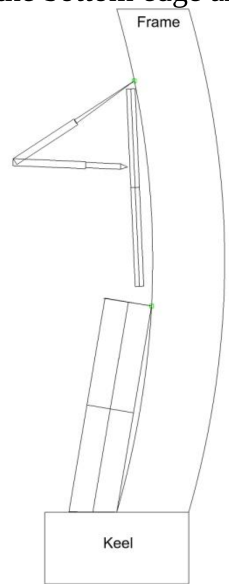

Fig. 7

Also, scribe arcs at the plank ends and other detail locations (such as nibs), unless templates are used. In the end, the spiling batten will be littered with arcs such as the ones in red in the figure below. When spiling, it’s important to keep a constant arc radius. So, it’s a good idea to record this information on the spiling batten. That’s the purpose of the arc and point in magenta.

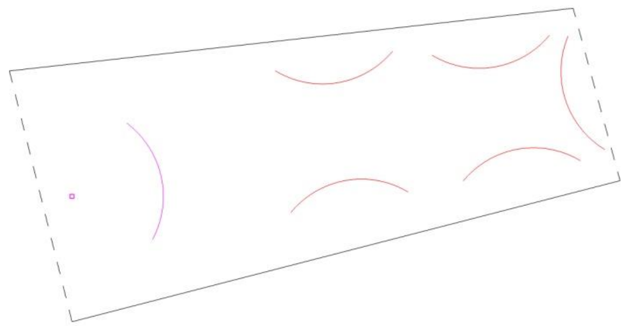

Fig. 7

When all the pertinent data is recorded on the spiling batten, remove the batten from the boat and transfer the frame-location data to the front of the spiling batten. At this point, the standard procedure is to transfer the spiling data to the planking stock; however, I perform an intermediate step first, which I believe allows me to determine the bevel angles more accurately.

Tack the spiling batten to a new piece of spiling stock (3/16” Luan underlayment), and transfer the plank dimensions to the spiling stock, creating what I call the plank template. Fig. 8 illustrates this process.

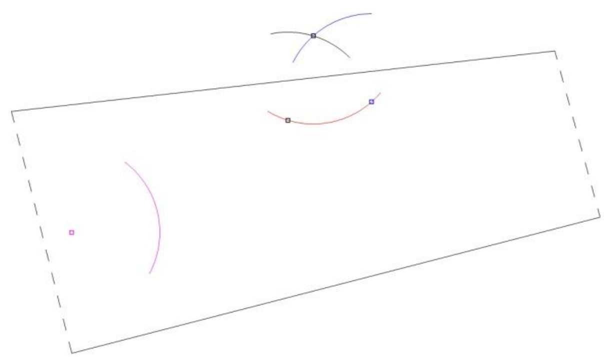

Fig. 8

The red arc represents one of the many arcs that were scribed onto the spiling stock. The data in magenta records the proper arc radius as mentioned previously. Now with the compass set to this radius, put the point of the compass on the red arc (at the blue point) and scribe an arc (blue) onto the plank template. Do the same at another point (black point) producing the black arc. The intersection of these two arcs defines one of the points that defines the plank edge. A third arc can be scribed to check for accuracy (the three arcs should interest at one point).

Connect all the points using fairing battens and cut and plane to the lines. You now have an accurate replica of the shape of the plank. We will use this plank template to determine the bevels and the gaps (if there are any). Note that it is better not to construct the template from one long piece. Instead it is much more convenient to make the template in overlapping sections; e.g., for a 12’ plank you might make the template in two 8’ sections.

Before removing the spiling batten from the template, transfer the frame locations to the template. This will help in positioning the template sections on the boat.

Now, tack the plank template (or template section) in position on the boat such that the top edge of the template lines up with the points defining the top edge of the plank. The presence of the plank below might prevent proper positioning of the template. In that case, just trim the bottom edge of the template to provide sufficient clearance. A precise fit at the bottom edge is not required. Fig. 9 shows the template in place.

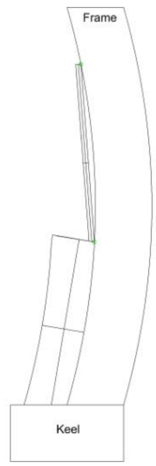

Fig. 9

At some frames, the template might not lie against the frame (or the backbone) at both top and bottom edges, forming a gap. This is illustrated in Fig. 10 below.

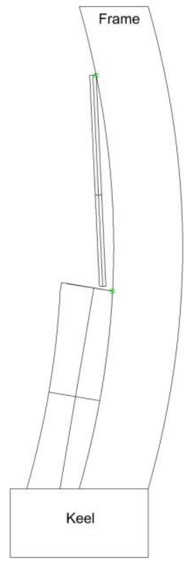

Fig. 10

With the template in place, we can now measure the bevel angle (Fig. 11) and the size of the gap (Fig. 12) at each frame location and at regular intervals where the template lies against the backbone. We refer to these locations as stations. Note that computing the bevels in this fashion is more accurate than taking them directly from the frames (when gaps occur).

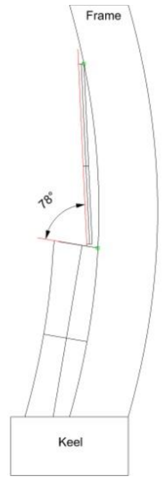

Fig. 11

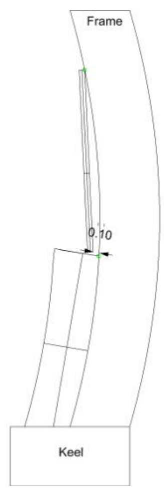

Fig. 12

In practice, it's easier to measure the gap indirectly. We measure the distance from the outside edge of the plank to the outside face of the template. Call this dimension d. If the thickness of the plank is T and the thickness of the template is t, then the gap g = T – t – d.

Gaps can also occur (but less often) at the top edge of the template. These we can measure directly.

The following data is recorded on the plank template:

- Frame locations. Previously transferred from the spiling batten.
- Station locations. The positions along the template where the bevels and gaps were measured. The location of a station should be in the form of line extending across the face of the template, so that both lateral position and orientation are recorded. The stations should be numbered for reference.
- Gap sizes. At each station, indicate the size of the gap (even if 0) at the top and bottom edges of the template.

Measure the bevel at each station and transfer the bevel to a bevel boad (Fig. 13).

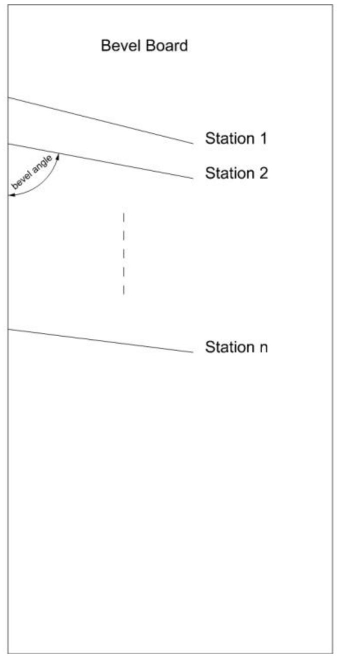

Fig. 13

Before removing the plank template from boat, mark on the boat the location of all the stations. Mark where the station intersects both the top and bottom edges of the plank.

The ends of the plank might also require bevels. If so, record these bevel angles on the bevel board.

We now need to capture the curvature at each station so that the inside face of the plank can be shaped to fit. We do this using a pattern at each station (Fig. 14).

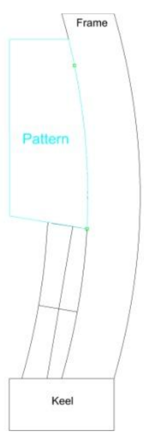

Fig. 14

If the station corresponds to a frame location, you can just trace the shape of the frame onto a piece of spiling stock and cut/plane to the line. If the station corresponds to a backbone member, some trial-and-error fitting will be required. I usually start by laying a straight edge "between the dots" and measuring the gap between the straight edge and the backbone. I then use a fairing batten to draw an arc on the pattern. The arc has a cord length equal to the distance between the dots and a cord depth equal to the gap. This usually gets me pretty close. Then, since the pattern is quite thin, it's easy to trim to final shape with a small block plane.

When the pattern is shaped correctly, place the pattern against the frame (or backbone) and mark the location of the top edge of the plank. The bottom edge will naturally be at the apex of the pattern where it contacts the plank below. It is not necessary for the bottom edge of the pattern to lie flush with the top of the plank below.

Record the following additional data on the pattern:

- Plank identifier; e.g., P4 for the fourth plank up on the port side.
- Station number.
- Gaps at the top and bottom edges of the plank.

On the pattern, draw a line between the apex and the mark for the top of the plank – this is the cord. Measure the height of the cord. Add to this height the maximum gap at this station (conservative). Write this number on the template. After completing all the templates, find the one with the maximum cord height + gap. This represents the extra planking thickness that is required for scrubbing.

For each pattern that you made, create a mating pattern. If your initial template was convex its mate will be concave (Fig. 15). Transfer the locations of the top and bottom of the plank and the gaps (top and bottom). Also include the plank identifier and station number.

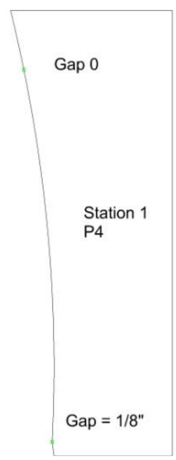

Fig. 15

Now that we have all the data that we need, we're ready to cut the plank. Attach the spiling batten to the planking stock and transfer the points on the batten to the stock. At every station that contains an obtuse bevel (describe in detail later), increase the width of the plank (bottom edge) by the amount indicated on the bevel board. Now use a fairing batten to draw a fair curve through all the points.

You must be careful when drawing the bottom edge of the plank. This edge has to mate with the previous plank, so if the top edge of the previous plank is not fair, then you'll have to live with that unfairness on the bottom edge of the new plank.

Rough cut the plank to size. I recommend that you cut the plank ¼"-1/2" or more oversize to allow the plank stock to relieve any internal stresses. Then spile again and cut to the finished dimensions.

Next we scrub the inside face of the plank to match the curvature of the frames. This curvature changes from frame to frame, so we need to mark our plank with station positions and keep checking the curvature with our patterns as we go.

Maintaining the correct curvature is one constraint but we must also cut to the proper depth. Let's consider an example.

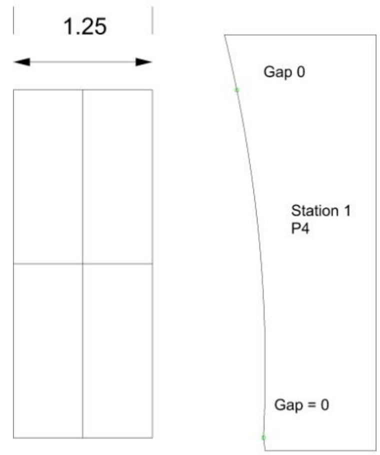

Fig. 16

In Fig. 16, we see the cross section a plank at station 1. The plank is 1-1/4” thick, where ¼” has been added to the desired finished plank thickness of 1” to allow for scrubbing. To the right of the plank we have the pattern for plank P4 at station 1. Note that the gaps are 0 at this station. Since there are no gaps, the scrubbing should result in a plank thickness of 1” at both the top and bottom edges. So as a guide while scrubbing, we scribe a mark, indicating the depth limit, on both top and bottom edges of our plank 1” from the outside face. We then scrub until the pattern intersects the marks. The result is shown in Fig. 17 below.

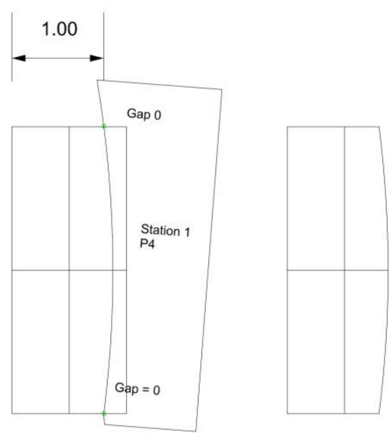

Fig. 17

Note that in Fig. 17, wood is removed from the center of the plank as well as the edges. That’s because the curvature at this station is less than the maximum. At the station(s) having the maximum cord height, little or no wood will be removed from the center of the plank. The pattern will just touch the inside surface of the plank as the edges of the template intersect the depth marks. At other locations, wood will have to be removed from the center of the plank, and for patterns with no curvature, a full ¼” will have to be removed across the width of the plank. We could instead remove the bulk of the wood from the outside surface, but it’s easier to remove wood from a convex surface that one that’s concave.

What happens when we have gaps? Let’s look at another example.

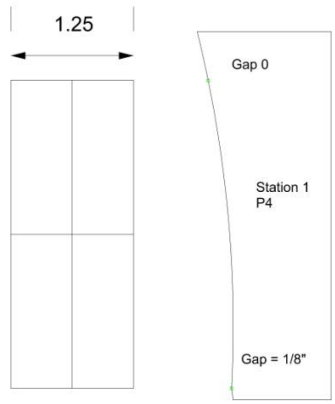

Fig. 18

The pattern in Fig. 18 indicates that we have a 1/8" gap at the bottom edge of the plank at this station. That means that the natural twist of the plank takes it's lower edge away from the frame. We could possibly force the plank to conform or modify the frame, but it's often easier just to provide a little extra thickness to the plank at this point to fill the gap. Fig. 19 illustrates this technique.

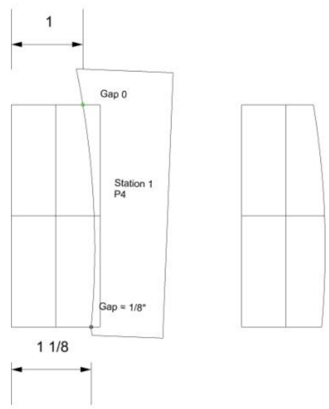

Fig. 19

In this case instead of strubbing down ¼" both top and bottom, we scrub down only 1/8" on the bottom. This provides the extra plank thickness to fill the gap. Note that the rotation of the pattern due to gaps causes a discrepancy between the actual plank width and the plank width recorded on the pattern; however, the gaps are typically quite small (<1/8") which makes this error negligible.

Keep in mind that as the gaps change from station to station, so do the dept limits for scrubbing. So at each station we compute the depth limits (top and bottom) by adding the desired final plank thickness (1" in our examples) to the gaps. We can then use a fairing batten to connect the depth-limit marks on both plank edges and scrub to the two lines.

It's now time to cut the bevels. We will assume that the top edge of the plank will remain square to the face of the plank, so we only have to bevel the bottom edge. Our bevel board (Fig. 13) contains all the bevels, which typically change from station to station (rolling bevels). Although it's possible to just start cutting the bevel and regularly check the angle against the bevel board with a bevel gage, this is a slow tedious process. Instead at each station, we scribe depth-limit marks on the face of the plank and connect these marks using a fairing batten. We then plane the bevels until we simultaneously reach depth limit and the edge of the plank (although it's still a good idea to check the bevel with a bevel gage occasionally). We use the bevel board to determine the depth limit at each station.

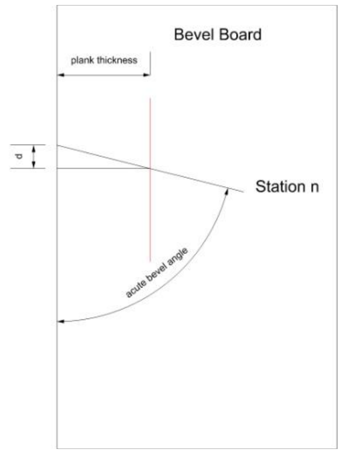

Fig. 20

Fig. 20 shows a bevel board with only one station for simplicity. Note that the bevel angle is an acute angle (<90 degrees). It's also possible to have obtuse bevel angles, but these require special treatment that I discuss in the next section. On the bevel board, we draw a vertical line (red in Fig. 20) parallel to the edge of the board at a distance equal to the finished plank thickness. This line intersects the bevel line for station n. At that intersection, we project a line perpendicular to the edge of the board. The distance d between this line and the bevel line (at the edge of the board) is our depth limit at this station.

After beveling the bottom edge of the plank, we can scrub the outside surface of the plank. We use the mating pattern to approximate the required curvature. The depth limit for both is such that the plank thickness at both edges is the desired finished thickness. This should be viewed as a rough cut with final fairing done on the boat.

To finish up, we paint the inside face with two or more coats of Primocon, mark for fasteners, and clamp the plank to the boat to check the fit. After making any adjustments to the fit, steam the plank if necessary, clamp and fasten the plank.

Obtuse Bevel Angles

Fig. 21 shows a planking problem similar to the previous one except now the top edge of the previous plank is angle downward causing the bevel angle to be obtuse (>90 degrees). This causes some additional complexity, which I will now address.

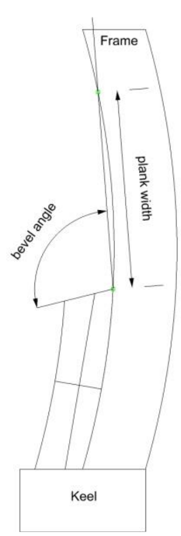

Fig. 21

Fig. 22 shows the finished plank in place.

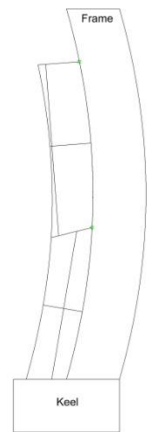

Fig. 22

Fig. 23 shows a cross-section of the finished plank (in red) overlaid on the plank before it is scrubbed and before the bevel is cut (in black). Note that the initial thickness of the plank must be greater than the desired final thickness to account for scrubbing. This additional thickness complicates the process of cutting the bevel.

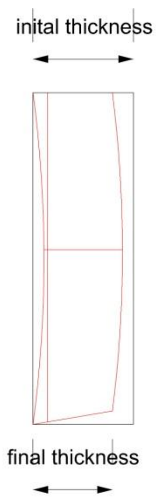

Fig. 23

Fig. 24 illustrates what must happen to cut the correct bevel, assuming that the bevel is cut before scrubbing. You can of course scrub before cutting the bevel, but then it becomes difficult to locate the correct depth limit because the face of the plank is curved. So, we'll assume that the bevel is cut before scrubbing.

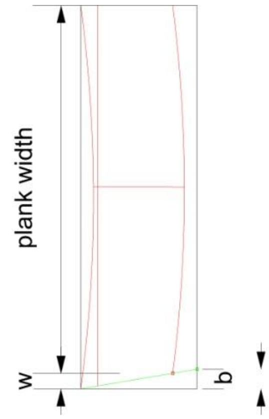

Fig. 24

Again referring to Fig. 24, note that the obtuse bevel angle means that to create the bevel we must remove wood from the inside face of the plank. The plank width is defined at the inside face (where it contacts the frame), so we must increase the initial plank width by an amount w, to make up for the amount removed due to the bevel. Fig. 25 illustrates how we compute w from the bevel board. Note that we must compute this w at every station and adjust our spiling accordingly BEFORE we cut the plank!

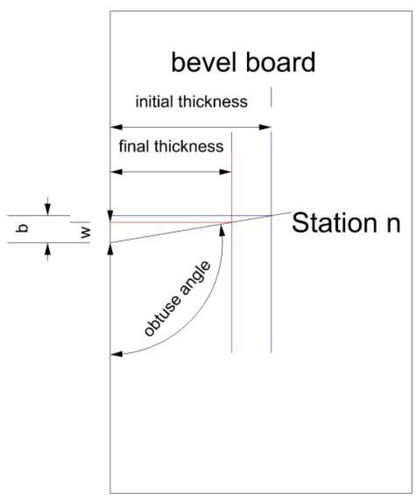

Fig. 25

As we did in our first example, we measure our bevel angle from the plank template on the boat. Note that in this case the bevel line slopes upward creating an obtuse angle with the edge of the bevel board. To get the amount of width w to add we draw a vertical line (in red) at a distance from the left edge of the bevel board equal to the final plank width. We then project a line (also red) from the intersection of this line with the bevel line. The distance w is then taken from the edge of the bevel board.

After the plank has been cut to size, we can cut the bevel. To do this we need to scribe a depth limit b on the inside face of the plank. To compute the value of b, we again use our bevel board. In this case, we use the initial thickness of the plank to draw our vertical line (blue line in Fig. 25). Proceeding as before, the value of b is taken from the edge of the bevel board.

Once the bevel has been cut, we can scrub the inside face of the plank as before. We can also scrub the outside face using the mating pattern, but because the outside face is wider than the inside, the scubbing should be viewed as an approximation that will be finalize once the plank is on the boat.

Planks above the Turn of the Bilge

Planks above the turn in the bilge require a somewhat different treatment than those below. The following text describes this process as I envision it – since I have not yet dealt with a plank in this area.

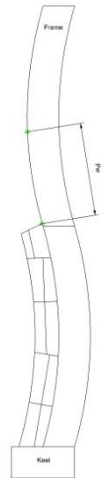

Fig. 26

Fig. 26 shows an example frame with the new plank to be positioned between the two green points. Pw is the plank width at this station.

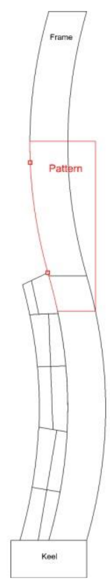

Fig. 27

First we construct a pattern describing the shape of the frame at this location. Using the pattern, we can determine the cord depth Cd at this station, as show in Fig. 28.

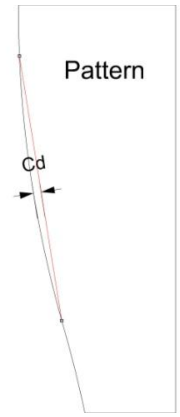

Fig. 28

After developing patterns for every station, we can determine the maximum cord depth MCd over all the stations. MCd is used to determine how much extra thickness we will need to account for scrubbing. If the desired final plank thickness is labeled FPT, then FPT + MCd represents the initial plank thickness, IPT.

We also use the pattern to creating its mating pattern, as shown in Fig. 29 below. The mating pattern will be used when we scrub the outside face of the plank. Note that this is one of the differences between planks above the turn of the bilge and those below. The former are concave on the inside face and convex outside, whereas the latter are convex inside and concave outside.

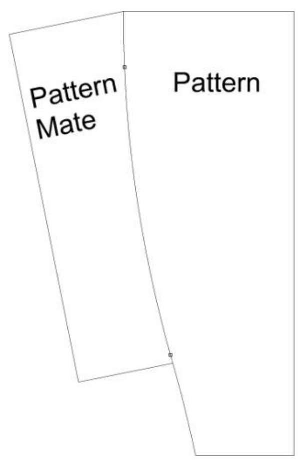

Fig. 29

Next we tack our spiling batten in place on the hull (Fig. 30), making sure that the batten defines a fair surface. As mentioned previously, we don't want to introduce any undue twist that cannot be accommodated by the plank. In so doing, it's possible that the batten will not lie square to the frame. Of course there will always be gaps between the batten and the frame because the outside face of the frame is convex whereas the batten is flat. Ideally, with the plank square to the frame, the gaps at the top and bottom of the batten should be the same. If not, we need to make some adjustments to the shape of the plank.

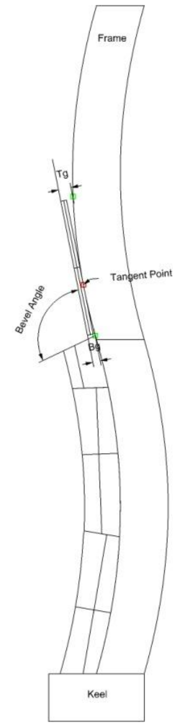

Fig. 30

In Fig. 30, we see that the gap at the top of the batten is larger than the gap at the bottom. It's awkward to measure the gaps directly, so instead we use a scale to measure the distance from the outside face of the batten to the face of the frame. The measurement at the top of the batten is labeled Tg and that at bottom is Bg. Since we are primarily interested in the difference between the gaps, Tg – Bg gives us the desired result.

Fig. 30 also illustrates how we determine the bevel angle, which we transfer to a bevel board (Fig. 31).

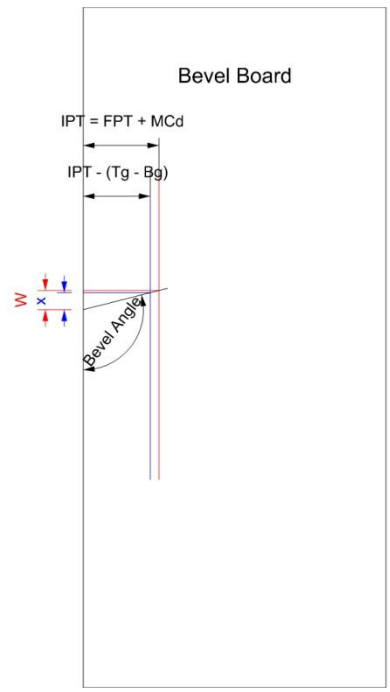

Fig. 31

Fig. 31 shows that our bevel angle is obtuse, meaning that we must increase the width of our plank to allow for removing wood from the inside face of the plank. The extra width is labeled x in Fig. 31. The quantity x is determined from the bevel angle and the initial plank thickness IPT less the gap difference.

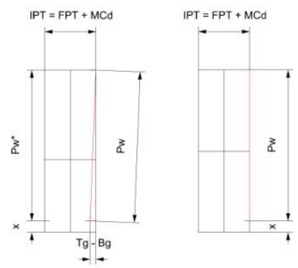

Fig. 32

Fig. 32 shows the dimensions of the plank before beveling or scrubbing. The drawing on the left shows the precise way of determining the plank dimensions, whereas the one on the right shows an acceptable approximation. Considering the approximation on the right, we see that the plank thickness is the desired final plank thickness FPT plus the maximum cord depth over all stations MCd. The width is the plank width from the pattern plus the extra x that we need for the bevel. The drawing on the left shows that the plank width must be adjusted (Pw*) for the rotation of the pattern due to the gap difference. Since the gap differences are quite small the error in using Pw instead of Pw* is insignificant. Also observe in Fig. 31 that if the gap difference is small and/or the bevel angle shallow, the quantity W can be used in place of x.

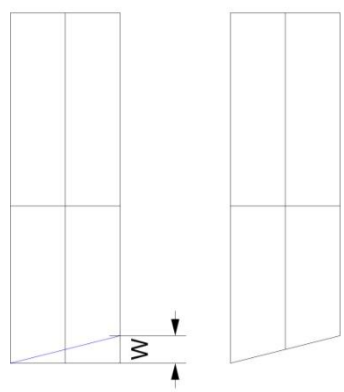

Fig. 33

We can now layout and cut the bevel. Referring back to our bevel board in Fig. 31, we determine the depth limit of the bevel W using the bevel angle and the initial plank thickness IPT.

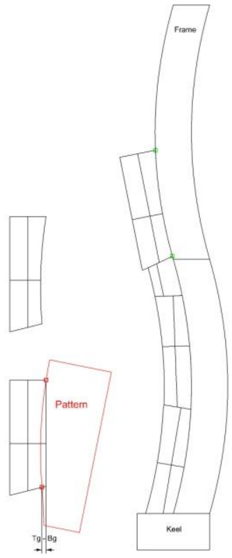

Fig. 34

Fig. 34 shows how the pattern is used to scrub the inside face of the plank. Fig. 35 shows how the outside face is scrubbed using the mating pattern.

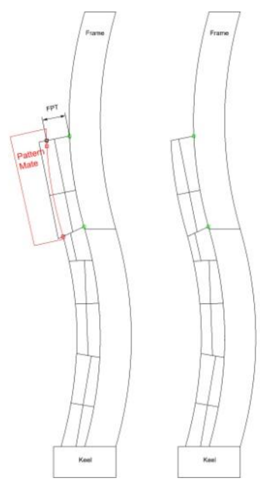

Fig. 35

Gaps Caused by Nibbed Planks

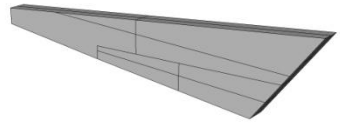

Fig. 36

Fig. 36 shows an example of two mating planks the lower of which has a nib end. Fig. 37 shows an exploded view of these two planks.

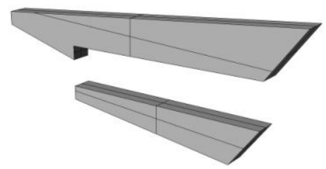

Fig. 37

The nib is used to avoid a feather end, which would be difficult to fasten.

Let’s assume that the lower plank is already in place and that we wish to create the plank above it. Fig. 38 shows the associated spiling batten.

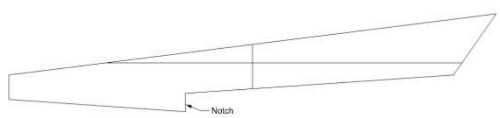

Fig. 38

To appreciate the problem, let’s consider what happens in the vicinity of the notch, which accepts the nib of the plank below.

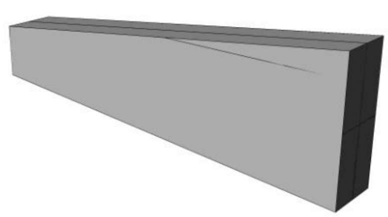

Fig. 39

Fig. 39 shows the plank just forward of the notch, and Fig. 40 shows the equivalent cross-section, with the location of the nib indicated.

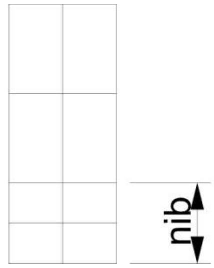

Fig. 40

Fig. 41 shows the spiling batten and a frame that is assumed to be located just to the left of the notch. Note that the spiling batten contacts the frame at both its top and bottom edges (at the red points). This means that the cord between the two points is parallel to the plane of the spiling batten and thus parallel to the face of the plank. This is very convenient for measuring the bevel angles (angles can be measured relative to the face of the batten or relative to the cord) and scrubbing the inside face of the plank (equal depth limits top and bottom).

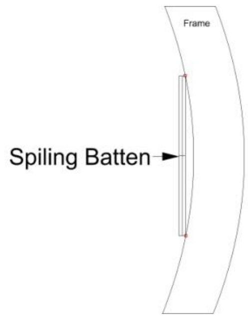

Fig. 41

Fig. 42 shows the plank as it lies against the frame. All is well at this point.

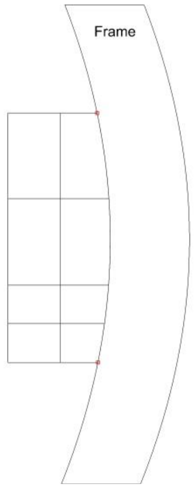

Fig. 42

Now consider what occurs just to the right of the notch.

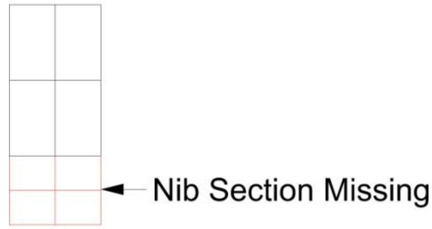

Fig. 43

Note that there is now a step change in the width of the plank – the section adjacent to the nib is missing. Consequently, the spiling batten also exhibits a step change in width at this point. The result is shown in Fig. 44.

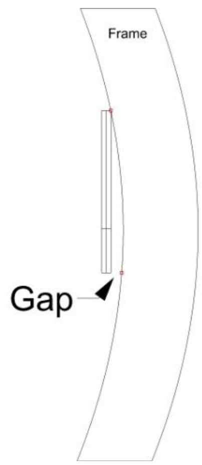

Fig. 44

Observe that the spiling batten no longer makes contact with the frame at the bottom, thus creating a gap. If we attempted to eliminate the gap, the batten would have to rotate as shown in Fig. 45. This rotation would cause the batten (and ultimately the plank as well; Fig. 46) to twist instantaneously, which is impossible.

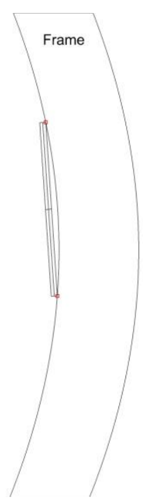

Fig. 45

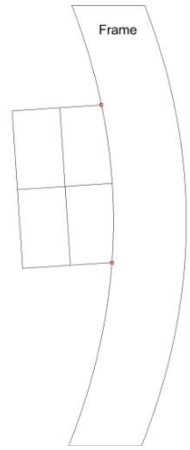

Fig. 46

Compare Fig. 46 with Fig. 47, which is the correct shape of the plank.

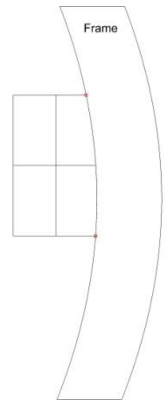

Fig. 47

To achieve the result in Fig. 47, one must be very careful how the bevels are measured and how the plank is scrubbed. In particular, one cannot measure the bevel angle relative to the cord, you must instead measure relative to the face of the spiling batten. Also, depth limits for scrubbing will be different for the top and bottom of the plank. All this is taken care of if you account for the gaps as described previously.