

## Physics Lecture 14 - Building the Simple But Fast (SBF) Car-Part 1

### Introduction

The following lecture uses information from the Car Construction E-Book on the [Virtual Race CD](#). This Lecture does *not*, however, have all the links and other features on the CD. Below are some of the details and step by step processes one should follow in building the SBF car. It is a recommended car for the beginner but still competes very nicely with more sophisticated designs. SBF templates are available on pages [14 & 15](#).

## Car Construction E-Book

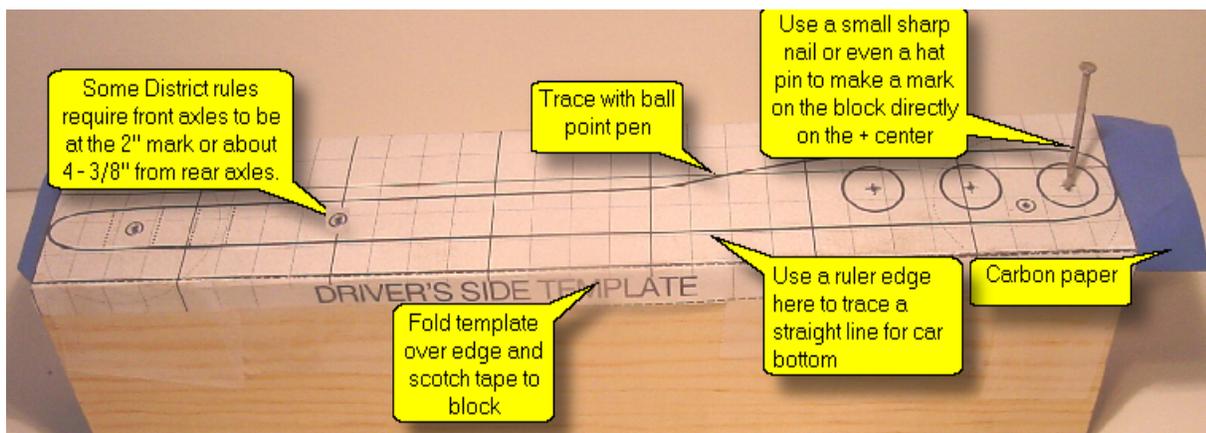


Let the Cub do as much of the hands-on work as possible and always practice safety first. Work as a team.



### 1. Using Template

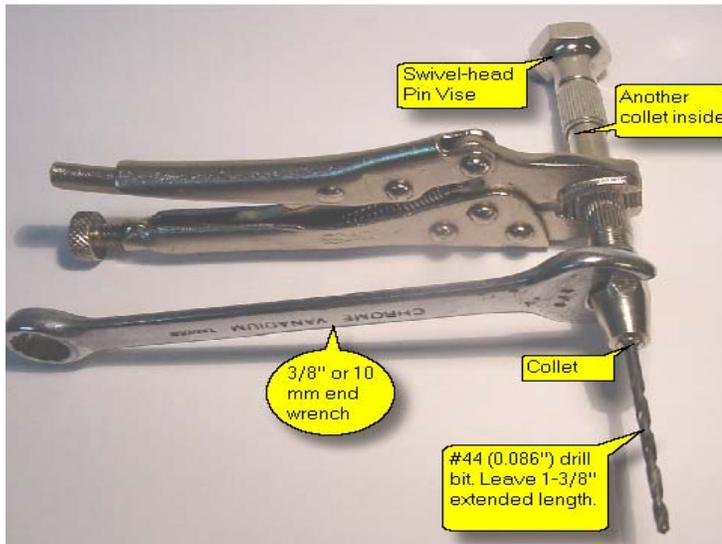
- In **Figure 1** cut the appropriate driver's side template as shown ([p14](#)) and fold over the top of the body block with carbon paper underneath. Some car lengths are  $\frac{1}{2}$ " longer than Cubs at 7.5" overall length. For such versions, cut the template in half and extend  $\frac{1}{2}$  - in by using Scotch tape and extra paper.
- Tape the edges of the template to the wood block sides using clear Scotch tape.
- Trace the outline against the block using a ball point pen. The car bottom trace should be a straight line except at the rounded ends so use a straight-edge here. We need the car body bottom line and indeed the whole body to be toward the block center as shown so the drill guide will have a large flat surface around the axle hole spots on which to rest.
- Carefully make drill center marks through the paper and into the wood using a sharp nail. Probably a more pointed object like a compass point or even a hat pin would let you get right on the center of the + mark.
- A circular or round hole plastic drawing template is good for marking circles around the 3 larger lead holes.



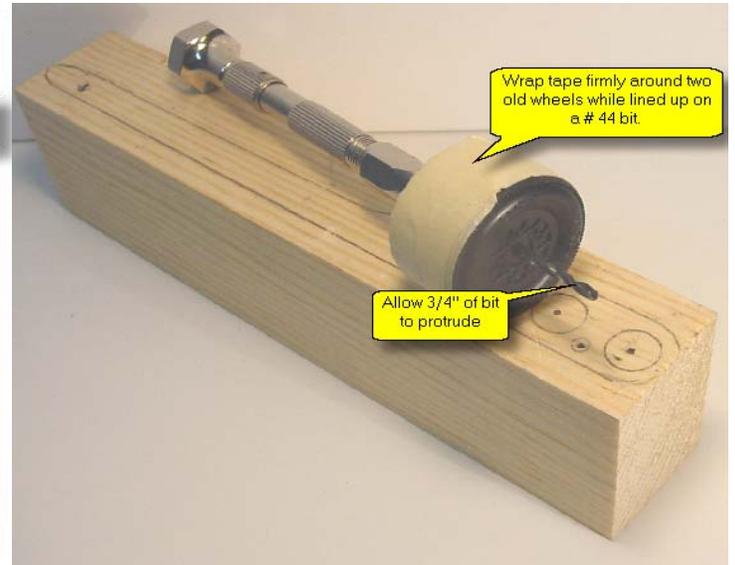
**Figure 1** - The long wheelbase template from the next to the last page printed out and laid out on a standard kit body block over a piece of carbon paper. Check to make sure it is 7" long as printed.



## 2. Drill Guide



**Figure 2** - Showing how to tighten a No 44 drill in the collet of a swivel head pin vise.



**Figure 3** - A simple drill bit guide.

- In **Figure 2**, insert the #44 drill bit (0.086") into the chuck of the pin vise and tighten using pliers on the ribbed shank and an end wrench on the hexagonal chuck. Leave about 1-1/2" of bit length protruding. (See [Online Store](#) for the pin vise). If the pin vise has a ribbed (rather than hex) chuck, use pliers instead of an end wrench as shown.

- Note that hidden just below the head (unscrew the pin vise shaft at the top) inside the pin vise shaft is another collet (chuck) that has openings for 2 different sized shafts. Between the 2 collets there are 4 different sized openings. Choose the next to the largest for the No 44 drill bit.

- In **Figure 3**, make a drill guide by taping 2 old wheels together or use some extra wheels. Use a 3/32" drill bit to keep bores lined up during taping.

- About 3/4" of the bit should protrude from the bottom of the drill guide when the chuck is all the way against the top of the pair of drill guide wheels.



**Figure 4** - Put double-stick tape on the drill bit guide.

- In **Figure 4**, double-stick Scotch (TM) tape (two pieces) is put on the letter side of the wheel to reduce slippage when drilling. This face of the drill guide is pressed against the wood block during drilling.

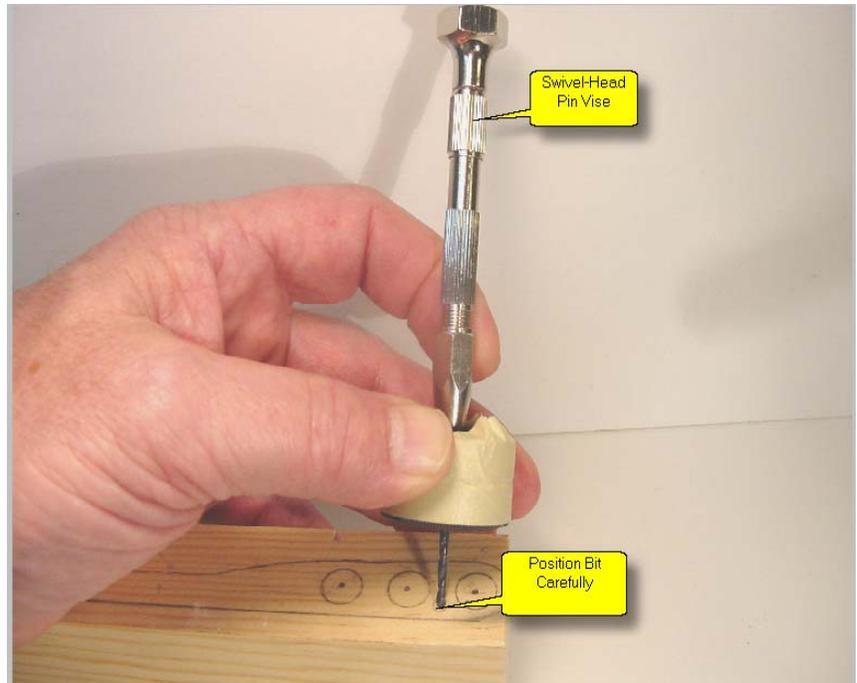
### 3. Drill Axle Holes

- In **Figure 5**, carefully position the bit in the starting hole in the wood. You may twist the bit a few times in the hole to make it deep enough (say 1/16") to ensure the bit will not wander off the right spot when you are really drilling seriously. The swivel-head pin vise is also an item provided in the [Speed Package](#) for axle lubrication.

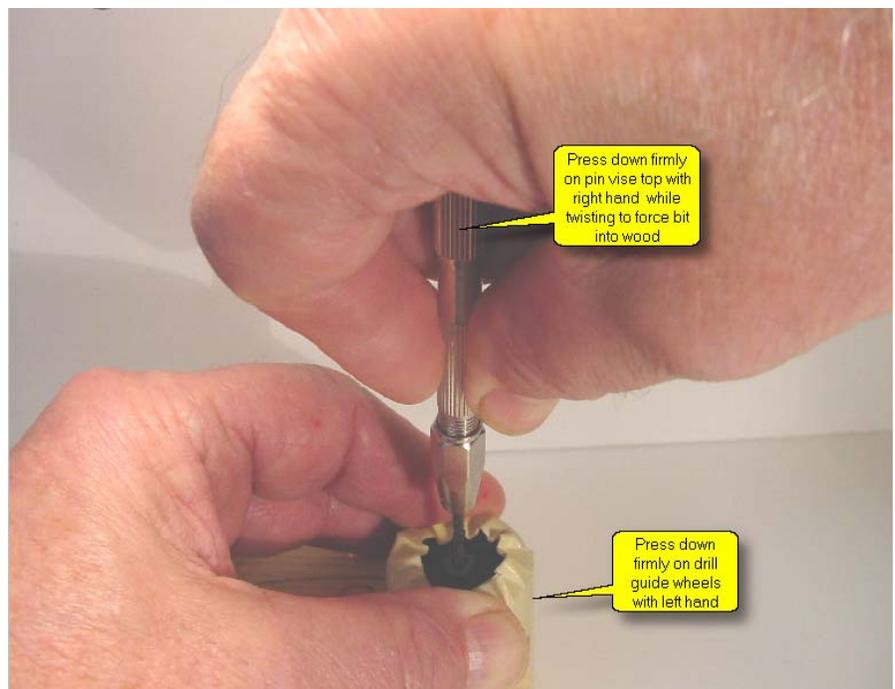
- In **Figure 6**, hold the drill guide firmly against the wood face while with the other hand you press down hard as you twist slowly to drill the hole. Try not to "tilt" the drill bit shaft one way or the other against the sides of the drill guide hole. Straight down is the aim. **Note there is a chance the drill bit may snap if pressure is not straight down and the possibility of injury if the hand hits the broken shaft.** If you are not experienced in hand drilling, gloves are suggested.

- Drill a few practice holes in the block in places not on the actual body area. Check for perpendicular by using the wheel/body profile check as shown in **Figure 7** . A final check may be done later using the 3/32" wooden dowels.

- If the wood is hard with a lot of rings it may be difficult to hand twist the drill. In such cases, it may be necessary to use a small battery operated electric drill, similar to an electric screwdriver. A large heavy drill should be avoided because the makeshift drill guide is not robust enough to keep a heavy drill perpendicular.

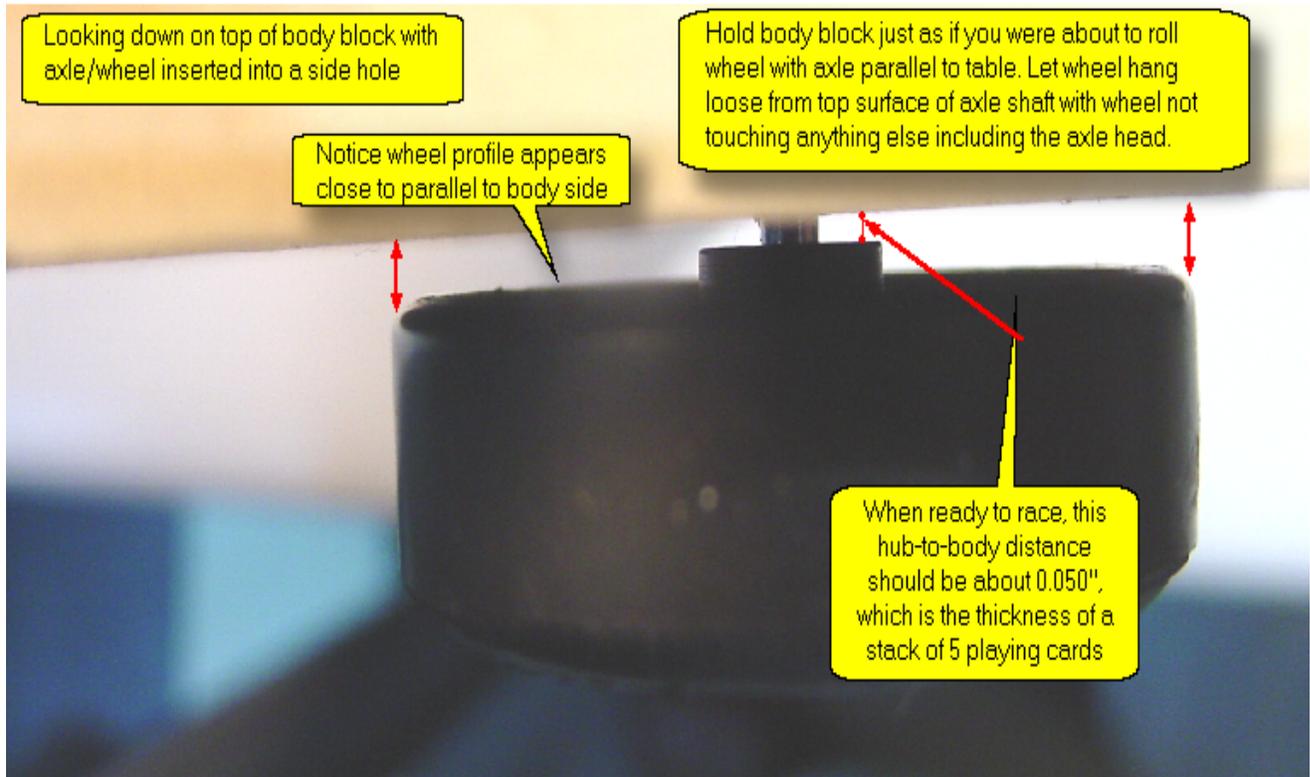


**Figure 5** - Put double-stick tape on the drill bit guide.



**Figure 6** - Drilling the axle hole

## 4. Check Wheel Alignment

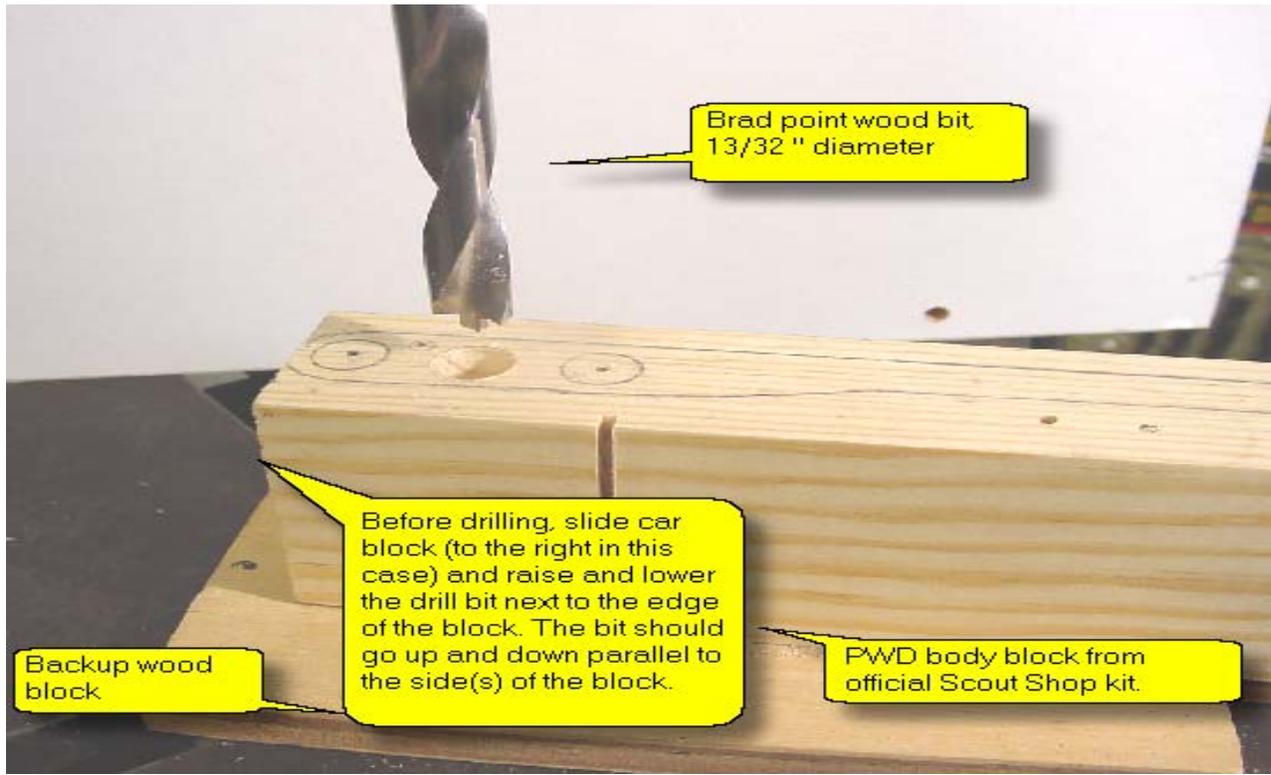


**Figure 7** - Checking if the axle hole is perpendicular to the body sides.

- In **Figure 7**, after the hole is drilled, insert a wheel and axle into the hole by thumb pressure on the nail head. No hammering. Later, remove the axle nail by pulling straight up on the wheel with fingers under the wheel. If an axle hole is too loose for a good tight axle fit, swab the hole with the tan-colored carpenter's wood glue using a skinny toothpick so just the inside of the hole is coated. Let the glue set overnight (see **Fig. 24** in **Lecture 15**)
- Hold the body block at arms length parallel to the floor directly under your eyes and look at the gap between the wheel profile and the body.
- You should be looking at the top of the car and the top of the wheel bore should be resting on the top of the axle shaft as the wheel hangs freely with the axle horizontal.
- The wheel profile should appear parallel with the body as in **Figure 7**.
- If your axle hole did not go in perpendicular, you may plug it by using a mini-dowel (see [Grab Bag](#)) with its tip sharpened like a nail and wetted with glue. Hammer a 2" long piece of the mini-dowel in as far as possible by lightly tapping its end. Then cut it off flush with the body and sand smooth. You should practice hole drilling some more before you try to redrill a straighter permanent axle hole. It can be tricky but it will work OK with practice. There is a final wheel alignment check using the mini-dowels shown in **Fig. 20, Lecture 15**



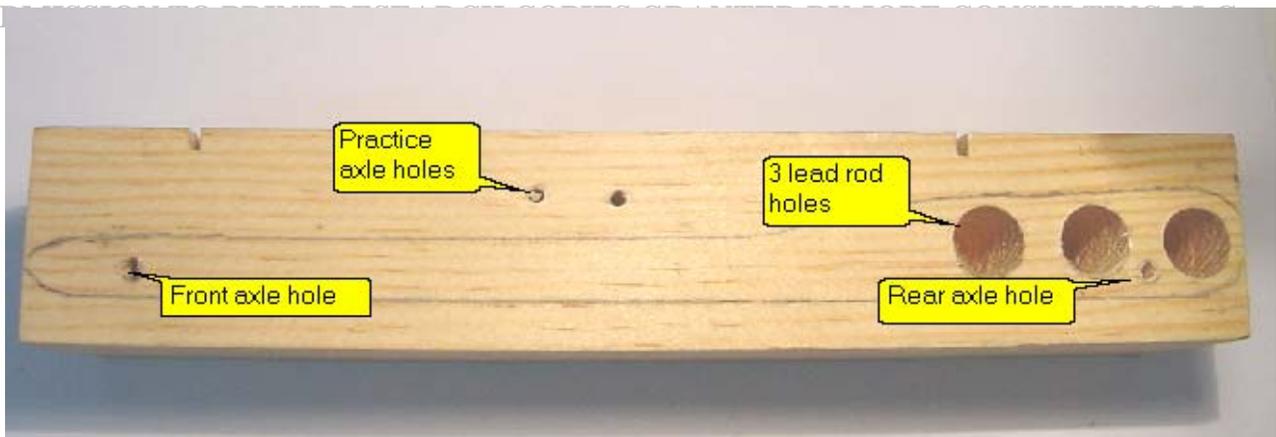
## 5. Drill Lead Holes



**Figure 8** - Drilling the 13/32" holes for the 3/8" lead burning bar ( or "worms"). A 27/64" bit will also work.

- Referring to **Figure 8** ,it is pretty tricky to drill these lead rod holes without a drill press. You may be able to drill with a 1/2" chuck and electric drill if you have some way of keeping the bit perpendicular to the body.
- Be sure and use only a brad point wood bit of 13/32" diameter. Ordinary tapered point metal-type drills of this size will not cut cleanly through the wood and can cause splitting and splintering. The 2 rearmost holes are all the way through (1-3/4") and the front lead hole is approx. 1-1/2" deep.
- Use a backup wood block to accept the end of the bit when it breaks through.
- Before drilling lower and raise the drill bit next to the edge of the block and adjust the support table so the bit travel is parallel to the wood block.

Note: If this much hole drilling is simply beyond your capability, you may purchase already drilled body blocks from [Winderby.com](http://Winderby.com). In order to raise one front wheel on these body blocks, simply plug the hole as explained under **Figure 7** and drill this one hole 0.050" higher. Steering is simplified if one front wheel does not touch the track plus if this wheel does not rotate from rolling you save energy that goes into increasing main body speed.



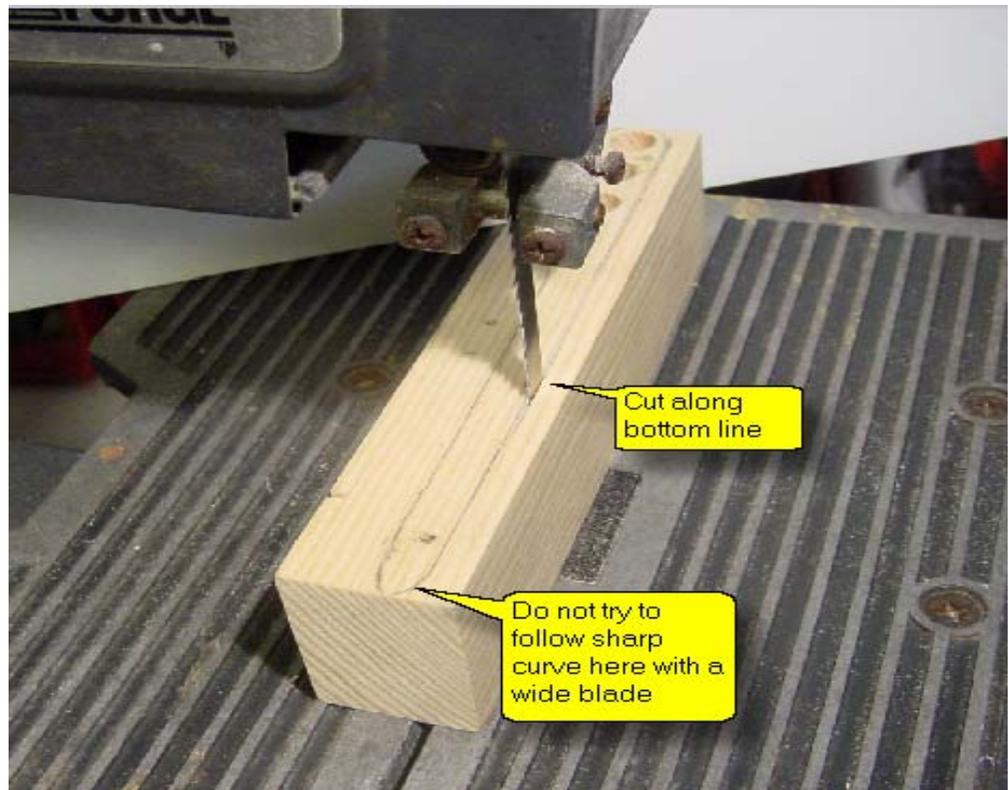
**Figure 9** - The driver side holes have now all been drilled..

- All holes from the driver's side have now been drilled as seen in **Figure 9**.
- Notice the practice axle holes.
- Notice all axle holes are drilled away from block edges so the drill guide has a wide flat surface on which to rest.

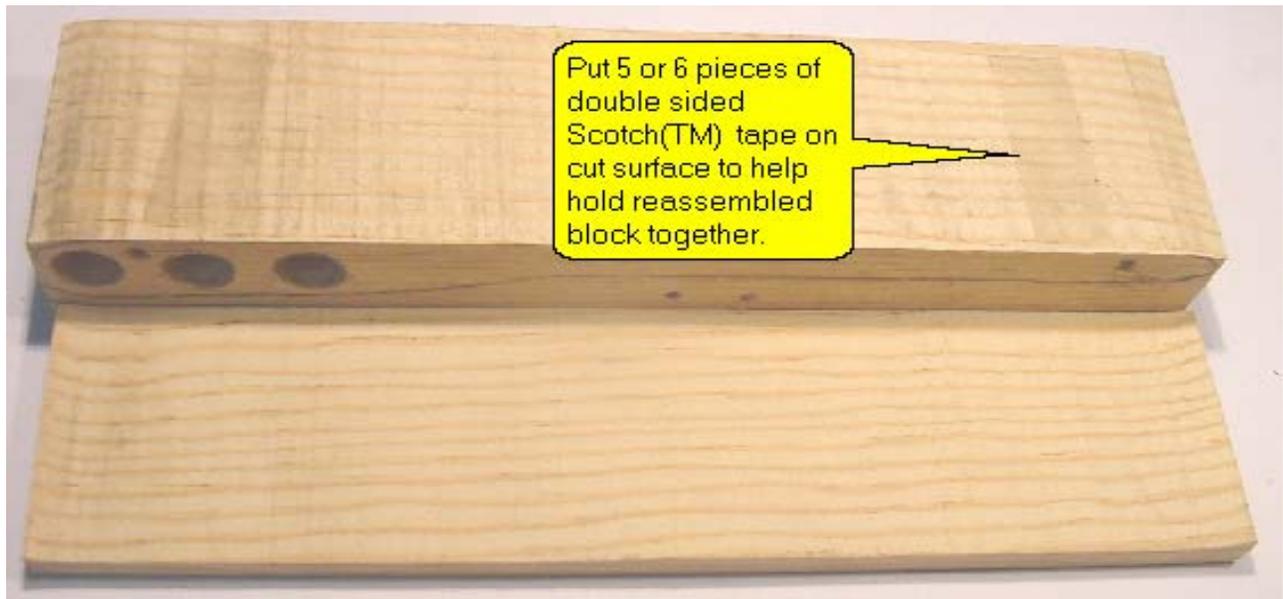


## 6. Saw Cut Car Bottom

- Next, as in **Figure 10**, cut only the bottom of the car body as shown. Do not try to follow the curved ends with a wide blade as they may be sanded round later. Make sure the blade cuts parallel to the wood block bottom, at least with not too much tilt. Before sawing, test to see if the edge or side of the block is parallel to the blade. Adjust the table tilt if necessary. Save the bottom piece as we will need to stick it back on the block temporarily. The reason is the previous bullet above (more surface for drill guide support). You may be able to use a coping saw for this cut but it is pretty tedious to cut a block this thick.

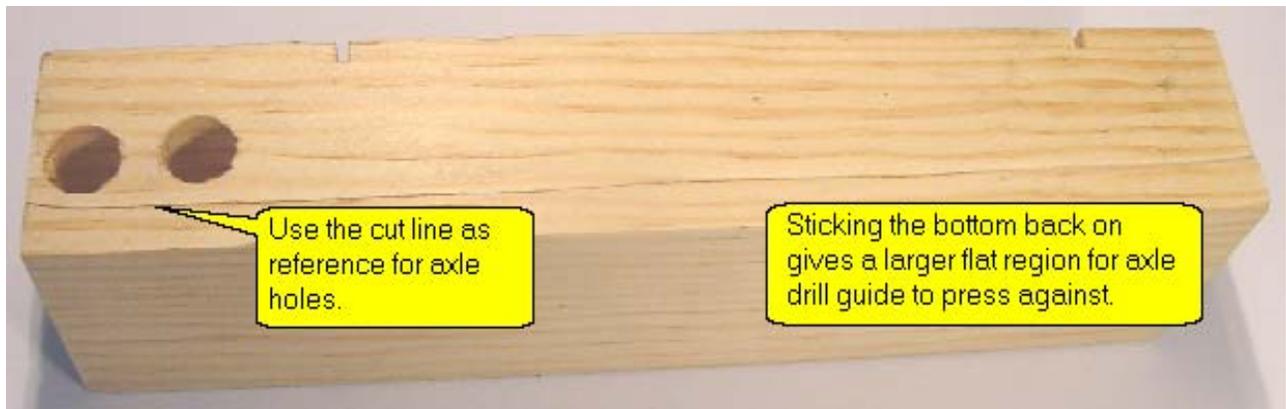


**Figure 10** - Saw cut along car bottom trace



**Figure 11** - *Preparing to stick the bottom piece back on*

- As shown in **Figure 11** , put 5 or 6 pieces of double stick Scotch™ tape on the saw cut surface to help temporarily stick the bottom piece back onto the block.



**Figure 12** - *Sticking the bottom piece back on*

- Now, as shown in **Figure 12**, you can see that the reason the bottom piece is stuck back on is to give a larger flat surface for the drill guide to press on so the axle holes will come out perpendicular to the body side. Another reason is that we have a better “bottom of the car” reference line for determining how far from car bottom to drill the passenger side axle holes.

## 7. Drill Passenger Side Holes

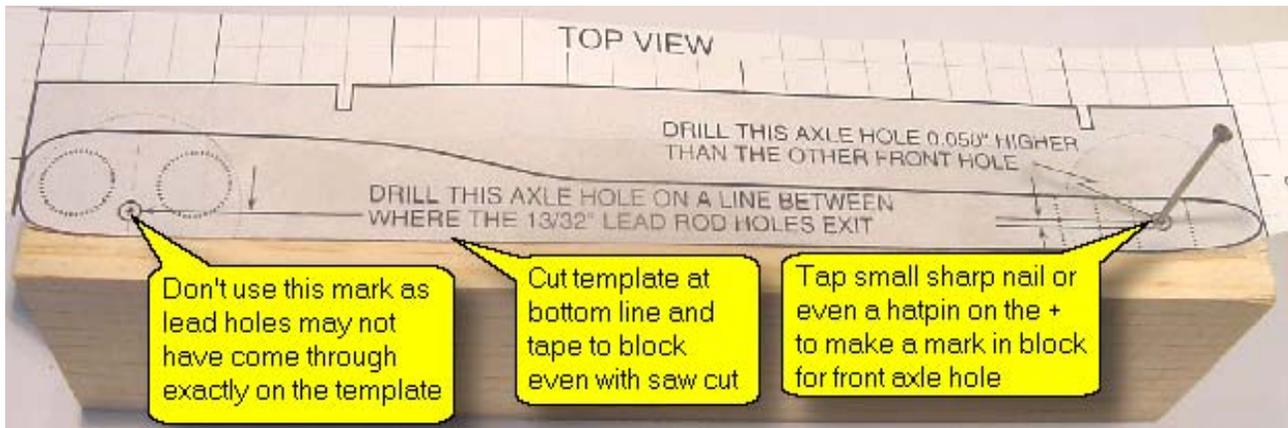


Figure 13 - Sticking the bottom piece back on

- In Figure 13, the passenger side template must be cut at the car bottom line and lined up with the bottom saw cut before it is taped to the block. The reason it should not be applied like we first did the driver's side template is that the saw cut may not have been perfectly true and the axle holes might thus come out too high or too low.
- So as shown above, we use the saw cut or actual bottom of the car body as a place from which to measure the front axle hole.
- Note that this front axle hole should be about 0.050" higher than the one on the driver's side. Mark it carefully. The width of a stack of 5 playing cards is about 0.050" ..
- Do *not* use the template for positioning the rear axle hole. The reason is that the 13/32" lead rod holes may not have come out exactly where the template shows them and they might get too close to the rear axle hole. Go ahead and remove the paper template after marking the front axle hole.

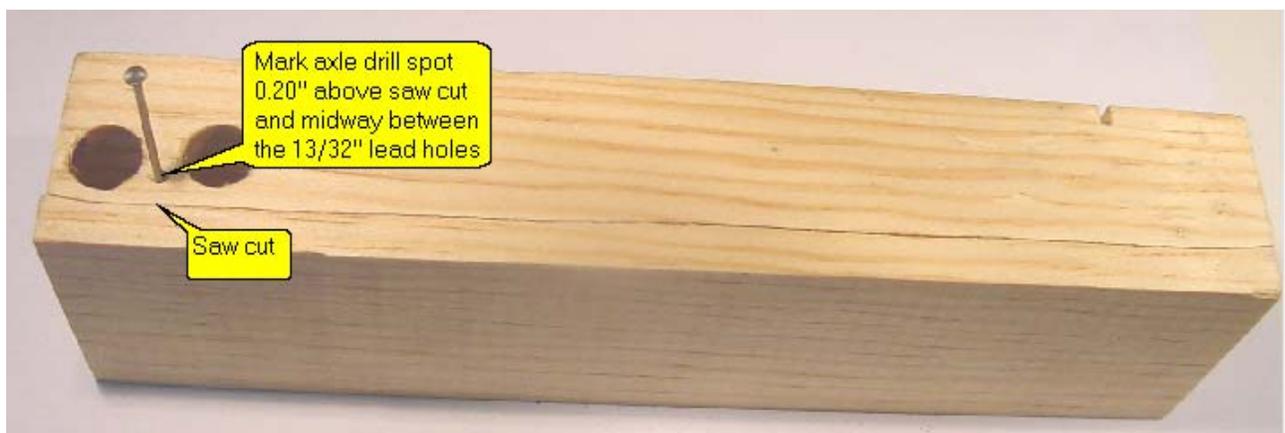
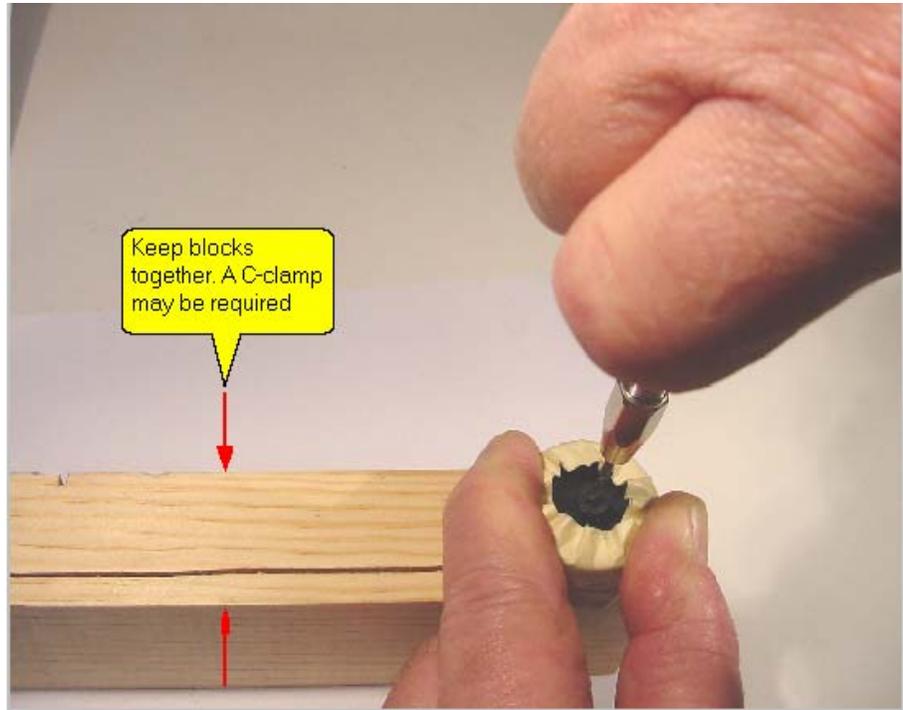


Figure 14 - Sticking the bottom piece back on

- Now make an indentation (Figure 14) on a line equidistant between the lead holes and 0.20" above the saw cut.

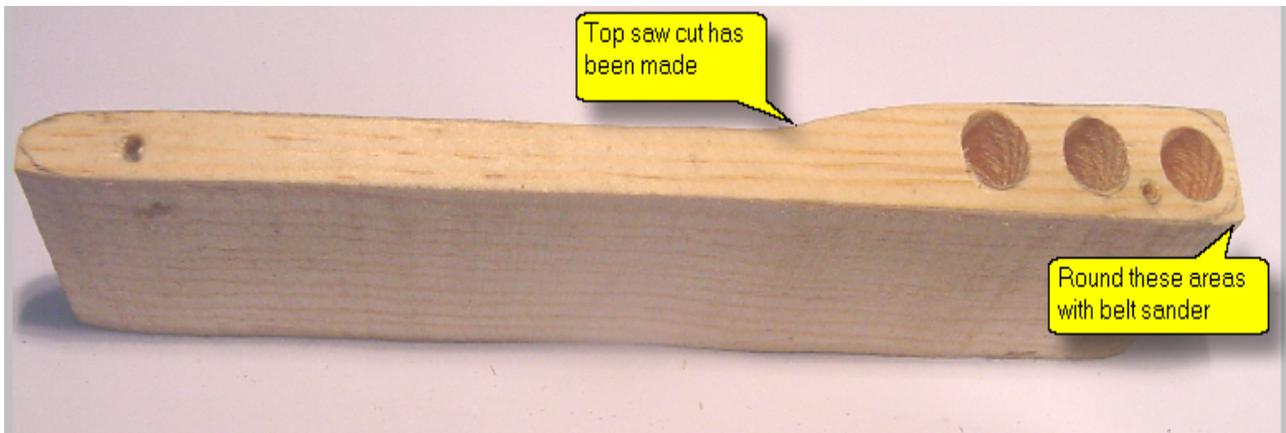
- **Figure 15** shows the rear axle hole being drilled using the same technique as applied to the driver's side holes.

- Go ahead and also drill the front axle hole.



**Figure 15** - Drilling the axle hole

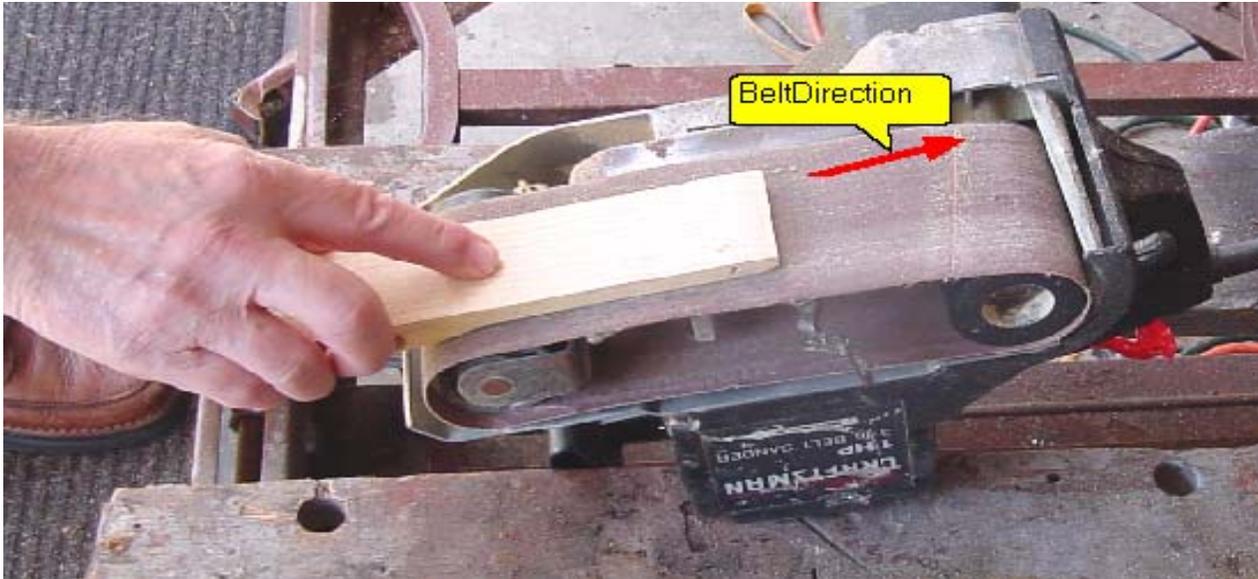
## 8. Make Top Cut



**Figure 16** -Making the top cut

- As shown in **Figure 16**, make the body top saw cut-out similar to the way the bottom cut was made.

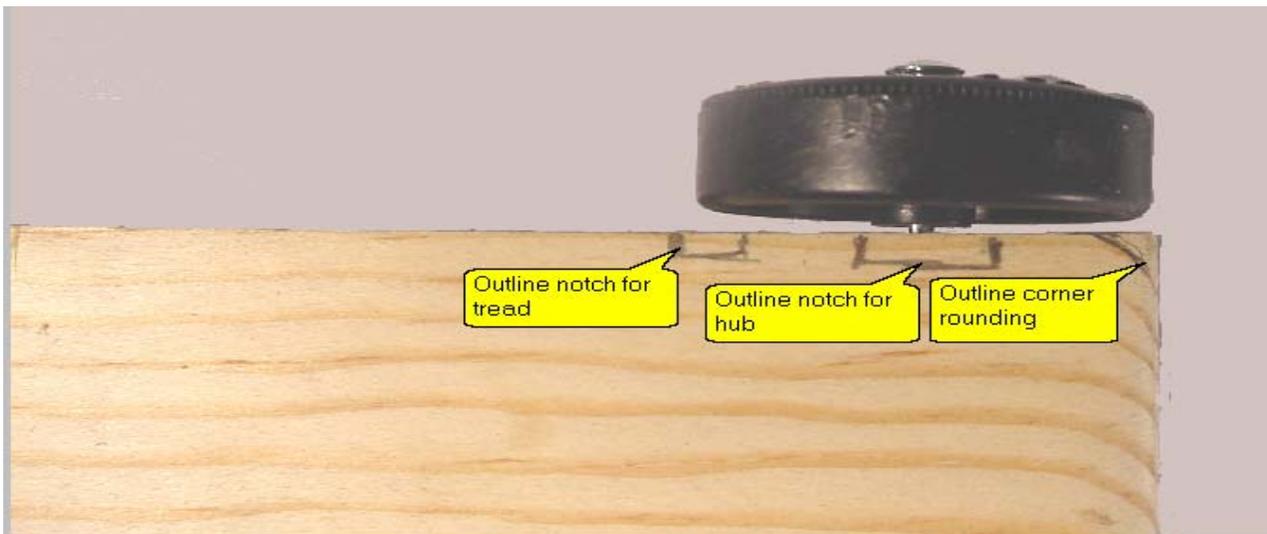
## 9. Sand Body



**Figure 17** - Sanding the body with a medium grit.

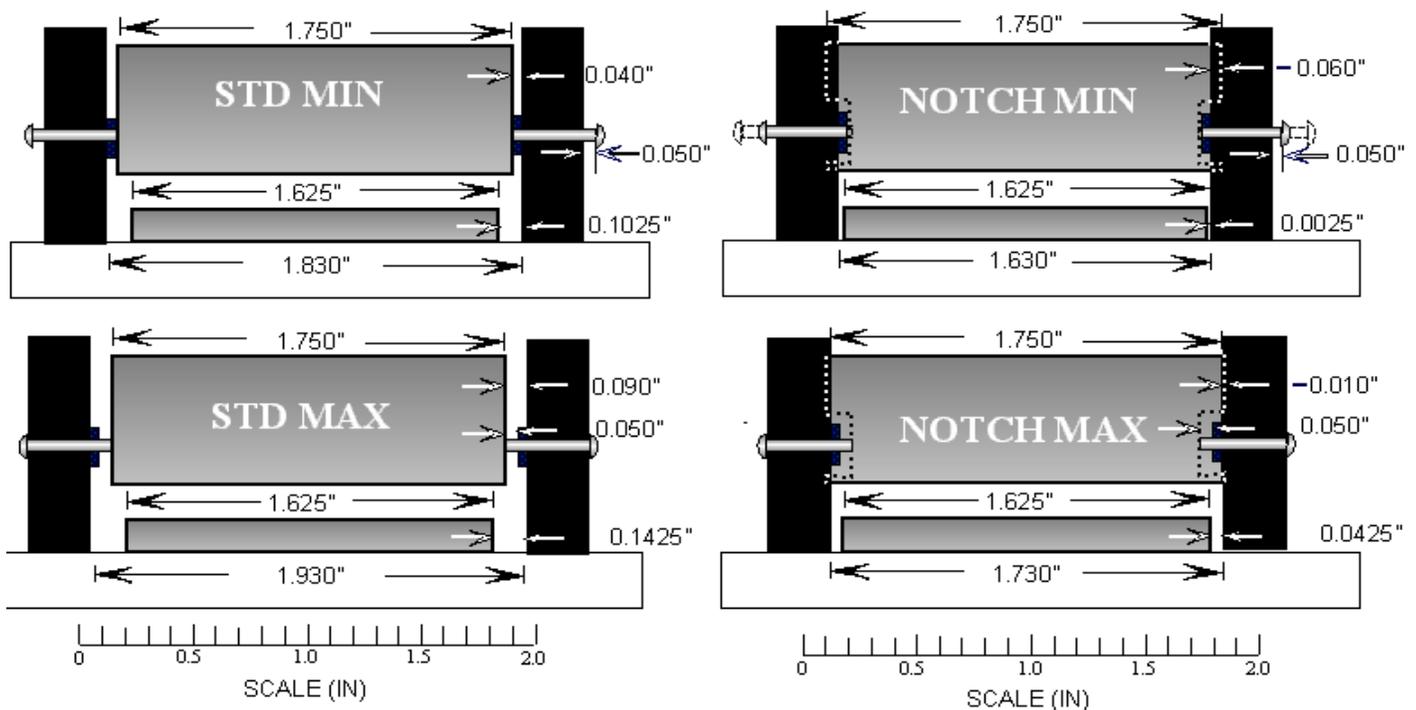
- As in **Figure 17**, carefully sand the body, preferably with a belt sander and a medium 120 grit paper.
- Also round and smooth front and rear contours where the bottom curves up to meet the front and rear. Later you can sand further with a finer grade sandpaper just before priming and painting. ([Lecture 15](#))

## 10. Notch Body for Front Wheels



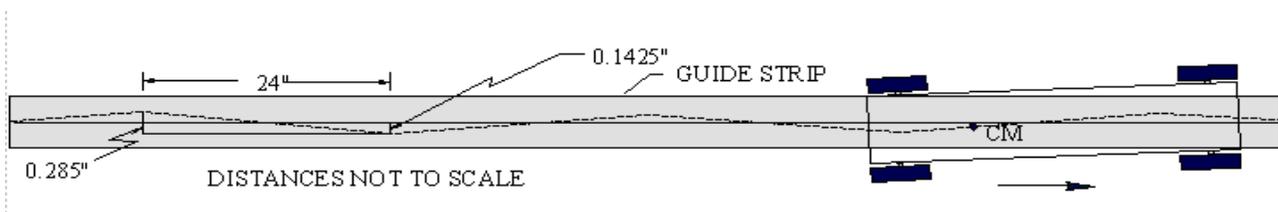
**Figure 18** - Sanding the body with a medium grit.

- Prepare to notch the front of the body as shown in **Figure 18** so the front wheels can "hug" the center guide strip.
- Use a pencil to rough out the notch outlines 1/10" deep for the hub and also around the tread contact area to provide body clearance for the wheel hub and tread.



**Figure 19** - 4 views that explain why notching helps make for faster finish times. The rear wheels will follow the front ones provided the wheel tread surface is dry and free of graphite.

- As shown in **Figure 19**, the standard center guide strip is usually 1-5/8" (1.625") wide.
- Usually wheel inside hubs need about 0.050" clearance each (axle play) from the body when pulled tight against the axle head or vice-versa.
- The normal body (without notches) is 1-3/4" (1.750") wide. With wheels pushed (squeezed) against body (with no wheel tilting) we have the STD body with MIN minimum wheel spacing. Note the wheel hubs stick out by 0.040" more than the inside of the tread part of the wheel.
- With wheels pulled (spread) against axle heads we have the STD body with MAX maximum wheel spacing.
- So even with the STD MAX spacing there is 0.1425" on each side which allows the car, at least that part between wheels, to wander around the center strip side to side by up to 0.285".

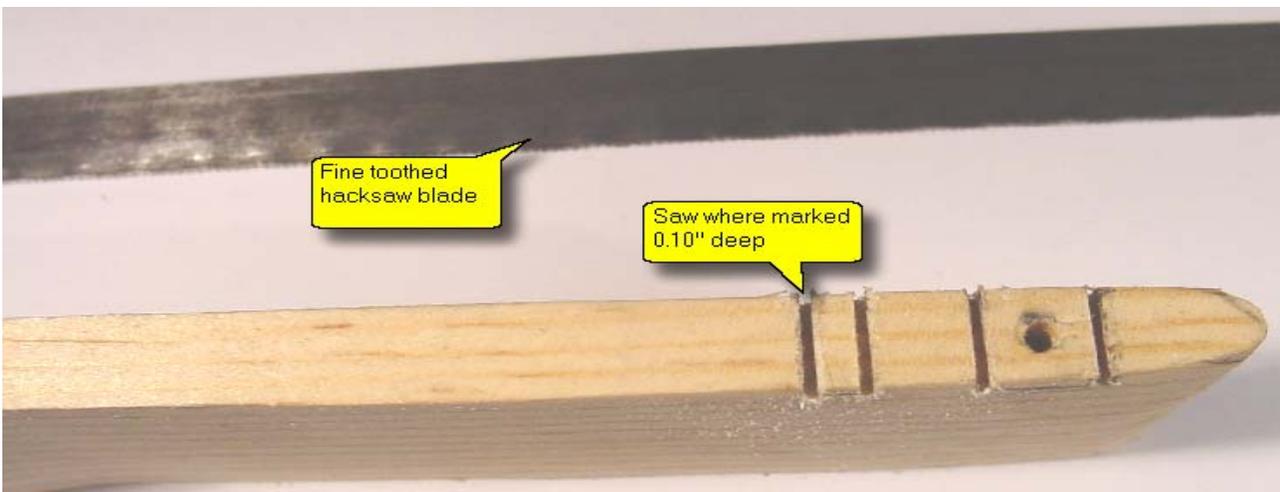


- As you can see in the above figure, suppose for each 2 feet of travel the car center of mass (CM) swings from one possible extreme to the other, a distance of 0.285". So the extra distance the CM must travel, especially if it is towards the rear axles, could be as high as the square root of  $(24^2 + 0.285^2)$  less 24" which is only 0.0017". Even if this happened 16 times (every 2 feet on a 32 ft track) that is only 0.027" total, an almost negligible distance at the finish line. The reason then that a car that "wiggles" side to side loses speed is that the bumping of the center guide strip can be hard enough to cause substantial energy loss.

- The 0.100" (per side) deep notches give the car owner the opportunity to push the front axles in by 0.100" each to reduce the maximum wheel/track clearance down to  $0.0425 \times 2 = 0.085$ ", a substantial amount. See the NOTCH MIN figure at the top right.
- So the front of the car can only move side to side by about a tenth of an inch (0.085") as shown in NOTCH MAX view.
- Even though the front wheels may still rub the guide strip somewhat the angle of attack is now much less and the associated frictional energy loss is also less.
- Tests have been done on tracks tilted slightly so the insides of a front and rear wheel on one side of the car stay against the side of the center guide strip all the way to the finish line. There is a slight friction increase between the wheel inside and the side of the guide strip, but because of the straight trajectory, such cars do not lose the larger amount of energy caused by the side-to-side center strip bumping.
- Such a strip, 1.75" wide, is very close to the 1.73" above that we get with 0.100" deep notches. And it satisfies the intent of the 1 3/4" spacing rule as written on the rules in the Scout Kit which is simply to make sure the wheels don't bind against the center guide strip



**Figure 20** - Mark notch edges on sides of car.



**Figure 21** - Use a fine toothed hacksaw blade to cut notch edges on inside of pencil mark to 1/10 - in deep.

- Referring to **Figure 20 & 21** mark the notch outlines on the body sides.
- You can use a fine-toothed hacksaw blade to cut on the inside of the pencil marks.



Figure 22 - Mark notch edges on sides of car.

- As in **Figure 22**, make a small chisel by honing, filing, or grinding the end of a jeweler's flat blade screwdriver.
- Tap the chisel from the body top to cause the wood to pop out from between the saw marks.

## 11. Cut Lead

- As in **Figure 23**, use sharp dikes, preferably lead cutting dikes from a stained glass shop, to cleanly cut lead.
- Avoid excessive handling of leads and wash hands frequently unless protective gloves are used.
- Cut 3 pieces 1-5/8" long. Notice that dikes must be reversed to clip off and make flat the tapered cut end that forms as shown.

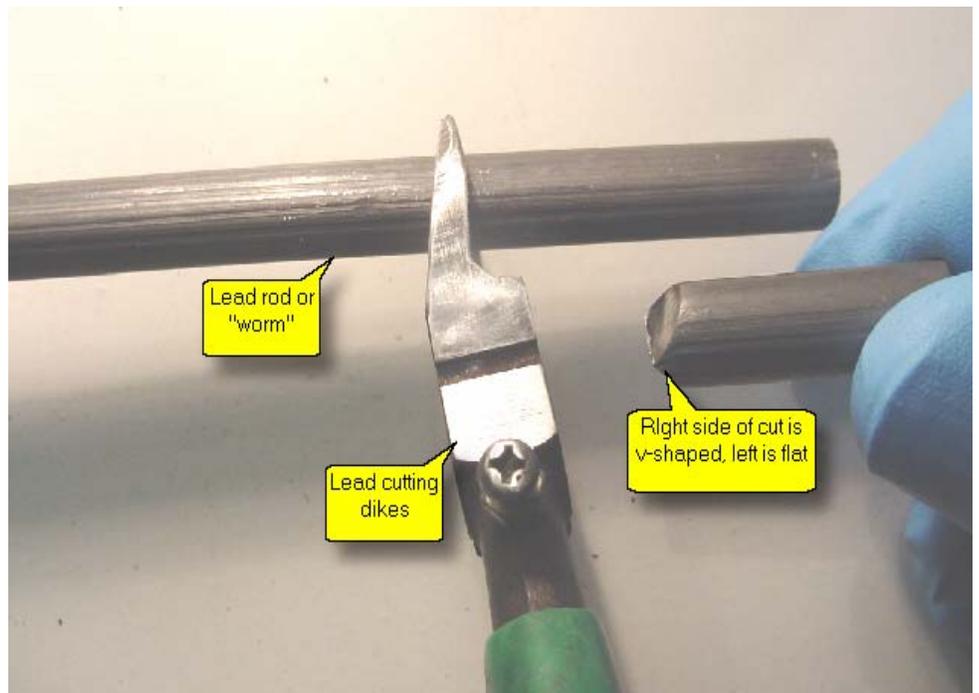
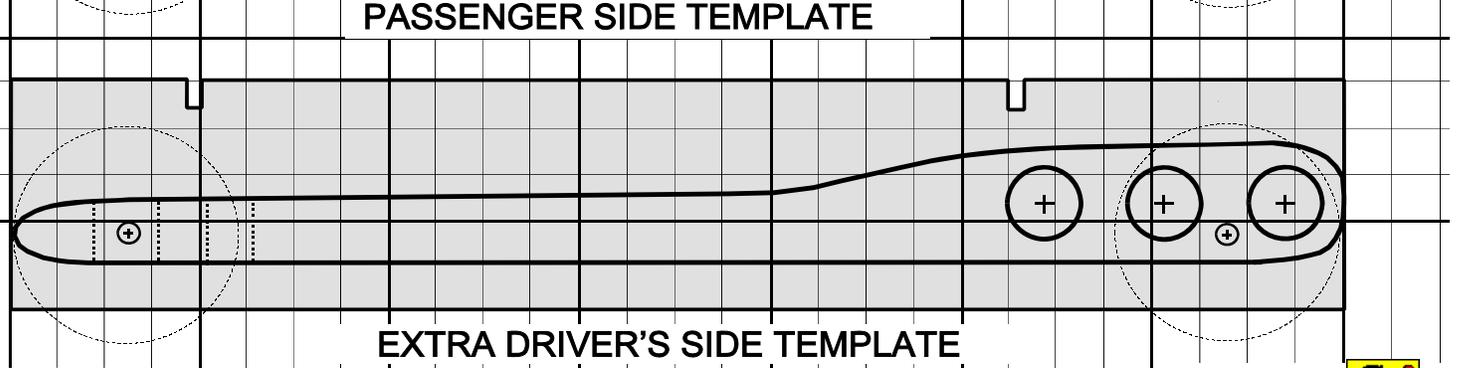
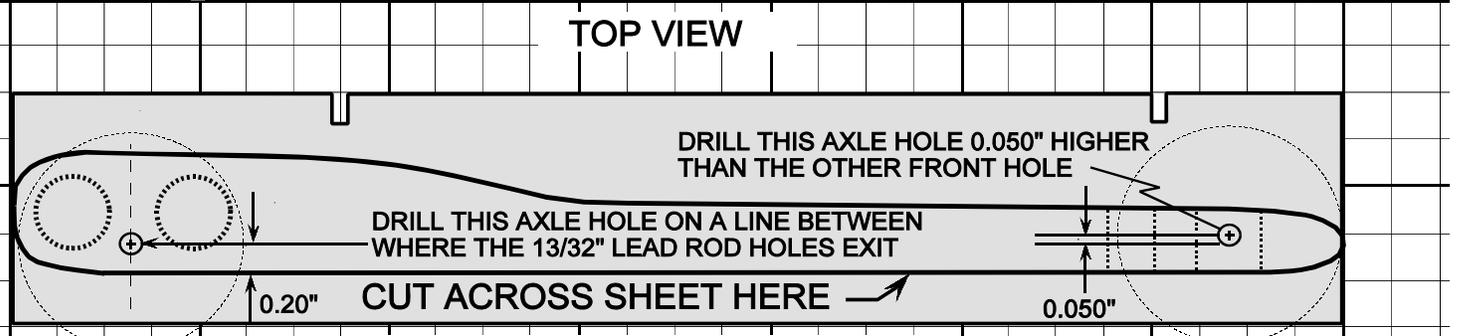
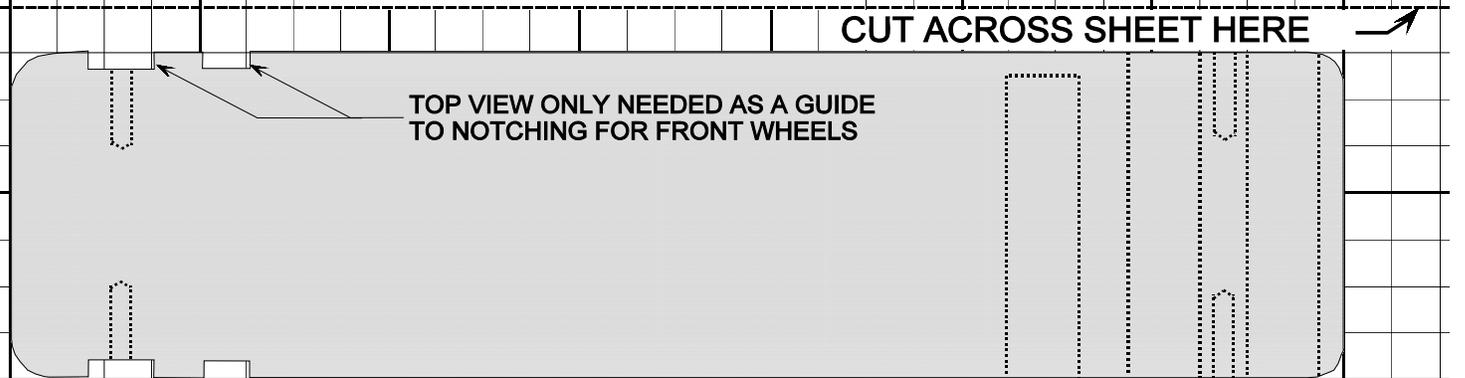
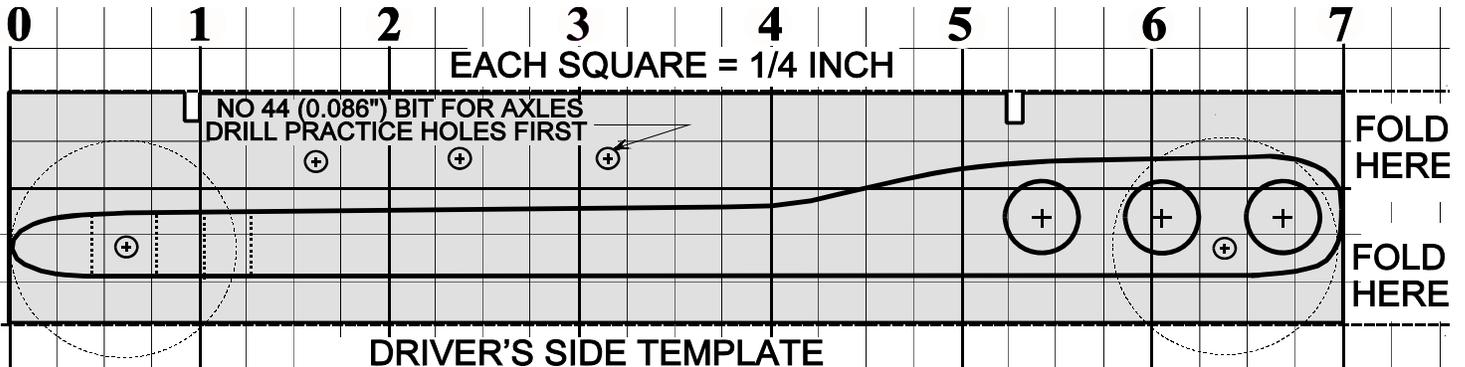


Figure 23 - Mark notch edges on sides of car.

**This is the end of this lecture - The templates are on the next 2 pages. Just print these pdf pages on a laser jet or ink jet printer. Check the inches scale for accuracy. In the Acrobat printer box setting, make sure [Page Scaling] = None. In the next Lecture, No. 15, we will assemble, weigh, and paint the SBF car.**

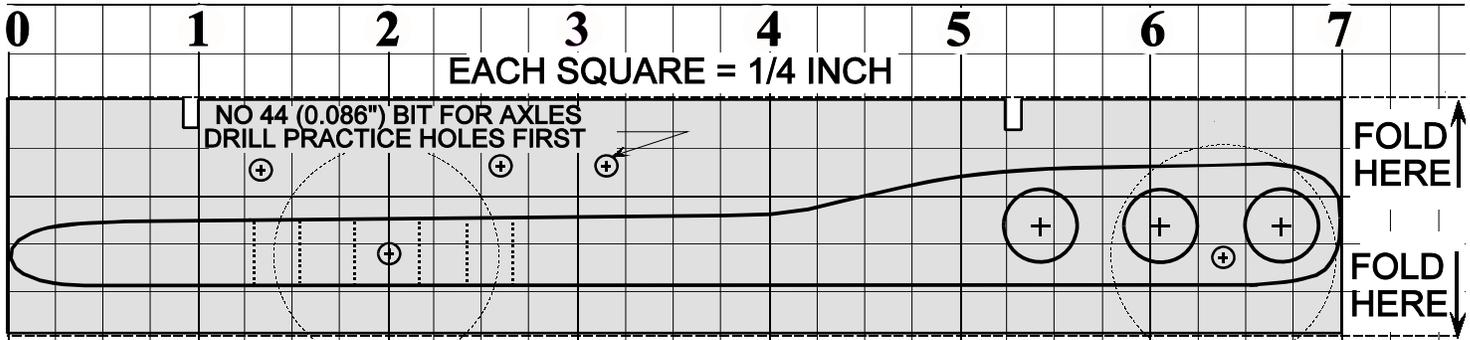
**In the Acrobat printer box setting, make sure [Page Scaling] = None. In the next Lecture, No. 15, we will assemble, weigh, and paint the SBF car.**



SEE PHOTOS/ INSTRUCTIONS IN THE E-BOOK - CAR CONSTRUCTION AND LUBRICATION

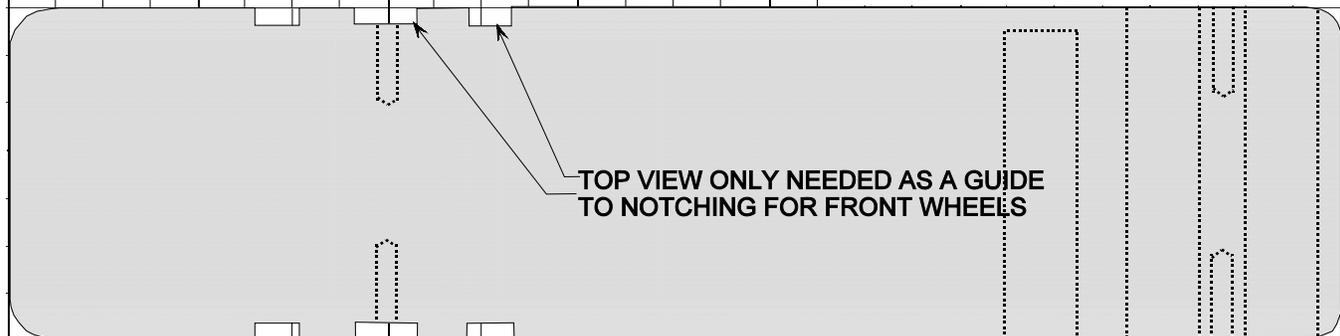


SEE NEXT PAGE FOR SHORT WHEELBASE TEMPLATES

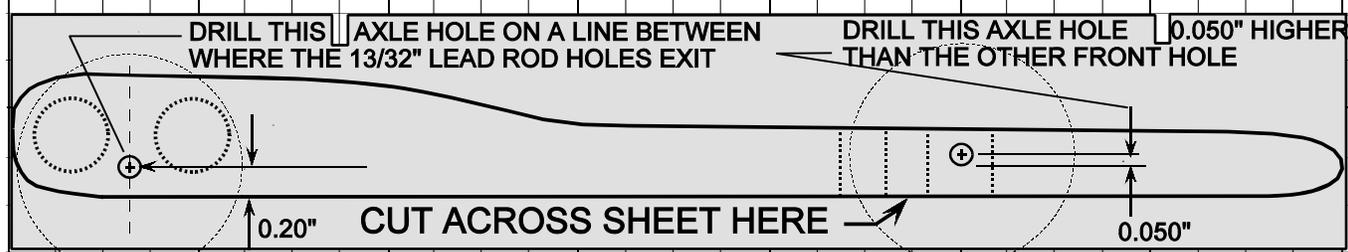


DRIVER'S SIDE TEMPLATE

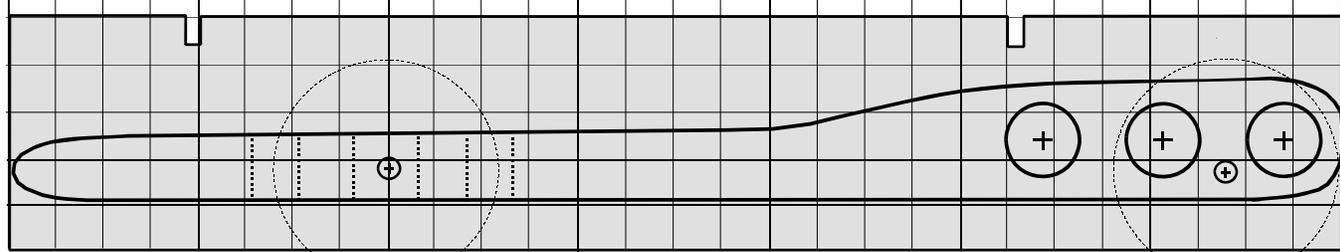
CUT ACROSS SHEET HERE



TOP VIEW



PASSENGER SIDE TEMPLATE



THESE TEMPLATES ARE FOR A SHORT WHEEL BASE CAR