Old School Chopper Frame Fabrication
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Part 1

The easiest frame to build is a traditional old school styled chopper since there aren’t any complicated bends or compound miters to cut so we decided to show the chassis fabrication process from A to Z as we do it. Others probably have different techniques but this system has worked for us over the past thirty years and guarantees a good straight frame using a minimum of special tools or really fancy jigs. About half of the frame is constructed without a traditional building jig being used to begin with so this is a good project to start with if you want to build a traditional frame jig but you don’t have a frame to use as a mock-up. As work progresses on the chassis you can fabricate a jig one piece at a time when it’s needed.

The frame for this particular project is derived from the stock 1948 Harley hardtail design but we stretched the downtubes four inches, the backbone two inches and raised the rear axle plates plates one inch and shifted them two inches rearward. These changes result in a lower than stock frame having a perfectly straight backbone line from the steering neck to the rear axle when viewed from the side for the classic chopper look.

These instructions are intended to accompany part of the material that we provide with our large-scale building plans. This is the first time that we have published them separately and while we have tried to modify the diagrams and exhibits to fit into the size limitations imposed by a web page some of the pictures may be to small to be readable. If you don't have our plans and you reach a stumbling block on your project please contact us and we'll see if we can help you out.

The frame we’re building for this particular project will accept Panhead, Shovel and Evo engines and Knuckleheads and Flatheads with a front motor mount spacer. It’s designed to use a 140 or 150 rear tire with standard chain.

Our goal for this particular project is to have a rolling chassis for under $1500 or about $6000 less than if we bought one ready-made.

To start with you need thirty feet of 1.25”x.120” ERW tubing. We’d suggest that you buy two full twenty-foot lengths since this will give you some extra material in case you make a few miscalculated cuts or bends. You’ll also need two feet of 1x2x.120 rectangular steel tube for cross members. To start the project you won’t need a steering neck or axle plates until further down the line so you can get this frame started with very little up-front cash outlay.

After you’ve secured the tubing you can cut it into working lengths using an abrasive cutoff saw if you have one otherwise use a sawsall or even a small tubing cutter. As a last resort a regular old hacksaw will get the job done but will eat up a good chunk of time and give you some nasty blisters.

Figure 1 illustrates the primary chassis components of a typical V-Twin rigid frame that consists of the following primary elements:
1. Steering head. Also called the stem head, steering neck or headstock.

2. Frame Backbone. Sometimes called the Top-tube.


4. Backbone or Top Tube brace.

5. Wishbones. One left and one right. Also called the upper rear wishbones.

6. Wishbone cross member. Also called the upper fender mount.

7. Side tubes. Sometimes called the side rails, bottom rails or lower tubes

8. Seat post cross member.

9. Rear transmission mount/cross member.

10. Axle plates or side plates.

11. Front tubes or Down tubes which extend into the bottom rails

12. Front transmission mount.

13. Rear motor mount.

14. Front motor mount

15. Motor top mount.

The following table lists the pieces to be cut, the length and the quantity. Allowance has already been factored in to account for the bend lengths and to permit some room for possible cutting mistakes.

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Item</th>
<th>Material</th>
<th>Cut Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Backbone</td>
<td>1.25”x.120 ERW</td>
<td>36”</td>
</tr>
<tr>
<td>2</td>
<td>Wishbones</td>
<td>1.25”x.120 ERW</td>
<td>38” each</td>
</tr>
<tr>
<td>1</td>
<td>Wishbone Cross member</td>
<td>1.25”x.120 ERW</td>
<td>12”</td>
</tr>
<tr>
<td>1</td>
<td>Seat Post</td>
<td>1.25”x.120 ERW</td>
<td>23”</td>
</tr>
<tr>
<td>1</td>
<td>Seat Post Cross member</td>
<td>1”x2”x.120 CREW</td>
<td>12”</td>
</tr>
<tr>
<td>2</td>
<td>Spacers</td>
<td>1.25”x.120 ERW</td>
<td>12”</td>
</tr>
<tr>
<td>2</td>
<td>Downtubes/Lower Rails</td>
<td>1.25”x.120 ERW</td>
<td>84” each</td>
</tr>
</tbody>
</table>

Table Error! Bookmark not defined.

To make this an easy project and to minimize the need for a full blown frame jig until later in the process we’re going to basically build what can best be described as the upper half of the frame with the seat post and seat post cross member as one unit and later we’ll add the down tubes and bottom rails as a secondary assembly.

When the first set of tubes have been cut and the wishbones have been bent we’ll have a group of parts that should look very much like those pictured on my driveway in Figure 2 below.
This assembly actually represents about 70% of the overall chassis tubing and while it may not look like much in this condition it represents a tremendous amount of work and very few do it yourself builders get this far on their first project.

If you don’t have a tubing bender you can probably find a chassis or welding fabrication shop somewhere near your locality to bend the wishbones. You can also try posting a message on one or more of the motorcycle forums and you might find somebody near your location who has a bender and who’d be willing to help you out. I do not recommend that you attempt to make these bends with a hydraulic pipe or conduit bender and if you try to heat the pipe and bend it by hand the radius will be to small and the tube will probably flatten anyway.

If all else fails and you can’t find anybody to make these bends you may be able to successfully accomplish the task by using a 1” thick-wall (rigid) conduit bender with a long extension handle as the outside diameter of 1” rigid electrical conduit is very nearly the same as the O.D. of 1.25” ERW tubing.

Part 2

Before we go much further we need to decide what style of connection we want to make between the backbone or top tube and the seat post. There are three joints that are commonly used. The first, seen in Figure 3 is probably the most common and the one I personally prefer as it allows easy access for running wiring inside the tube. It seals off the seat post to water intrusion yet the open end of the top tube is naturally sloped to drain.
The second method is almost as popular but a much older style of connection going all the way back to the days when the seat post really served a purpose. The problem with this style is that water can get down inside the seat post tube and even if you provide a drain hole it will eventually get clogged up with rusty gunk.
The third connection style as shown in Figure 5 is becoming more and more popular because it is easier and quicker to make than either of the two methods shown above that both require a coped or fish-mouthed joint in one of the two tubes.
I have mixed feelings about this last connection method, which is correctly called a fully mitered joint. Even though it can be made quickly with a chop saw to my eye it just doesn’t look right but it definitely has the advantage of sealing off both the top tube and the seat post. This is a common connection seen in high volume mass production shops.

For a first-time builder this is probably the method I would select but on this particular build we’re going to use the first style where the top tube extends over the seat post.

The first piece we’ll finish is the seat post since it’s length, tilt from the vertical and the angle between it and the backbone set the primary parameters for almost the entire frame.

The plans I prepared call for an 18-29/32” seat post length measured along the back side of the post from the seat post cross member up to the bottom of the top tube but to be honest I usually notch it and cut the bevel in the bottom so that measurement is really 19” but by the time I touch up the fish-mouth and get it welded my tape says its 18-29/32” so it pays to make each cut and miter notch just slightly longer than specifications to allow some room for fine tuning. Throughout this build I strongly suggest that you err on the side of making cuts and fish-mouth connections longer rather than shorter.

Figure 6 below is a detail of the measurements and angle cuts for the seat post which is made from 1.25”x.120” wall ERW.
While this might seem like a simple operation it pays to stay alert when you’re knocking this little item out in the garage some late evening. I admit that on more than one occasion while under the influence of certain health beverages I have cut the fish-mouth in the top of the seat post tube backwards relative to the angle cut made in the base. What’s worse is that I welded it together and didn’t notice the problem until the next day.

The slope angle on the seat post relative to a vertical line is 17 degrees. The stock angle is just a hair under 16. The extra degree of slant combined with the 19” length gives the frame room enough to house Evolution motors. In effect the top of the seat post has been moved .625” towards the rear and the backbone has been raised .625” in relation to a stock Panhead frame.

I think the easiest way to build the seat post is to first make the fish-mouth cut with a hole saw mounted in a tubing notcher or by using a miter template and die grinder. The angle between the seat post and backbone is 97 degrees. If you’re using a notcher set the angle to 7 degrees and make the cut.

Figure 7 shows my cheap imported tubing notcher with the seat post set up for the cut.

Do not trust the protractor built into your notcher. Always check the actual angle with a good accurate angle finder. In this picture as we set the tube up for the cut our little yellow angle finder said we were right on 7 degrees but the factory supplied dial on the face of the notcher read 5 degrees. Had we turned the tube to the 7-degree mark on the notcher we would have actually cut a 9-degree angle.
In case you’re wondering I don’t bolt the notcher to a bench since no matter how I installed it there never seemed to be enough room for long tubes so when I’m ready to make the cut I put the whole mess on the floor and stand on the mounting tab as I’m running the drill. On the rare occasion that I do bolt it down I like it to be in a horizontal position.

Figure 8 is pretty fuzzy but I think you can see how rough of a cut these cheap notchers make.
This type of notch needs to be cleaned up and dressed with a half round file and the sharp edges at the top of the mouth need to be flattened slightly and shaped to fit the adjoining tube perfectly. If the angle of cut was slightly off, the bottom of the throat can be deepened to bring the fit back to the proper joining angle. Figure 9 shows the dressed notch ready for final fitting and fine-tuning before tacking.

![Figure 9](image)

As you’re working with the tubing sections you’ll notice that the interior surface starts to accumulate a lot of metal shavings that stick to the grease applied to the material at the mill so now that we’ve got the pieces cut into shorter lengths it’s a good idea to run a lacquer thinner soaked swab down the inside of all tubes before we start the assembly process. If we left this fine debris in place it would start to rust almost immediately.

Figure 10 below shows the finished miter at the junction of the seat post and the frame backbone ready to be tacked.

![Figure 10](image)

Once the notch is finished and dressed up measure down from the throat of the fish-mouth along the backside of the tube 19 inches and make a mark where the back of the base-cut is to be made. This cut can be made with a chop saw or reciprocal saw and the angle is 17 degrees. As I said before be careful and keep track which side of the tube faces forward and which side faces aft. It is imperative that the transverse axis of the fish-mouth and the base cut be perfectly aligned otherwise the seat post will sit at a sideways slant on the seat post cross member and the backbone will veer off from the longitudinal centerline of the frame once the two tubes are welded.

If you have a chop saw the task is easier since you can use a machinists level on a short piece of pipe temporarily held in the fish-mouth as you clamp the seat post tube into the saw vice. This insures that the two cuts are in proper alignment.

Now we need to finish up the seat post base cross member made from 1”x2”x.120” rectangular steel tubing shown in figure 11.
This cross member sets the width for our frame which in this case will be 9-5/8” between centers which works out to 8-3/8” inside between the bottom rails. The old stock frames measured only 8” so we allowed a little more room so we could fit a larger rear tire.

I don’t have an End Mill so I make the radius cuts in the ends with a hole saw mounted in a drill press allowing an extra sixteenth of an inch between throats which I clean up with a die grinder and file until the distance between the throats of the cuts is exactly 8-3/8”.

Mark a transverse centerline in the middle of the piece and another line 5/8” to each side and make two pencil lines running parallel with the longitudinal centerline. One line will be 3/8” away from the front edge and the other will be 3/16” from the rear edge. The seat post will fit inside the box formed by the four lines.

This is a good time to cut the fender mount cross member that is positioned just aft of the bends in the rear wishbones. In the old days this piece of tubing had a slight radius but since it can’t be seen in the finished bike we usually just leave it straight. Like the seat post cross member this tube needs to be 8-3/8” long measured between the throats of the fish-mouth notches as shown in Figure 12.
While the notcher is set up I'll usually make two more identical pieces of tubing to be used later as temporary spacers between the wishbones and even later on between the bottom rails.

Now we'll finish up the wishbone tubes and get them ready to be welded to the backbone. This isn't a complicated step but it has been hard for me to describe verbally so in an attempt to clarify the process we made a small layout board from plywood.
Initially the wishbone tubes were rough cut a little longer than needed and bent 26 degrees in towards the top tube. The layout above shows how the pieces look now in relation to the centerline of the frame and lines demarking the 8-3/8” inside frame width.

What we want to do now is to chop off the excess material at the end of the tubes where they will be welded to the backbone and bring the pieces inward until they are at the proper spacing.

Figure 14 show the left hand tube moved in towards the centerline of the frame so its inner edge is 4-3/16” off center (8-3/8” divided in half).
The cut we want to make for the time being should run parallel to the frame centerline removing about two inches of tubing. This should be done to both halves of the wishbones. This is not the final notching step. At this stage we just want to be able to insure that we can set the wishbones at the correct spacing. In effect what we will be creating is a straight mitered cut in the tube ends as if we were going to weld them together without a backbone tube between them.
Figure 15 shows the end results of this trimming. Note how we used the spacer tubes fabricated earlier to temporarily set the 8-3/8” inside width and that the wishbone tubes come together in an apex on the imaginary backbone centerline.

Figure 16 is the same layout but shown from a different angle.
The next task is to form the fish-mouths in the wishbones that will accept the frames top tube.

**Part 3**

Most hole saw based tubing notchers can’t be adjusted to make angled cuts as shallow as the 26 degree notches required for the connection of the wishbones to the top tube. The alternatives at this point are to use an end mill, set the tubes in an adjustable vice on the drill press and mount a hole saw in the chuck or use a miter template and cut the notches with a die grinder. I’ve been doing it so long with a grinder that for me at least this seems to be the easiest and fastest way to make the cuts.

Regardless of the method used it is always a good idea to have alignment lines on all your tubing sections. Depending upon the particular application you might just need control lines on the front and back faces of the tube or front and back plus each side face.

In figure 17 below we’ve used an indelible marker to scribe the control lines where the toe and heel of the wishbone fish-mouth cut will be made.
There is a corresponding longitudinal control line 180 degrees around the tube on the reverse side.

Using a tube mitering computer program we generate a printed template for a 26 degree connection angle in 1.25” tubing. Cut the template and scotch tape it together at the seam leaving it just loose enough to slip down over the tube end.
Using an indelible marker outline the miter path around the inside edge of the paper template and slip it off the tube before starting the trimming operation.

If you need to remove a lot of material you can trim the tube back to within an eighth or so of the marked line using a reciprocal saw and then finish up the fine cutting with a grinder. The objective is to create a nice tight joint at the intersection and also to move the wishbone tubes in towards, and parallel with, the centerline of the frame keeping the 8-3/8” inside clearance.

Just keep grinding, filing and fitting a little at a time until the connections are perfect on both sides of the backbone and the distance between the wishbones is 8-3/8” right about where the fender mount cross member will eventually be welded.

You’ve probably been in a bike shop somewhere or over at a friend’s house while someone is trying to install a new rear wheel and the swing-arms or the wishbones on a rigid frame are too narrow for the hub and spacers to be installed without using a small bottle jack to pry the rear end of the frame out a little bit. Well this isn’t supposed to happen but every time you make a weld a little bit of material gets displaced and shrinks upon cooling and on motorcycle in general the tendency is for the back end of the frame to get sucked in slightly during the final welding process so it’s a little tighter than the specs call for. To account for this phenomenon I strongly suggest that you fit the wishbone to the backbone in such a manner so that the measurement between the tubes near the axle plate location measures from three-sixteenths to a quarter of an inch more than at the fender mount cross member. If you have a choice here err on the side of too much space rather than to little.

To get this clearance you’ll have to trim just a very little bit more off the fish-mouts at the backbone connection so the wishbones flare out just ever so slightly on the rear end. Do not trim the fender mount cross member down below the 8-3/8" throat to throat dimension under any circumstances.

Man, I love building motorcycles, hand me that hammer and where’s the beer!

Part 4

This new section was prepared after we made our move into the new digs so it may appear more disorganized than our normal state of disorganization so cut us some slack as to presentation quality but we’ve had dozens of folks asking us to get on with this series and to stop making excuses.

At this point we’re ready to start building the down-tubes and bottom rails. Again the material is 1.25”x.120” ERW tubing. We’re going to make these pieces in two stages. Each down-tube/bottom rail piece needs to be 84 inches long. In the first stage we need to make the two bends where the down-tubes make their transition into the bottom rails as shown in Figure 19 below.
I call this area of the frame the front ramps. I’m sure there is a factory-legitimate terminology for this area of the frame but to be honest I have no idea what anybody else calls it. This is the section of the frame that will eventually hold the front motor mount bar. Many frame manufacturers gave up this particular factory configuration years ago in favor of a simple, and cheaper to fabricate, single long radius bend. I personally don’t think the big bends look very good or are as strong as the old factory method so this is why I continue to build them even though it takes a little more work.

Figure 20 provides the dimensions and angles for the bends on the bottom rails. Click on the picture for a large image. Note that the down tubes, when they are rough cut, extend up past the location of the top tube and steering neck and that the rear end of the bottom rails, in their rough cut condition, extend past the area of the axle adjusters. We’ll trim the tubes to their final dimensions later.

These two simple bends between the down-tubes and lower rails are fairly critical and should be made with care to insure that the angles are accurate and that the dimension between the two bends is within an eighth of an inch, preferably better.

What we want to do initially is to create a set of rails that have a 27 inch piece of straight down-tube, a forty degree bend, another section of straight tube four inches long, and another forty degree bend ending up in a long straight section that runs rearwards to the end of the seven foot piece of tubing we started with for each side of the bike as seen in Figure 21.

Both of these bends in each piece of tubing are made in the same plane. They are not compound bends. If you take the pieces of bent tubing and place them sideways on a flat surface, like your driveway, they should lay perfectly flat.

Do not attempt to make the final upward bend in the rear of the bottom rails at this stage of construction. We’ll get to that point later in the construction.

Some builders start at the rear end of the bottom rails and work their way forward and upwards towards the backbone connection but for me at least I think it’s much easier to work from the top down and head towards the rear with the last
bends being made in the lower rails where they sweep up into the axle adjusters. This is especially true if you're not using a welding jig.

Figure Error! Bookmark not defined.

These ramp angles as mentioned earlier are fairly critical and after you've made the bends stand the tubes up on some surface that is absolutely flat and using an angle finder check to make sure that the tube geometry is as it should be.

Figure 22

The slope angle of the down-tube should be ten degrees off vertical.
The slope angle of the 'ramp' should be forty degrees above horizontal (fifty degrees off vertical) and the length of the tangent piece of straight tube should be four inches.

If you're 'off' by thirty minutes, (one half of a degree), or more, put those tubes in the scrap bin and try starting over again. In all seriousness though you can be off by as much as one degree either way but if the bend is too tight you'll need to move the lower rails forward slightly so the downtubes don't hit the motor's front cylinder head.

**Part five**

Once the forward bends are made in the lower rails it's time to fit these into the upper section of the frame we've already made. Specifically at this point we want to cut the tube miters where the uppermost portion of the down tube attaches to the backbone.

The frames I build are based upon the old original Harley-Davidson frame design where the down tubes attach to the frame backbone and not to the steering neck tube as you'll see on a lot of modern choppers. Figure 1 illustrates a stock Harley neck and even though this particular neck is a casting the same design principal applies to a tube type neck.
In Figure 2 we see the more common design where the down tubes are welded onto the lower portion of the steering neck.

People will argue all day about the various pros and cons of either type of design but basically the reasoning goes that the old design puts less bending stress on the neck tube proper. In other words the tube itself is not subjected to a bending load and isn’t really a structural member of the main frame. The more modern design actually makes the neck tube a structural frame member and when loads are applied from the backbone or the down tubes the neck is subjected to a bending load.

When one considers the wall thickness of the typical steering neck I doubt whether either design type has a structural advantage or disadvantage over the other.

I personally think that its easier to fabricate the type of connections shown in Figure 2 but having built frames the old way for so long I'm kind of stuck in my habits. One big advantage of building frames the old way however is that the neck rake angle can be very easily changed without messing with the down tubes. This is a very practical feature as it allows you to re-chop a Chopper if you want to change its appearance or handling characteristics later on. Additionally it is easier to straighten a frame built with the old style of neck connection if it ever gets banged up in an accident.

All of the plans, diagrams and photos of our projects are intended to be fabricated using what we've called the old-style neck connection. If you opt to build it the other way you will have to make changes in the down tube angles and dimensions.

In part four of this series we bent the forward portion of the lower rails that created the down tube section and now we’ve got to create the joint where the two down tubes connect at their uppermost end.
In Figure 3 we can see the two tube sections temporarily held in position with some 2x4 wood spacers, a pipe clamp and some duct tape. The spacers are cut to 8-3/8” which is the inside width of the frame rails and two are used so we know that the rails run absolutely parallel to one another.

Figure 4

Figure 4 shows the same setup from a different perspective.
Figure 5 is a snapshot taken from the front showing how the down tubes slope in towards each other. It is important to remember that the inward slope of the down tubes is not created by bending the tubing but is instead the result of simply 'rotating' the entire assembly about the long axis of the lower rails.

The object will now be to remove material from the inside face of the upper portion of the down tubes so they slope inwards even more and in effect become one piece of material where the notch for the backbone will eventually be cut.

It is now a little easier to understand why we haven't made the bends in the lower rails where they turn up and run out to connect with the axle adjuster plates. If we had made those bends already the tail ends of the tubes would actually be pointing inwards because of the slope angle of the down tubes. As we work the notches where the backbone connects to each down tube this inward slope angle will increase and we can't make the final upward bend in the lower rails until we know exactly what the final slope angle will be.

**Part Six**

In part five we formed the bends in the lower portion of the bottom rails to create the down tubes for the frame and in this section we'll be preparing the tube notches where the backbone intersects the down tubes.

By now we should have tack welded the rear wishbones to the seat post and backbone so we have what I call the upper assembly of the frame, and we should have our two down tube/lower rail assemblies bent. It is also a good time to tack the seat post cross member to the base of the seat post tube.
Figure 1 shows the basic components built so far set up in a rough mockup.

![Figure 1](image)

The wishbones haven't been raised up at the rear into their correct attitude in this snapshot so it looks a little weird. Note that the lower rails at this stage are simply straight with no bends in the rear sections.

What we want to do now is to crib and shim-up the upper frame assembly into its correct attitude and to mark the location in each down tube where the backbone will eventually penetrate each tube near the steering neck location.

Before we do this however I want to digress a bit and talk about the importance of preparing mockups and checking dimensions and clearances at every stage in the fabrication process.

We have developed our frame plans over the course of several decades of working with Harley based choppers and doing custom frame work for over forty years now. We know from experience what works and what doesn't but even today I still check every dimension, angle and component mount point constantly at each and every stage of building a bike. It is essential that you mockup your components with your particular frame project to insure that everything is going to fit before you do any final welding. A miscalculation or erroneous measurement of even an eighth of an inch and make or break any particular fit-up if it occurs at a critical junction.
Figure 2

Figure 2 shows the rough mockup for our particular project frame. In this case we've simply bolted up the motor, tranny and inner primary to check for clearances at the seat post and seat post cross member. Our 'motor' in this case is a plastic 'dummy' Evo made specifically for frame builders by Payr which is listed on our Links page. If you're interested, we're a dealer and can save you a couple of bucks on one of these if you don't already have the real thing.

Figure 3

In this particular situation where we were using a thick cast aluminum inner primary we noticed that the bolt boss on the outside of the cover, opposite the pencil shown in the picture, could potentially rub against the lower rail. After rechecking this area in more detail we found that there would be slightly less than an eighth of an inch of clearance so we just barely ground down the extreme end of the boss by a little over a sixteenth of an inch. Wherever possible we try to maintain at least
an eighth of an inch clearance between components and frame members. An alternative would have been to make the frame a sixteenth of an inch narrower but in this case since there was only one point of potential interference it made more sense to just get out the grinder as the cast bolt boss was very thick.

Before we get back on track and start on the down tube notches it may be important to reemphasize the importance of building a welding jig one piece at a time while we're also building our first frame. A good frame can be built without using a conventional welding jig and all types of temporary jigs and fixtures can be made using wood, clamps, spacers and cribbing but it is far easier to just go ahead and build even a rudimentary jig out of two by fours than it is to rely on stop-gap temporary lash-ups that have to be disassembled and reassembled as you progress through the fabrication process. A jig, even a crude one, is your third hand and believe me there will be times when you wished that you hand four hands when you're trying to hold together three parts at one time and getting some good accurate tack welds into place without everything moving around.

To make the notches where the down tubes intersect the backbone (top tube) it’s best to create some arrangement of temporary fixtures or use a jig to hold the backbone in its correct attitude as it would set on a finished frame. on our particular build the top tube slopes down towards the rear axle adjusters twenty four degrees from true horizontal. The height is determined by the length of the seat post, the slant angle of the seat post and the width of the lower rails. If you've welded up the upper frame section with the seat post and seat post cross member you can simply set this assembly in place and hold it at the proper angle.

Place one of the bent lower rails in its correct position relative to the seat post cross member and let the down tube section lean in towards the top tube as shown in the pretty horrible snapshot of Figure 4.
As you can see we're still moving into the new house so half of the garage is being used for storage. Access to the opposite side of the jig is blocked off by furniture so this frame will have to get by with only half of its lower rails for a few more weeks. No, that little Merry-Go-Round toy in the background isn't mine but it might look good as a gas tank on somebody's 'Theme' bike.

Once the tubes are in position we need to mark a line on the down tube where it touches the backbone. Make the line parallel with the top tube and about one quarter of an inch higher than the actual point where the two pieces of tubing intersect. As we begin cutting the fish-mouth in the down tube it will begin to lean inwards even more and as this angle increases the notch will 'appear' to move downwards relative to the backbone so we need to do the initial notching a little higher up on the tube to begin with. If you make the initial cuts to low you'll end up with a big gap in the down tube notch, under the intersection point with the top tube, and you won't be able to make a nice tight joint for welding.

How you cut these notches in the down tubes is up to you and only limited by the number and types of tools you have at hand. Large shops usually use an end mill. Some places have built a separate fixture that holds a hole saw. You can do the cuts with a regular little disc grinder if you're careful. For custom work or one-offs I usually use a die grinder with a metal cutting bit for the rough cuts and switch to abrasive stones for the cleanup work. Even using the grinder it only takes about thirty minutes to make a very nice cut that's usually a lot more accurate than one cut with a hole saw.

Figure 5 shows the down tube and backbone with the first rough cut to give you an idea of what we're after and how the tube looks after the initial cut is started.

![Figure 5](image)

Note that we haven't cut off the upper end of the down tube where it extends over the backbone. On this particular tube we have very little overhang but on others where we've left more excess material there can be several inches extending over the top tube.

In case you're interested the bungee cord allows me to quickly pull the frame out of the jig yet it keeps it pulled tightly against the stops while I'm trial fitting parts. That wooden object in the picture is part of a piece of furniture behind the jig and doesn't have anything to do with what we're working on.

The goal for making these notches in the down tubes is to fit them into the backbone as tightly as possible so that the two separate down tubes in effect blend into the backbone tangent to its outer surface. To do this we simply keep cutting the notches deeper and deeper until the down tube finally leans in as much as possible yet blends into the side of the backbone at a point that's just about on the longitudinal centerline of the top tube.
In Figure 6 we’ve deepened the initial rough cut and trimmed off some of the excess tube that extended above the backbone. The black marker line indicates about how much more tube needs to be eliminated by deepening the fish-mouth.

Figure 7 shows the completed rough cut notch in the down tube. It is hard to discern in this picture but the upper rim of the down tube notch isn't a sharp knife-like edge but is instead a blunt surface equal in thickness to the tubing wall. This provides plenty of meat for the final weld and the bead will do the work of smoothly blending the two tubes together at this particular junction.

I usually work on both down tubes at the same time, alternating from one to the other as I'm deepening the notches.

Note that there's no notch for the steering neck yet since that'll be one of the last pieces installed in the frame.
Once we have the notches cut and the two down tubes trial fit together nicely at the backbone we can finally measure the inward slope angles of these pieces and figure out how we need to place the lower rails in the bender to make the final bends where the tubing heads up towards the axle adjusters.

**Part 7**

We're getting very close to finishing up the basic frame now but there are a few more important points we need to cover before we can wrap up the lower rails.

In part Six we cut the fish-mouth notches in the down tubes at the backbone intersection and now we're ready to figure out how to make the last bend in the lower rails which isn't as simple as it looks. In fact some of our visitors jumped ahead of me and tried to make those bends only to be surprised that their rails were pigeon-toed at the rear end of the frame as seen in Figure 1 below.

The lighting in this pic is pretty bad but if you look closely you'll notice that the tail end of the lower rail is about two inches inward of lining up with the tail end of the left-hand wishbone. This is what I called pigeon-toed. The reason this happens is because the final upward bend in the lower rail was made in the same plane as the two small bends in the forward portion of the rail where it sweeps up into the down tube. If you sight down the lower rail you can see that all three bends are in the same plane. If you were to rotate the down tube until it was perfectly vertical the back end of the lower rail would match the upper wishbone perfectly.

The final rear bend in the lower rails can't be properly made until we know what the inward slope angle is on the down tube because that slope causes the centerline of the rail, drawn on the uppermost surface of the tube, to shift about one quarter of an inch to the left or right depending on the rail being measured.

Figure 2 illustrates what I'm trying to describe.
if you look closely you can see a felt marker line drawn on the uppermost surface of the tube while the down tube is perfectly vertical.
In Figure 3 however we have tilted the down tube over into its actual position and we'll note that the black marker line is rotated inward towards the right and that the uppermost surface of the lower rail, indicated by the red marker line is about one quarter of an inch away. That red marker line represents the control line we need to use in the bender when we make the last rearward bend in the rail. In other words the last bend will be pointing straight up relative to the lower rail and not in line with, or in the same plane, as the down tube.

This last statement bring us to the subject of learning how to find up, down and sideways on round tubing. This is the question I am asked most often and my standard reply is to buy a good book on pipe-fitting because there you will find literally hundreds of handy methods of dealing with angles on cylindrical structural members and round pipe or tubing. You'll also learn how to use a few special tools designed just for pipe and tubing work but the tool used most often is the little nine inch magnetic torpedo level.

The key to successful tubing work is to be sure that all of your horizontal tube runs and the base plate, jig or frame table, and your bender, are absolutely level in all directions. You cannot work with tubing unless you have total confidence in the levelness of your horizontals. In the same vein all of the vertical members should be plumb. For instance the seat post even though it slants to the rear of the frame should be plumb left to right, at a perfect ninety degree angle to the frame cross members. If everything is level and plumb you can find virtually any angle, distance, offset, or measured point anywhere on the frame just by using a level and a measuring tape.

One of the handiest books to have on hand is the "Pipe Trades Pocket Manual" by Thomas W. Frankland. This little book explains in lay terms how to do anything including how to find angles by using your wrist watch just in case you've lost your
angle finder. It explains is easy to understand terms how to calculate arc lengths, offset bends and how to cut miters just to highlight a few points. It's also loaded with dozens of handy charts, graphs and tables including all of the trig functions.

Even without such reference guides it's pretty easy to navigate around frame tubing.

You can use a simple combination square with a built-in level bubble to find the top center point and side centers ninety degrees opposite top center on a tube. If you locate these points at two different places on a tube run you can scribe control lines between them using a straightedge. It's almost as easy as working with square or rectangular tubing once you get the hang of it.
Welding supply shops also sell a host of measuring devices and tools specifically designed to be used on tubing but in most cases all we really ever need to know is where the surface centerline is on any given piece of tubing.

Before going much further I have to apologize for the poor quality of the pictures and the total mess in the garage which makes it hard to see things but I'm using our second tier camera as we can't find the good one and the garage/shop looks like it's going to be used for storage for at least another month before I can get the tools and benches unpacked. One thing is for certain though and that is if I can work on a frame in this cramped space you probably can as well.

Looking at our lower frame rails again take a gander at Figure 6 below.
In this shot I've propped-up the down tube at pretty close to the actual installed angle and even though the vantage point is off-center you can see how the upward bend in the rear portion of the rail, at the bottom of the image, lays in a true straight up and down plane and not canted to the left or right. It's almost impossible to make this bend correctly unless your bender is level and plumb.

Figure 7 shows this lower rail in position. Note that we haven't trimmed off the excess tubing heading out past the location of the axle plate and we haven't bent another tube to replace the pigeon-toed rail on the opposite of the frame.
Figure 8 shows the frame as it now stands.

We need to finish up with fine fitting on the down tube miters at the backbone, bend another left-hand rail, trim off the end of the right-hand rail and then we'll be ready to do some initial tack welds and start on the axle plates and steering neck.
In case you're interested I messed up the left hand rail by putting it in the bender pointing in the wrong direction and doing the bend at the same time that I was trying to carry on a phone conversation with another frame builder who probably did the very same thing as we were comparing notes on exactly how to best describe this particular bend to others. In the end it all worked out pretty good as I ended up with a sample of tube that shows perfectly how not to do something.

Within seconds of posting this page I was already getting calls about the 'backdrop' for Figure 8 and for those who might be interested the grayish clamshell looking thing is an old Edison Mutoscope that shows dirty pictures if you crank the handle and peek through the viewer. It's in the shop for welding on the case which is busted at the base. The orange thing is a 1937 Rockola jukebox that we haven't had time to move into the house yet. The big white slabs are the doors from inside the house that were supposed to be re-hung three weeks ago. The other pieces of bent tubing laying around are parts of a Sportster chopper frame for Tom Toby that were supposed to shipped out in January.

Part 8

In part 7 we bent the lower rails to form the upsweep to the area of the axle plates and now we're ready to cut and install these plates but before we do it's a good idea to understand exactly how the axle adjusters came into being and what it is exactly that they do for us.

On modern bikes the axle plates house the axle adjusters and in almost 99% of all cases bike owners and professional bike mechanics believe that the axle adjusters are used primarily to tension the final drive chain (or belt) and secondarily to align the rear wheel in the chassis.

Well this is true up to a point but if we align the rear wheel in the chassis with the axle adjusters we have also in all likelihood misaligned the rear drive sprocket with the transmission sprocket unless we also realign the motor and transmission in the frame.

In reality nobody does this so as a result we have constant premature wear on all of the drive components even though the bike goes straight down the road. Ironically the bike goes straight even thought the tire is wobbling about the hub axis because the adjusters only work in a horizontal direction and vertical alignment is totally ignored in almost all designs.

At one time chain tensioning was taken care of by frame mounted 'chain tensioners' which do a superb job and do it correctly without changing the alignment of the wheel and transmission sprockets. Of course these devices were used when frames were built straight to begin with and the rear axles holes were properly aligned from the factory and there was no need to 'adjust' the axle to achieve proper alignment.

As mass production processes demanded cheaper manufacturing methods the so-called axle adjusters in the axle plates came into being. With the slotted axle holes you could build a little less than perfect frame and then monkey around with the wheel's axle to make the frame roll straight and halleluiah, you could also tension the chain at the same time saving about twenty bucks on every frame you built.

So there we have it. Axle adjusters are used to 'adjust' an axle that isn't square with the frame or the transmission sprocket to begin with. The fact that you can also tension the final drive chain is just a freebie.

In the real world 'axle adjusters' are totally unnecessary if you're using a frame mounted chain tensioner to keep the chain 'slack' properly adjusted as it stretches.

Our original frame designs all used a simple piece of 1.25" DOM tube with a 3/4" I.D. as the axle 'plate' but we found that even the large shops which spent thousands of dollars on their jigs could not produce frames that were straight enough to use this particular configuration. Small independent builders however, who can spend the time, have successfully adopted this style of axle collar and in fact I think that a few 'notable' builders have built some production frames on a limited basis using the 'old' style non-adjustable axle collars but that's another story.

To get back on track we're going to make and install axle plates for the Old School frame in this article that incorporate conventional axle adjuster slots only because this type of plate is widely known and understood. These plates are made from 3/8" thick cold rolled steel plate but there are literally hundreds of more inventive and creative ways to fabricate adjusters.

Several builders and manufacturers have made their axle plates/adjusters a trademark or hallmark for their shops and it's pretty easy to spot a frames origins by looking at the adjuster design. Paughco for instance uses an old-school type plate on...
most of they're frames where the plate actually extends completely through the rear tubes by about three eights of an inch on the top and the bottom. Santee uses a distinctive 'boxed' adjuster housing with cover plates.

Figure 1

Figure 1 illustrates a stock WL axle plate casting and you'll notice that it's designed like a bicycle axle adjuster where the tire could be removed from the rear without pulling the axle.

Figure 2

Figure 2 shows an oval tubing type of adjuster housing.
Figure 3

Figure 3 depicts a plate type adjuster and note that the frame rails have been bent parallel with the top and bottom of this simple rectangular design.

Figure 4

Figure 4 illustrates what is becoming a very popular style of adjuster. This particular example is a 'boxed' design but the way the tube rails are extended to the rear until they join in an apex is easy to build and adds a custom touch to the frame.
Figure 5

Figure 5 is another simple plate design but uses two plates between the top and bottom rails.

Figure 6

Figure 6 is a very fancy 'boxed' design with a little 'decorative web reinforcement added.
Figure 7

Figure 7 is another 'boxed' style adjuster providing a better shot of the adjuster bolt.

Figure 8

Figure 8 is something different and original on an old-school custom chopper. Note the mechanical brake linkage.
Figure 9

Figure 9 is a non-adjustable axle housing which is the style I personally prefer. It's clean and simple, lightweight, trouble free and very easy to build. This particular one is on a Sporty if you haven't noticed.

These snapshots only show a very few of the design possibilities for adjusters, plates and housings and are included here only to give you some food for thought.

Figure 10 shows a drawing for a 'round' three dimensional type of adjuster housing that we've used on several bikes. It gives a 'fixed' axle look but still provides adjustment. The axle nuts can be hidden with a cover if so desired. This particular piece is to be machined from solid stock but it can just as easily be made from tubing with a 3/8" plate welded into the inner side. The overall diameter and length of the slot is up to the builder.
Regardless of the style or type of adjusters, plates or housings you finally decide to build it is imperative that they be installed in near perfect alignment with the motor, transmission and front wheel axle axis. You'll no doubt realize that I deliberately didn't say that they need to be installed in alignment with the frame itself because they don't, and in some cases shouldn't.

It is almost impossible to build a 'perfectly' aligned frame with zero tolerances even if you're using a fairly accurate welding jig. Accumulated errors and welding distortion will inevitably creep in to the design. Consider yourself either very good or very lucky if your frame is within one-eighth of an inch square and plumb measured in every conceivable direction when its finally welded up prior to installation of the steering neck and axle plates which brings us to a problem of sequencing the fabrication.

There are two schools of thought about necks and axle adjusters. One school holds that it's better to weld in the axle plates before you weld on the steering neck and the other holds that it's better to weld in the neck and fit the adjusters secondarily.

I've done it both ways and haven't personally found one method superior to the other so I'll leave it up to you to decide which method produces better results on your own projects.

For the purposes of this article we'll be installing the axle plates first.

The axle plates, or adjuster boxes, if that's what you're building, have to be installed so that the rear axle holes or slots are situated in such a manner so that the axle itself, when it is 'adjusted' stays in the same plane and remains 'square' and 'plumb' with the front axle axis and the transmission output shaft sprocket.

![AXLE PLATE MISALIGNMENT](image)

**Figure 11**

Figure 11 illustrates a typical 'alignment' problem where one plate, shown by the light gray line in the picture above, has the adjuster slot 'canted' in relation to the opposite adjuster plate. If the axle is centered in this particular example everything is great but as the axle is adjusted to the rear or to the front it will become 'canted' relative to the tranny drive sprocket and the front wheel axle.
In Figure 12 we see another common alignment problem where one of the adjuster plates has been welded into the frame without being perfectly square and plumb with its opposite counterpart. In this case the rear axle will always be crooked no matter how it's 'adjusted'.

Ninety percent of all mass produced frames we've worked on over the past couple of years have had the plates installed with a combination of these two common adjuster alignment problems which is why we want to point this problem out at the onset of this article. It also is the reason that we don't provide 'standard' templates for axle plates.

If you're having a problem on a stock or aftermarket bike with the chain or belt not tracking properly the first place to look is at the alignment of the adjuster plates relative to the transmission sprocket or pulley and the location of the adjuster slots relative to one another.

I strongly suggest that you not cut your plates or adjuster boxes until your frame is almost completely tacked together and you can use your tubes, as they are, to make a template from. You will do doubt find that one side of the frame tubing is ever so slightly different than the opposite side and for this reason you'll probably have to make two different templates (or one oversized) to make your plates exactly match the angles that your rear tubes ended up being bent. The objective of course is to keep the axle hole or slot exactly the same even if the two plates themselves are slightly different in dimensions and angles.

In addition to aligning the adjuster slots as seen in a 'profile' view its also vitally important that the plates be perfectly parallel when viewed form the top or bottom or from the front or rear and not only should they be parallel to one another but also aligned in the same plane as the chain or belt as it leaves the transmission drive sprocket or pulley and it goes without saying that the rear and front axles should be aligned as well.

How accurately these components are aligned is subject to debate but in general most builders agree that if the front and rear wheel are within an eighth to a quarter of an inch the bike will track properly. The drive sprockets or pulley's however require much more precision and if you're off by more than a twentieth of an inch (0.05") you'll probably have some long-term problems.

To make the template for the axle plate I'll usually just use a piece of cardboard and 'scribe' around the frame tubes freehand as shown in figure 13 below.
At this point all you need is a very rough idea of the shape and general dimensions so that the plate matches the physical dimensions and angles at the rear of the frame tubes. Once you have this rough template you can keep refining it down until you get something elegant. Quite often I'll go from the cardboard template to a wooden mockup from cheap 3/4" pine and I'll refine this pattern until I'm satisfied with the shape and proportions and then I'll use that as a template for cutting the 3/8" steel stock for the real axle plate.

The frame tubes in the picture above have not been trimmed to their final lengths which we'll get to later.

In figure 14 below we've made a nice clean illustration board pattern for the final plate design we're going to use on this particular frame.
Once the pattern is cut it can be used as a template to scribe around on the 3/8" cold-rolled stock used to fabricate the adjuster plates or it can be used to make a wooden 'follow' block if you're going to plasma or flame cut the material. We prefer doing this type of work on a Band saw so we simply transferred the pattern directly to the steel.

![Figure 15](image)  
**Figure 15**

The rough cut plates are shown in Figure 15. The slots for the axle tube were cut on a milling machine but they could have been done with a drill press using multiple passes cleaned up with a little grinding. As you can see we deviated from the patterns inside cut on the final product and made a nice large radius that matched one of the ideas we sketched out on the original cardboard pattern shown in Figure 14 only because it ended up being easier to make on the band saw.

For this project we're using a 3/4" axle and the slot is configured for a 2" range of total adjustment.

The plates ideally should be installed in such a manner so that the axle is positioned closer to the front of the slot when the chain or belt is initially installed so you have plenty of room for rearward adjustment as time goes by. I try to mount then so that there is about 3/4" of forward adjustment and 1.25" of rearward adjustment. This gives you enough room to bring the axle all the way to the front to install a chain. Of course if you're installing a belt you have to pull the axle anyway but once it's on the pulley you'll still need some wiggle room on the front side which brings us to another matter.

As we've mentioned before there is no 'standard' measurement between the tranny and wheel sprocket or pulley on a chopper so this dimension is usually set during the frame mockup stage to match the chain link or belt nib count you're planning on using. For those interested we've measured several types of frames and this dimension ranges from as short as 19 inches to as long as 23 inches. On our rigid frames this distance is usually 21.625 inches. For those of you wanting to run belts I strongly suggest that you use a 136 nib belt as they're now the defacto standard on most factory bikes. The original 4-speed drive belts used 125 nibs, being about 1.375" shorter (installed) than the newer five speed setups. For those of you wanting to do this without the benefit of a real mockup you can figure that one link or nib equals roughly .2" of horizontal axle movement using average sized sprockets.

Here are the axle plates finally cut from the template we made in Part 8. I've slid them on the dummy axle shaft just to check that they line up with the angles of the tubes.
You'll no doubt realize that we haven't installed the rear transmission mount cross member yet and we need to do so just before we do the actual installation of the axle plates but we've left this pretty critical part of the frame fabrication until this late point in the build-up so we have a final chance to do some frame straightening before we button it up at the rear.

Chances are that unless you have a pretty good tubing bender and an accurate jig that the ends of the lower rails and the ends of the upper wishbones don't exactly line up vertically if you're looking at the frame from the rear as seen in figure 2.

Actually this photo was taken after we straightened the lower right tube that was about 1/8" off center and had already tacked the transmission cross member in place. The short focal length camera lens and our poor setup for a vantage point in this shot makes the frame look pretty out of whack but it isn't.
The easiest way to straighten or align long sections of tubing is to insert a piece of 1” thick-wall tube or solid bar as an extension handle deep inside the rail and apply a little manual pressure in short ‘bursts’ using the leverage of the ‘extension’ handle. Hopefully you won’t have to do this but if you do be very careful as it’s easy to over bend tubing using this rather primitive technique.

Once you're satisfied that everything lines up install the cross member and I suggest that you complete any welds that remain to be fully finished at every point on the frame except for the axle plates and steering neck. Do a final check for alignment afterwards and then we're ready to install the plates.

The back half of the frame should now resemble what is shown in figure 3 below.

![Figure 3](image)

We're now ready to trim the rear tube ends to their final length so that the axle plates will mate up properly. If I'm using a jig, the plates are just slid onto the dummy axle and a mark is made on the tube ends that will give us about 2” of the axle plate 'leg' embedded into the tubing.
Actually the plate will be embedded into a 2” deep slot we’ll cut in the tube ends once they're trimmed to length. If you're not using a jig the plates can be held tightly against the tubing by running some all-thread rod completely through both halves to hold them in place as you're measuring and marking.

I usually trim off the excess tubing with either a sawsall or one of the small mini-grinders fitted with a very narrow abrasive blade.

I prefer to have the plates centered along the longitudinal axis of the upper and lower tubes but some builders prefer to have the face of the plates flush with the inside edge of the tube rails. Again, the matter of personal preferences dictates many facets of custom chopper construction.

**Part 10**

In part 9 we finished up the fabrication of the axle plates and cut the ends of the wishbone and lower rail tubes to their final length and now we're ready to install the plates and button up the major portion of the work on the rear end of the frame.

Since we're going to install the plates on the centerline of the tubes for this project start by marking out the location of the 'slots' that the 'legs' of the plates will slip into as shown in Figure 1 below.
You can cut these slots with a reciprocal saw, a saber saw, a hack saw or with a small grinder fitted with a very narrow abrasive disc but the objective is to make the cuts very straight and just ever so slightly to narrow for the plates to slip into without doing some fine-tuning and touchup grinding or filing. To start with deliberately cut the slots a little to short and as you're fitting the plates into their final position deepen the cuts as necessary to insure a good tight fit while keeping the plates plumb and square to the frame and the axle axis.

Figure 2

Figure 2 is a snapshot of a plate slot in progress that was cut with a abrasive disc on a small grinder. It's pretty rough at this stage but we'll dress it up as it's deepened to fit the axle plate. The only really critical thing at this point is to keep the centerline of the notch parallel to the frame rails in the longitudinal direction and square and plumb with the frame centerline in the transverse or horizontal direction.

Fitting the axle plates is one of the most laborious steps you'll probably ever undertake when building a cycle frame and I cannot over emphasize how important it is to take great care in setting up the alignment of the plates since in effect they determine to a great extent the overall handling characteristics that your frame will inherit. Axle plate alignment is so important in fact that many shops build their entire jig around the plates and work forward with the rest of the frame work.
If you're building a frame without the benefit of a jig I strongly suggest that you at least build some kind of fixture that insures both plates are installed in exactly the same manner with the axle slots perfectly parallel and square to one another even if they are not perfectly in alignment with the main frame rails.

If the slots (or holes) in the plates are not identical from side to side your bike will experience rear wheel wobble which not only causes premature drive train wear but gives the cycle pretty horrible handling characteristics.

Like everything else in life there are certain acceptable 'tolerances' as to how far you can be off and still be within reason so it might be of interest to learn that on about fifty or so factory frames we've measured over the years the plates were 'misaligned' on average by just under a tenth of an inch from front to back at the plate slots and about a sixteenth of an inch top to bottom of the plates themselves.

When you're lucky enough to have accidentally bought one of the few bikes where everything is spot-on you'll have a ride that you can steer just by sneezing in one direction or the other.

To get off track for a moment I'd just like to say that most of us have probably never ridden a perfectly aligned bike so we have nothing to compare our riding experience against. The very first motorcycle I ever owned vibrated and wobbled so badly that I thought all bikes behaved the same way so I was utterly amazed when I had an opportunity to ride a properly built bike years later and discovered that the ride I owned at that time was a piece of crap and should have been in the junk yard. When you buy a frame via mail-order and sometimes even if you go to the shop in person you won't be able to put the frame up against a 'square' and do a rudimentary check on alignment so you have to take the builders 'word' for the quality you're going to be getting and unfortunately this 'quality' is sometimes pretty awful.

Figure 3

Figure 3 is a snapshot of a 'name brand' swing arm cage made for a very popular wide tire conversion kit provided by a so-called 'top quality' manufacturer that sells thousands of these units every year. A very quick rudimentary check on alignment shows that the axle plates are almost .25 inch out of whack relative to the vertical plane and even though we couldn't get a picture since we didn't have the entire frame we found later that the longitudinal alignment was even worse once we started to put this assembly together. Unfortunately there are hundreds of riders out there running this piece of shit and not knowing how horrible their bikes are handling due to rear wheel misalignment problems.
Getting back on track again and working on a frame you have complete control over, once you've cut in the notches in the rear tube ends you'll have to fit and fine-tune the axle plate fit until they're as perfect as you can possibly get them.

![Figure 4](image)

In Figure 4 we've tacked the plates into position and we'll show how to make some nice 'end-pieces' that dress-up the transition from the tubes to the plates themselves in another article.

Once you're satisfied with the fit of the plates it's time to mount a 'dummy' wheel on an axle and check for final alignment before doing the final plate welding. If you want perfection you can mount a dial-indicator on the frame rail and measure the run-out on the wheel.

The easiest way of visually checking to see that everything is properly installed is to mount the wheel and pick the frame up by the front end and 'drive' it down the driveway like you were pushing a wheelbarrow. If you can see any wheel wobble whatsoever you have to break the tacks and try to re-align the plates.

When you've done everything that you can possibly do to get the rear end aligned you should have a frame that resembles that shown in Figure 5 below.
Now that the plates are installed we can do the first 75% mockup of the frame and see for the first time the real shape of what we've spent all this time creating which is shown in Figure 6 below.

In this picture we've mounted a 150 rear tire and blocked the frame up to ride height. As you can see even with the radical chopper profile of the stretched straight backbone line this is very low frame. The steering neck will be just slightly higher than our work bench when it's finished.

So far we've only spent $490.00 on this project which includes the wheels and tires so we're well under budget.

The next step is to install the steering neck itself.

Part 11
In Part 10 we mounted the rear axle plates and now we're ready to install the steering neck which is actually quite easy but requires a great amount of care to insure that the neck is straight relative to the centerline of the frame. In addition this step of the buildup also requires some very good welding since we'll be joining a very thick piece of tube stock to the relatively thin material of the backbone. It is essential to get deep penetration into the neck without burning away the edges of the top tube.

There are several different methods of cutting the notch in the backbone that will accept the steering neck. In the production shop environment this notch would have been cut very early on in the fabrication process but for the garage-based builder or those doing one-offs it's better to cut the notch last as we'll be doing here.

To start with, mark a centerline running down the top of the backbone and then using the neck-piece as a guide, mark out the location of the upper portion of the miter cut. If possible leave this initial cut-mark a little on the long side so you'll have some 'fudge' room for fine tuning and fitting as we progress.

To actually make the notch you can do one of several things.

First of all you can have a friend help you hold the whole frame up on a tilting drill press table and use a mounted hole saw to make the cut at the desired rake angle. I usually work alone so for me I've found that it's easier to just use a hole saw mounted with a long pilot drill. I'll center-punch the top tube where I want to center the pilot drill and then standing over the frame I'll drill down at an angle I think is close to the neck rake angle I want. I usually make this initial cut about one quarter of an inch further forward on the top tube than I really want to install the neck so I'm sure I've got room to do some fine tuning later. If possible try to use a hole saw that's just a little smaller in diameter than the outside diameter of the neck-piece you're planning on using. Someday I'll get around to making some kind of fixture to make this all a little easier.

Remember that if the frame's sitting in the jig or on the ground that the top tube is already sloped at a 24 degree angle so for a 40 degree neck angle for instance the drill only has to be sloped rearward sixteen degrees from perpendicular with the tube. If the angle of your initial notch is little off it can be corrected very easily with a grinder when you dress up the cut.
Clean the notch up slightly and make a trial fit of the neck piece and check the rake with an angle finder. To decrease the rake grind away on the lower edge of the notch and to increase the rake grind away on the upper portion of the notch.

If you're installing one of the so-called 'hourglass' shaped necks you'll usually have to do some fine grinding on the shape of the upper notch to get it to perfectly match the tapered segment of the neck piece. The lower portion of the notch will almost always be a perfect semicircle. We use several different styles of necks as seen in Figure 3 but for this low-cost bike we're just going to use a piece of .156 wall DOM tubing. If you're interested in looking at other possibilities check out the section on steering necks.

Once you get the rake angle roughly set it's time to check that the neck notch is properly aligned with the centerline of the frame and not twisted to one side or the other. This is very easy to do if you're using a jig with a neck fixture but for this segment we'll work without the benefit of the welding jig.

First of all we need to find someplace in our shop or garage that is absolutely flat both longitudinally and transversely where we can set the frame. If this is a problem you can set the frame on cribbing and shim it level with some wedges but it's fairly important that the frame be stable enough to work on without moving it around.
Using a very long straightedge (or piece of steel or a chalk line) scribe a perfectly straight line on the floor that will extend well past the limits of the frame and the 'projected' intersection of the steering neck angle and the ground as shown in Figure 4 below.

![Figure 4](image_url)

This is the only spot in my garage where the floor is level and it's a tight fit to get the frame in here and be able to work around it but we make do with what we have just like everybody else out there.

Once you get the control line scribed out it's time to sit the frame on top of it. The objective is to get the frame perfectly centered along this line. Using a plumb-bob front and rear keep shifting the frame until it is perfectly centered.
The frame in Figure 5 is on the line but I took the shot from a slight angle so it only appears skewed from this vantage point.

At this point in time I take measurements from the extreme ends of the long dummy rear axle bar to an imaginary point way out in front of the bike on the control line as a quick double-check that the axle plates are indeed square to the frame centerline.

There are countless ways of temporarily holding and aligning the neck-piece with the frame. If you have the benefit of working with a jig it is simply a matter of just setting the neck into your steering head fixture. If you don't have a jig however you'll have to improvise some way of attaching the neck-piece onto some type of long rod that you can use for alignment.

You can develop some pretty sophisticated fixtures for doing this but I've found that a true Old-School method from the sixties works pretty good.

It just so happens that 1.25" ERW frame tubing has almost the same O.D. as the raw steering neck I.D. and to top it off ERW tubing has a nice straight seam running down the inside that we can use as a reference for aligning the neck.
If you've done a good job of fitting the neck to begin with it will stay in place on the frame just from the weight provided by a long piece of tubing slipped down through middle as seen in Figure 6 above.

The objective is to use the inside weld seam as a straightedge and to move the long piece of tubing until that seam aligns perfectly with our control line we scribed on the floor. To double-check just drop a plumb-bob down from the top of the 'alignment' tube and see if it hits the centerline of the backbone tube. For best results you have to 'sight' down the inside of the tube.
The tube in Figure 7 above is used for a variety of purposes in our garage so I painted the ends metallic green so I could find it mixed in with all other other tubes laying around and to make sure one of the occasional 'helpers' didn't chop it up.

Before you tack anything together take a gander at the neck and frame from every conceivable angle. It is amazing how perceptive and accurate the human eye is. This is your last chance to change the rake and the long alignment tube will give you some idea about the final proportions of the finished bike.

On this particular project I took a 'two-beer' break to conjugate and contemplate the shape of the frame and at the last minute decided to rake the neck out another three degrees to a thirty eight degree angle even though we had already bought the front forks to fit a 35 degree frame.

This is just part of building choppers. Nothing should be chiseled in concrete and you should look upon the entire process of putting a bike together as a creative expression and not get stuck into the technicalities.

I have spent almost my entire life dealing with precision drawings, machining, and fabrication but there comes a time when you have to leave the math behind and follow your instincts and this is that indefinable 'something' that separates humans from computers and provides the distinction between mass-produced bikes and custom built choppers.

Once you're completely satisfied that the neck-piece is perfectly aligned go ahead and tack it up using a bunch of very small tacks around the perimeter of the connection alternating from one side to the other to minimize distortion. When you're done you should have a frame that's almost ready to be detailed.
What we've done so far is the easy stuff. It's the final detail work that really takes the time but at least we're at a point where we can say that we've got a frame and we can do some more mock-ups to decide on how we want the finished bike to look.

We still have to add the neck gussets and a bunch of mounts but we're getting there slowly but surely.

So far we've put together the basic frame and scrounged up enough parts to begin assembling what most people call a 'roller'. To date we're still below our original $1500.00 budget and the bike is looking pretty wicked if I do say so myself.
We'll now begin doing the detail work and deciding on what type of tank, fender and handlebars we'll want to use.

In Part 11 we more or less finished up the major portions of putting a frame together but there is still a lot of work to do and in many ways the last 10% of frame construction will take up 90% of the time involved in finalizing a typical cycle chassis.

Once I can put wheels on a frame, even if the forks have to be a set of wooden dummies, I like to take a few days and even weeks to consider what I've built and to decide on how I want the bike to look when it's finished. I'll leave the bike in pretty much the same stage as you saw in Part 11 and if possible, weather permitting, I'll park it outside where I can see it from a distance and from a variety of angles over the course of several days and even weeks if need be.

I'm not ashamed to admit that I sit on the frame and 'imagine' how she'll be to ride. I sometimes make mockups of the handlebars, foot pegs, shifter position and other 'control' types of features until I'm satisfied that I have a chassis that 'fits' not only my body but my riding 'style'. In other words I try to fit the 'control' parts of the bike to fit my stature and posture.

On the other hand I want the bike to have a certain 'look' but I won't sacrifice riding comfort for appearance so I make compromises back and forth for several days until I'm satisfied with both 'look' and 'feel' before I start to do any more welding.
The mistake most first-time builders make is to simply bolt on a bunch of ready-made parts in a rush to finish the project and bikes built this way will show it. In photos they appear awkward, out of proportion and unbalanced with respect to the size and placement of the ancillary components.

The human body comes in all types of sizes and shapes but regardless of the differences they are are proportioned in ratios that architects long ago recognized so when you're building a bike the shape of the human rider has to be a major consideration in the design and fabrication process and the best 'formula' to use in this endeavor is the real body of the rider that the bike is intended for. This is what real choppers are all about. They are created for an individual and this very fact is what makes them so distinct from mass produced cycles.

No matter how hard I try I can never give you any ‘magic’ dimensions for building frames or any ‘secret’ measurements for choppers that create the ‘perfect’ bike as each one will be unique. In fact if they weren't unique they wouldn't really be a chopper regardless of how they looked outwardly.

Building a ‘real’ chopper is a lot like building a Rolex watch. You assemble a bunch of bits and pieces that you’ve pretty much ‘standardized’ on but as you put them together you deviate from the ‘standard’ and fine tune and fine-fit the various individual pieces until you have a unique creation that functions both mechanically, ergonomically and aesthetically.

When you get aboard a truly custom built chopper you’re not just a rider, you become a part of the machine and function as a single unit, which if you ever experience it will come to understand, but very few people ever have this chance because they rush through the project believing mistakenly that the end result comes from just bolting on parts and components.

Figure 1 below shows the Old School Chopper as it now stands in the shop during the ‘think about it’ phase of the project.

![Figure 1](image)

We're thinking about a Sportster tank at this stage but we haven't decide whether to mount it low, high or in-between.

We have however decided to use a certain part that we've had bouncing around in the shop for the past 34 years but I bet you can't figure out what we're going to use it for.
The charge has been removed from this little beauty so we're pretty safe in using it any way we see fit and to my knowledge even the hardcore builders out there will have a hard time topping this one compared to a knife handle, a Maltese cross or a pair of brass knuckles. To my way of thinking if you're going to build a chopper it had better be original and if anybody else has already done this let me know so I don't make a fool of myself.
Frame Building Troubleshooting

We've had a few feedback letters, emails and phone calls from builders who for one reason or another had some problems in laying out their frames and/or building their jigs, which can cause some clearance problems.

Fortunately however if your frame was built to within a quarter of an inch or so of our drawings and the geometry is within one degree of specs almost all of these problems with fit-up can be corrected.

It’s very easy to blow one or two measurements or to deviate a half-degree or so when putting together a frame. Welding distortion alone can easily cause an eighth of inch shrinkage between two connections. It’s also very easy to make some modifications in the design before you’ve had a chance to do mockups and occasionally these modifications and/or alterations should have been planned out a little better. That’s life and stuff happens and nobody should be blamed.

Problems, when and if they do occur, usually happen during the construction of a builders first frame project or during construction of the welding jig itself. We all learn from our mistakes pretty fast and I don’t know of anybody who has had problems with their second or subsequent frame projects.

In order of occurrence the most common problems reported back to us are:

1. Seat-post welded at an incorrect angle, which creates interference with either the top-front of the transmission or the upper rear portion of the rear cylinder head. If the seat-post is just one half of a degree away from specs it will move the top connection point three sixteenths of an inch either way, which can definitely cause some interference problems.

2. Seat-post cross member located to far forward or two far aft, which can create the same problems as number one above. A combination of number 1 and number 2 will create significant problems.

3. Forward down-tubes bent at too much of an angle, which creates interference with the forward portion of the front cylinder head.

4. Seat-post cut to short which prevents removal of the rocker cover without having to pull the whole motor.

5. Bending tubing with dies that don’t have a 4.5” centerline radius or using ‘pipe benders’ to fabricate the frame pieces.

6. Substituting tubing sizes with other than 1.25” outside diameter tubing.

7. Not being able to work back and forth between ‘design’ dimensions as shown on plans and converting to dimensions needed for any particular bender.

8. It should go without saying that if you offset the motor for a wide tire, even as little as 1/4”, the rear exhaust header will hit the seat post unless you but a slight bend in it.

Most of these problems could have been prevented by remembering to allow a little extra material in the length of tubes being welded since welding causes slight shrinkage in tube length. Measuring twice before cutting or welding is also a good habit to develop. You cannot rely totally on ‘angles’ derived from any of the various ‘angle finders’ on the market today and this is why it is imperative to do detailed mockups of the frame and components at several points during construction. As the builder gains in skill and refines his or her layout techniques the use of mockups will become less important but for the first time builder this is a critical aspect of construction.

Several folks have reported problems when they are fitting short tubes like cross members as they grind them down for a nice tight final fit and then when they're ready to weld the joints are 'sloppy'. Do not ever do any 'fitting' while the materials are in the least bit hot after grinding as it doesn't take much heat to expand steel a significant amount. Let the material cool between the fine-tuning grinding and fitting and only take off a very little material at any one time. The goal is to get a good fit on cool materials.
Some people have reported problems with getting identical bends coming out of the bender or have noticed that bent tubes sitting around the shop seem to ‘magically’ un-bend slightly. Steel tubing has a ‘memory’ and tends to want to straighten itself slightly after it comes out of the bender and depending upon the composition of the steel this can happen quickly or slowly. All fabricators have to ‘tweak’ tubes back into submission and some shops actually have homemade ‘bender’ or ‘un-bender’ jigs specifically made to do the final tweaking on tubes that come out of the bender just prior to being set in the jig. The bender itself will get you 99% accuracy but the final 1% of fine tuning a bend or an angle will have to be done by the builder when the tubes are placed. This is just part of normal fabrication procedures and can only be learned through experience. Fabricating steel is a creative process and you have to use whatever means are at your disposal to get pieces properly and accurately shaped because all but the most expensive benders will only produce a very close approximation of the exact curve you want and the accuracy of any particular machine bend changes with very subtle differences in material alloy, wall thickness, temperature, die pressure and dozens of other variables.

If you have welded the frame up and find that there are some interference problems with fitting the motor and transmission remember that there is no ‘rule’ that really determines where the motor needs to be placed in the frame and likewise the motor and transmission mounts can be ‘canted’ up to two degrees from horizontal from the stock attitude.

In worse case’ scenarios you make have to slightly tilt the motor and transmission mounts and shift the mount points fore or aft by an eighth of an inch to get the assembly to fit without touching the frame. Alternatively you can heat and dimple a frame rail slightly at a point of interference and if you’ve really got a problem you can actually cut a section of the offending tube out and box it back in to create a recess or notch. Of course it’s better to avoid these problems in the first place.

Our frame designs, unlike most aftermarket frames, are designed to be very ‘tight’ with little ‘open space’ around the components and the plans we provide should be adhered to with respect to critical areas, dimensions and angular relationships of the various parts. If everything is put together properly you should have three quarters of an inch clearance between the backbone and the top of the rear rocker cover; one quarter of an inch clearance between the top of the seat-post and the rear of the rear rocker cover; one half inch clearance between the down-tubes and the front of the forward rocker cover. Deviations of one eighth of an inch at any point are acceptable and everything will still fit.

As we’ve mentioned elsewhere each particular type of bender has a certain amount of ‘slip’ before the mandrels grip the tubing enough to actually begin bending the tube. The amount of ‘slip’ can also vary by tube diameter and how acute the bend is. Lubrication or a lack thereof on the mandrels will also affect the bender behavior. In general you have to subtract anywhere from one eighth to as much as one half of an inch from the ‘plan’ dimension to arrive at the length to put in the bender so that the final result of the bent tube matches the ‘plan’ measurement in any particular run. Each bender is different and you will have to calibrate your particular setup to arrive at the proper conversion factors to use for various angles. The only way to become familiar with tube bending is to bend a lot of tubing and since every machine is a little different there is not a whole lot we can do on this end to help folks out with respect to this facet of fabrication.

Our plans work and if the prospective builder goes slowly and thinks through the various processes of building a frame and prepares mockups of the components they will be successful. Long before we began selling plans to individuals literally thousands of bikes were built from our designs so we know from experience that what we’ve provided to the public are high quality, accurate, stable and well handling Chopper designs that can be built by almost anybody with average fabrication tools and skills.
Materials and Preparation

Besides a variety of flat steel strap, angles, bars and plate the most important material for frame construction is tubing. When we say tubing we mean exactly that and not pipe. Tubing is sized by it’s outside diameter, pipe is sized by it’s inside diameter. For example 1 inch tubing is 1 inch in outside diameter while 1-inch pipe has an outside diameter of 1.315 inches.

Unless you are building cutting-edge world-class road racers Chrom Moly tubing is totally unnecessary for frame construction. The best material of choice is called cold rolled electric resistance welded tubing commonly referred to as CREW or simply ERW that can be purchased at almost any steel supply or fabrication shop. While cold rolled tubing has less ultimate tensile strength than chrom moly it is far more forgiving and will bend and deform under extreme loads instead of breaking between the welds.

For special components such a bungs, lugs or shaft sleeves we may also need what is called DOM (or seamless) tubing. DOM stands for drawn-over-mandrel, a technique that builds tubing having extremely accurate inside and outside dimensions free from an internal weld seam.

Ninety percent of all motorcycle frame tube assemblies and braces can be built with tubing having diameters of 7/8", 1", 1-1/8", 1-1/4" and 1-1/2" with a wall thickness of .095 to .120 inch. In the larger diameter tubes you could go as thin as .083-inch wall but your frame had better be well triangulated. The average road bike, one intended for some hard riding built from .120 wall tube would weigh about 40 pounds. The same frame built with .083-inch wall material will weigh in at 34 pounds. The six extra pounds in a 600 pound bike seems like a small compromise when you consider how much stronger the thicker wall tubing is. In fact the trend today is to use very large tubes, up to 1.5 inches in diameter with a .120-inch wall, which creates an incredibly strong frame, but one that is way to heavy in my personal opinion.

It has been our experience that most big V-twins are well suited to use 1.25x.095 inch tubes but we opt for .120-inch wall in the backbone and seat post if we want good long-term durability in the chassis.

If you are planning to build a bike from a bare pre-manufactured frame or kit please shop around for the highest quality components you can afford. Unfortunately today there are dozens of fairly poor frame lines on the market. We suspect that many are made overseas.

One of our customers brought us a custom frame he purchased on ebay to have the neck raked. That frame weighed ninety pounds and the tubes measured 1.3 inches in diameter, which told me that the tubing was in fact one-inch schedule 40 plumbing pipe. A good frame should weight somewhere between thirty and forty-five pounds depending on the tubing size. If you can’t easily pick the frame up and carry it by yourself it weighs too much.

The reader should understand that there are thousands of old but very hot modified bikes out there pounding the pavement everyday with 1-inch tube frames. In reality the trend to larger tubes is not because builders are trying to combat frame failures but rather instead that larger tubes are easier for inexperienced fabricators to cut, miter, fit and weld than smaller members. If you want to sell a lot of frames for a reasonable price you have to be able to build them quickly with relatively inexperienced assemblers and welders.

To start out then one needs to keep a couple of sticks (20 foot lengths) of the popular tubing sizes on hand. At the present time the average cost of ERW (at the supply house dock) is about $3.50 per foot, cheaper for small stock, slightly more expensive for the larger diameters. DOM and chrom moly is about twice as expensive.

If you build frames for a living it’s a good idea to cut all of the stock to length the same day you buy it. Shorter lengths are a lot easier to store. We cut all tubes about two inches longer than we know we need for any particular part of the chassis and whenever possible we also pre-bend the parts that need bends. This way all we need to do when we start a frame is pick out pieces, mark them with our pattern templates, run them through the notcher, wire brush the ends and put them in the jig. Putting the prep work up front, days or even weeks before you start to actually build the frame gives you the time to fully concentrate, uninterrupted, on fine fitting the pieces and doing the welds.

This same system works with building custom frames except you need to allow more room for dimensional modifications in your pre-cut components and you make your bends as you’re developing the lines of the bike.

Depending upon where you live you may or may not have access to a local steel supplier who can provide you with tubing but try to find a source that takes care of their inventory so you get good clean, straight, rust-free, un-dented tube sections. In some areas of the country material delivery consists of dumping the tube bundle four feet off the side of the truck and then the owner stores it outside for the winter before you get to it.
Steering Necks

For some unexplained reason we have had dozens of emails over the past few days concerning steering necks and where to buy them or how to build them so we decided to add this little section to clarify what seems to be the most mysterious part of building a frame of your own creation.

To begin with there are four basic types of necks that you’re likely to encounter. The first and by far the most common of course is the old factory stock cast neck (Figure 1) found on a variety of bikes and not just Harleys.

![Figure 1: Old factory stock cast neck](image1.png)

Figure **Error! Bookmark not defined.**

In the early days the races for ball bearings would have been machined right into the thickened rim of this type of neck casting but as production numbers rose somebody had the bright idea of machining a separate part to contain the bearings thereby making the entire assembly less expensive to produce.

These separate parts are usually called neck cups, frame cups or steering neck cups and are shown along with the bearings in figure 2.

![Figure 2: Neck cups and bearings](image2.png)

Figure **Error! Bookmark not defined.**

Neck cups such as these are available from a variety of suppliers and usually run around $25 to $30.00 per pair bare, or around $60.00 with the bearings and races included. If you plan on using this type of neck cup buying them with the bearing races already installed will save you a lot of hassle if you don’t have an arbor press handy.

These steering neck cups shouldn’t be confused with the bearing races, which are often erroneously called cups or bearing cups from the old days when ball bearings were used in steering necks.

Figure 3 illustrates a typical cast steering neck with the separate cups installed.
The second type of neck is a machined body that tapers in diameter giving it the appearance of the stock neck but it still uses pressed-in-place neck cups as shown in this beautiful photo from Bikernet below.

The third type of neck is completely machined from either solid bar stock (billet) or very thick walled tubing and the bearing cups are an integral part of the assembly as shown in Figure 5 below. These necks are available from a variety of machine shops and come in several different configurations but some are more graceful than others so shop around for a style that suits your fancy. Some supplier offer their assemblies with internal fork stops.

The fourth type of neck is usually just a section of tubing having a relatively thick wall with neck cups pressed into each end. Sometime such necks will be made from two sections of tubing. One piece having a relatively thin wall section will be the main body with two larger diameter pieces welded to each end forming a stronger area to accept the neck cups as seen in Figure 6.
All four types of necks do what they're supposed to do and the only reason for choosing one over another is for the sake of appearances or economics. Reproduction stock cast necks cost anywhere from $250 to $360 depending upon the source. Billet and otherwise machined type necks run from $85 to around $160. Necks built from DOM (or seamless) tubing are the least expensive and cost about $45.00 plus the cost of the cups.

Actually the cost of the material for a tubing steering neck is only $5.00 if you make it yourself but unfortunately you will usually have to buy at least a ten-foot section of tubing from the supplier so it is sometimes cheaper just to buy a pre-made assembly from a parts house.

If you’re going to make your own tubing neck use DOM tube having an inside diameter of 1.313 inches which will accept almost all of the manufactured neck cups available from the popular sources.

At a bare minimum you can use 1.625 x .156 wall tube will is commonly available at most steel supply yards and chassis shops since it is widely used for roll cages and roll bars. It is strongly recommended however that you try to find some 1.75 x .219 material if at all possible and if you’re planning to machine some taper in the neck tube move up to 1.875 x .281 or even 2.0 x .344 inch stock. All of these dimensions have an inside diameter of 1.313 inches. The absolute minimum wall thickness at any point along the tube should be at least .156 inch and .1875 is even better.

The parts for a basic tube type steering neck are shown in Figure 7 below.

The longer tube on the left is a piece of 1.75-inch stock snagged from a local chassis shop for a few dollars. The cut tube in the center is a neck I bought along with cups from a fellow on one of the discussion boards who had one left over from his own projects. The tubing cutter is needed to cut your new neck from rough stock. The overall length of the tube should be 5.625 inches. Be sure to de-burr the cut edges and to slightly chamfer the inside edge. The cup on the left is a bare one while that on the right has had the bearing race installed.