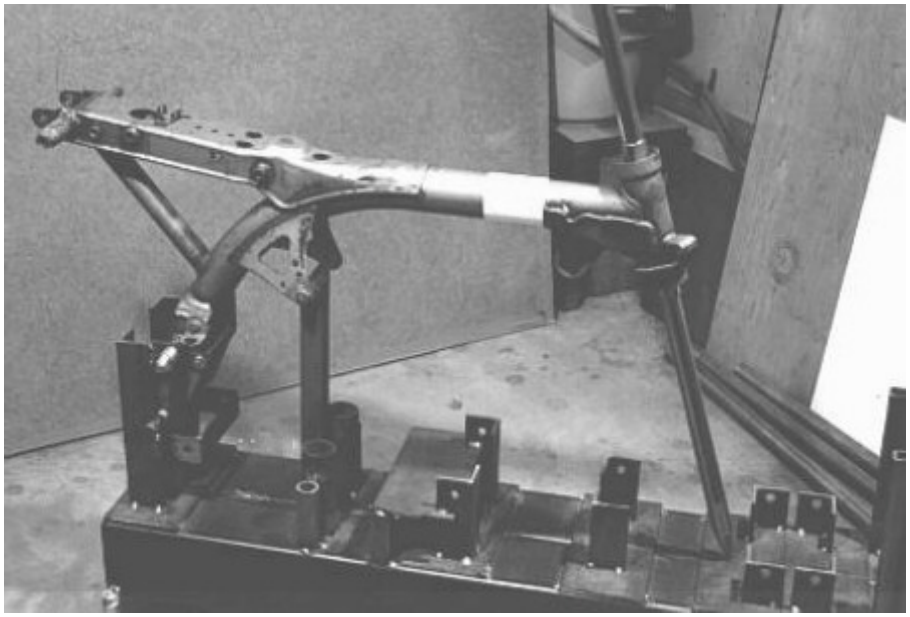
The Frame Jig

Many potential frame builders have the mistaken idea that the frame jig must be extremely accurate, built like a precision timepiece and yet possess immense strength for bending and holding the tubing sections in position for welding but in fact the *base structure* of the jig, sometimes called the *backbone, bed, table, base table, face table or frame face* can be almost any relative rigid structure.

As long as the frame bed or backbone is level in all directions the real precision and accuracy will come about through the fabrication of the *fixtures* that attach to this substructure or backbone and then will be adjusted and secured to position and hold the tubing and parts in place during the fabrication of the frame or chassis.

Figure 1 illustrates a typical jig assembly with the bed or backbone being made of two segments of box tubing with the various fixtures bolted into position.



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This type of frame jig is referred to as being a ‘bottom-up’ arrangement and while it has some disadvantages it is by far the most common type of jig used in custom motorcycle frame construction.

The following pictures illustrate a wide variety of frame jigs ranging from simple and crude homemade units to extremely complicated fully adjustable units manufactured for large chassis shops. Though the range of sophistication is wide, all of the pictured jigs can produce very accurately aligned tube frames. In fact the precision of the final product is more dependent on the builders skill than the frame jig being used and there are several custom frame builders who don’t use a frame jig to begin with.

In figure 2 we see a typical jig backbone, this example is made from channel and raised to knee height on cinder blocks.

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Another relatively simple layout below in figure 3 shows two longitudinal rails forming the backbone or bed framework.

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Another typical horizontal rail or bed type of jig is shown in figure 4. Note that in this example, built to fabricate one specific type of frame, the fixtures are not adjustable but are welded into position on the jig bed rail made from 3x3 square tubing.

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Figure 5 depicts a true building table, often referred to as a face table. Note the leveling legs at each corner.

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Figure 6 shows a typical jig fixture, this one used to position motor mounts.

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The same table as above but with the fixtures added is shown below.

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All of the jigs we've seen so far start with a foundation of a rail, multiple rails or table and build upward with the jig fixtures supported from below. An alternative to this scheme is the vertical jig, which is most often used in bicycle construction, but is occasionally seen in motorcycle fabrication shops especially where very lightweight racing frames are being built.

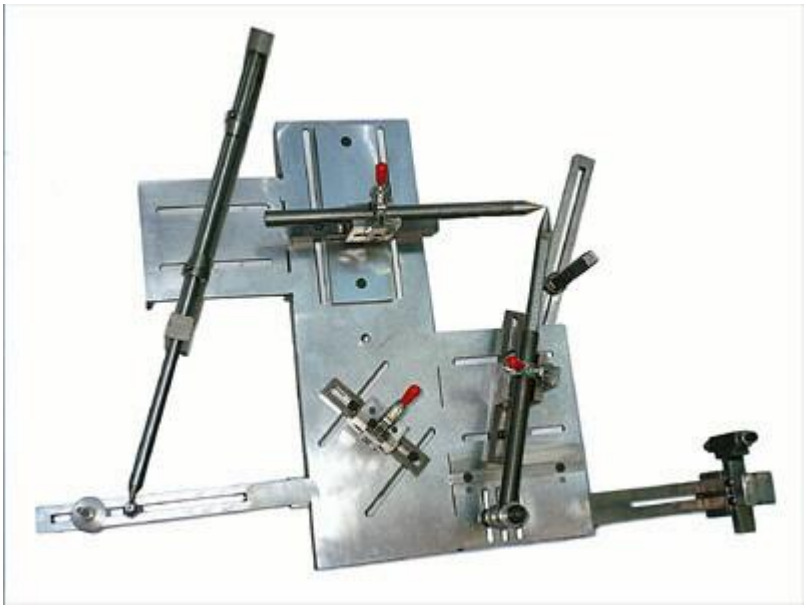

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Figure 8 illustrates a Bringheli jig. Note the gauge rods with pointed ends used to calibrate the fixture clamps, an alignment method that can be adopted on any type of jig.

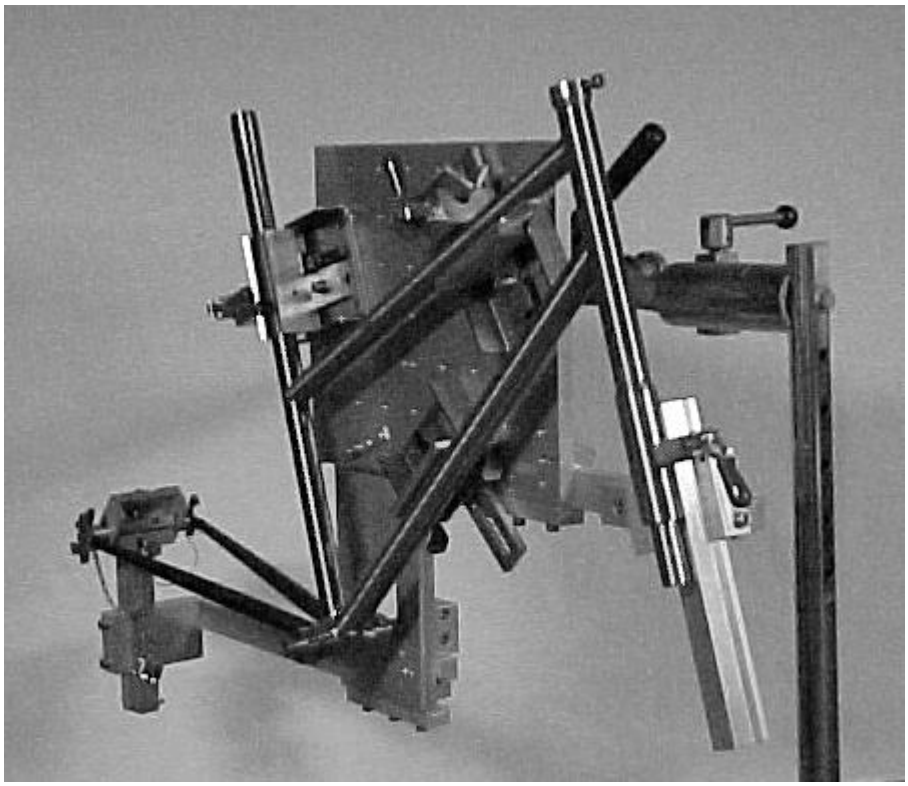

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Figure 9 illustrates a Henry James vertical jig. This structure is often called a modified plate jig or vertical plate jig since the ‘bed’ is basically just a large flat piece of aluminum.

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Figure 10 illustrates a motorcycle jig using both a building backbone or bed rail and a vertical panel made from spaced steel members.

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Figure 11 is another combination jig exhibiting both horizontal and vertical primary support members.

Jigs having vertical structural members or plates are superior to horizontal or backbone based jigs in that the fixtures that clamp the individual frame components are shorter, located closer to the joints and connections, hence stiffer than the same type of clamping fixture that has to extend all the up from the base plate. For this reason it is becoming more common to see at least some aspects of the vertical plate design incorporated into conventional rail or bed type building jigs.

Another very popular fabrication technique used to improve the accuracy, rigidity and efficiency of frame jigs is to incorporate as many pieces of the motorcycle as possible into the basic construction of the jig fixtures themselves.

For example it is very common to actually build the jig around the engine, transmission, forks and wheels that will be used in the completed bike.

Figure 12 illustrates a typical backbone type jig with major mechanical components included into the initial jig design.

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This type of jig design will produce the best ‘custom’ frame designs since the potential rider can better visualize the final product and adjustment can be made with the rider sitting in place over the motor. Needless to say accuracy will be superior because all of the component mounting points are located by the components themselves.

In our shop we use a ‘building’ jig that includes the bikes wheels, axles, transmission, motor cases and front forks for custom work and then if we decide to build more frames along the same lines we build a much smaller jig just to hold the chassis tubing.

Jigs can be extremely simple as seen below in the example used by Michael Moore

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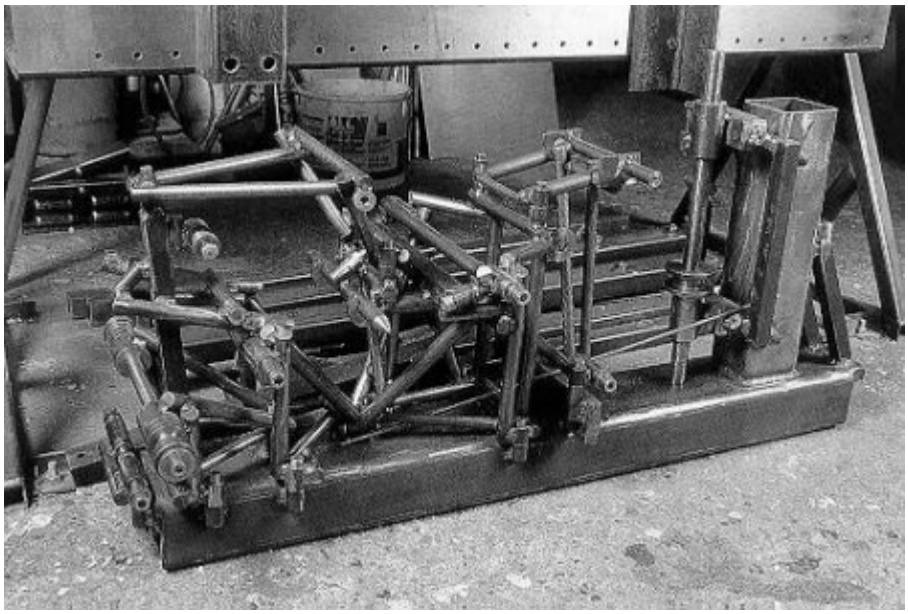
Or unusually complicated is seen in this unit used by the Harris brothers shown in figure 14 or the multipurpose building and alignment model shown in figure 15.



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The jig shown in figure 16 is a good example of a well though out arrangement for a specific type of cycle. Note that the rear axle adjusters are used to locate the wishbones and that the fixtures are mounted to pieces of channel iron that can be slid fore and aft along what looks like s 3x3 tube rail.

Figure 16

There are almost as many jig designs as there are frame makers since each jig is usually the work of the artist building the frame. Some jigs are used over and over again producing several if not hundreds of so-called ‘custom’ frames by frame manufacturers while other jigs are only used once for a ‘one-off’ bike. Sometimes a company or individual will sell a jig to another builder but without the actual plans or blueprints for the frame that the jig was built for it is almost impossible to reconstruct the frames produced by the jigs original owner. This is a hard fact for many people to believe but the sole purpose of the frame jig is to hold various bits and pieces of tubing in certain alignments and positions while they are tack welded together. The jig itself will not give you a clue as to the lengths of tubing or angles for the various bends.

As mentioned at the beginning of this section a welding jig doesn’t necessarily have to be massively built because the jig and fixtures should only be used to position and lightly clamp together the frame tubing for welding. If it becomes necessary to force a tube or fitting into position in the jig then something is wrong with your bender, your measurements or your design. Wherever possible I set up my jigs so that the frame tubes simply lay into angle iron guides so that no clamps are needed in the first place and in fact even if you do clamp down all the tubing tightly, the frame will distort anyway when it is taken out after final welding.

Quite often, especially if you’re making several frames that are similar but with minor customizations it is helpful to build separate jigs for separate parts of the frame in addition to the assembly-welding jig. In our shop for instance we use a jig to build up the upper rear tubes and another for the backbone and seat post before these sections are added to the main welding jig.

For true custom bikes it is very likely that you’ll wind up designing and building the frame and the frame-welding jig all at the same time developing individual elements and components of both the frame and jig in sequence. For example you sketch out the backbone curve full scale on the shop floor, build a large-radius bending jig to shape the tube and then weld up a jig fixture to hold the backbone in position over the seat post with both tubes held in alignment with the steering head fixture.

In addition to building and welding jigs it is often very helpful to build full-scale mockups of frame components or in fact complete frames from wood dowels before you commit a design to steel tube. Building a wood mockup is extremely useful in helping you decide on the sequence of construction, devising easy methods to position tubes for notching, pointing out ways to build effective fixtures and allowing you to visualize the form of the completed chassis before you spend hard cash on the steel. In a similar fashion try to build templates and patterns for components that are repetitive from one frame to another.

Each builder has his or her own ideas about what constitutes the ‘benchmark’ or ‘base-point’ that all measurements are taken from on the jig. Some fabricators start at the steering neck and base everything about this point working rearward.

Others use the rear axle and work forward. To my way of thinking about the only thing that usually doesn't change on a custom V-twin chassis is the center point of the motor so I always set a 'kingpost' at the vertical reference centerline of the engine and work fore and aft from this point. I believe this gives me far more freedom in planning and designing than having either the steering neck or rear axle as a fixed point on the jig.

A really good frame jig will never be finished. It will always remain a work in progress being tweaked and modified as the builder hones his or her skills and begins to develop their own unique construction methodology and artistic style. The key to good jig design is repeatability. Every time a part goes into or comes out of the jig everything should be absolutely identical.

Several site visitors have asked us why the jig plans we sell are so 'elemental' and the answer to that question is that the plans we sell are meant to form the foundation of the buyers personal jig that they tailor to their own specific needs and fabrication style. We could sell a copy of the plans of our own jig but then people would just be building a copy of what we use. This would actually hinder their own fabrication development and not enhance it. Almost all visitors here and on the discussion board and those that visit the sites we link to will see more jigs, more plans and more ideas about building and configuring jigs that anyone can possibly imagine. From the huge variety of images and personal build accounts in the forums a builder will get an eyeful and and earful of good down to earth jig fabrication information that will take them far beyond the basic jig plan in very short order.

Let your imagination be your guide.

Many people have asked us what dimensional tolerances we work towards in building both jigs and finished frames and while each maker has their own concepts about accuracy in our shop we strive for absolute perfection but we will accept dimensional discrepancies of up to 1/4 inch in an overall frame length or 1/8 inch in width if we have to. Between any to closely positioned components 1/32 inch is considered acceptable but anything over those ranges and we scrap the piece and start over. In reality it is almost impossible to detect defects caused by inaccuracies in the range of 1/8 inch over the length or width of the frame and if the axles are perfected parallel to one another and the steering neck is perfectly perpendicular the relative accuracy of the all the various interconnected tubes is actually immaterial which brings us back again to jig and fixture strength. Dimensional accuracy is far less important than angular precision where everything is plumb, perpendicular and parallel. Remember that the large portions of the jig don't necessarily have to be very accurately fashioned. In fact the fixtures don't have to be to precise either so long as the precision is used where it counts and that is at the frame tubing connection points and mount points. In other words the degree of accuracy or acceptable tolerance goes from gross to fine in ascending order up from the base rails and into the connections.

It is imperative that the tubes are properly cut to length, bent and mitered so that the joints are as close to perfect as possible. If this is done they can be positioned and held very lightly in place while they are tacked and if the welding sequence is done correctly no heat distortion will change the angular or dimensional alignment of the various tube members. The jig and fixtures no matter how strong or rigid cannot resist the bending and warping stresses caused by improper welding sequence or inaccurate initial layout and fitting once the frame is removed from the jig.

One way to test your building skills is to fabricate a frame and then saw through some tubes near connection points at various places on the frame. If the tube end suddenly springs away from the other end or springs to one side or another at the point of the cut it indicates that your frame has a lot of built up stress caused by poor welding sequence, too much welding heat or poor structural design considerations. If you cut an unstressed tube the hack saw will pass through the member and nothing happens, both ends stay in perfect alignment separated by about a sixteenth of an inch of air space.

After years of using a single rail jigs we have decided to start using a base frame made from two parallel rails. Since we build frames for a variety of bikes and not just Harley's we feel this gives us more flexibility since fixtures can be mounted between the rails for centerline type fittings or outside the rails as may be needed. Figure 17 below illustrates the basic foundation of this setup we just finished last night.

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Many people are surprised to find out that a jig will cost more than the frame that comes out of it. In fact a good *professional level* jig with adjustable fixtures will cost about four thousand dollars to build if you have to farm out the machine work. Machining, done in-house can shave maybe two thousand off that figure. If you work for free and deduct the cost of your own labor you can knock another fifteen hundred off the budget which means a good jig will cost you about five hundred in materials and incidentals if you do all of the work yourself. Compare this to the hundred bucks in materials you need to build a frame.

Always remember that you are better off without any jig at all rather than being forced to use an ill conceived one. A good jig can't be built in a day and most will take at least a week to put together properly. Accuracy is paramount so go slow, measure twice and cut once. Watch out for welding distortion. It is better to err on the short side as anything can be shimmed out to final dimension where it is much harder to grind something down and still maintain precision.

As mentioned above it is far more expensive to build a jig than to build a frame. It is also far more complicated to build a jig than a frame and it takes far more time to build a jig than it does to build a frame. For these reasons many people are tempted to bypass a jig altogether and try to weld up a frame without using a jig. There is nothing wrong with this if you're a good experienced fabricator and you have a lot of time on your hands since it takes longer to build without the assistance a good jig provides. There are some good builders who fab every frame from scratch but for every successful frame built this way by professionals there are probably ten built by amateurs that don't work out so well and have handling problems if they even make it to the engine stage in the first place.

The one point I forgot to mention is that it's a good idea to plan on how you're going to get your frame out of the jig after its welded together. You would be surprised how many novice builders have welded their jig fixtures to the rails in such a manner that the frame gets locked 'inside' after the tubing runs are 'closed up'. One of two things will happen. Either the cutting torch comes out of hiding or the jig becomes a go-cart with a motorcycle frame on its top.

We'll be adding more pics of our own jigs as we get time to finish the new ones and get the old ones unpacked. If you're building a new jig of your own or have pics of your old one send us a copy to include here and drop me a line so we can compare notes.

Building the Frame Jig

(If you came directly to this page it may be worthwhile to review the previous section concerning frame jigs in general before proceeding)

There are three basic types of jigs we can build for welding motorcycle frames. The first and most common type is usually just called a 'Frame Jig' and is designed specifically for holding the frame tubes in position for welding and has very little flexibility to provide for custom work. The second type of jig is customarily referred to as a 'Full Bike Jig' or 'Custom Builders Jig' and is designed to accept components for the bike such as wheels and tires, an engine and the transmission case to be used in the mock-up. The main difference between a frame-only and a full bike jig is the length of the building rails. The last jig type is more appropriately called a 'fixture' since it is designed to perform a specific holding function for only a portion of the bikes frame. An example of this type might be a sub-jig inserted in a finished frame to position and hold the plates for motor mounts or the lugs for tanks mounts and fender mounts.

As I mentioned in the last section I have come to prefer working with I call a twin-rail welding jig so in this section we're going to just briefly describe such a jig. This particular design can be built as a frame-only or full-bike jig. Remember however that there is no such thing as the ideal or perfect jig design since each builder will eventually develop his or her own techniques for jigging up frame tubes. The jigs we'll be discussing here are relatively lightweight and are intended primarily to be used in small fab shops or by home builders who do a limited number of frames every year. For production work we recommend that you review the other sections of the site and search the web for what are sometimes called 'commercial' or 'production' welding jigs which are normally substantially heavier, more complex and generally thought to be more accurate. These lightweight jigs however can produce outstanding work in the hands of a good craftsman.

The system I'm now using consists of two parallel 2"x3"x.120" rectangular steel tube rails, set on edge with a 2" space running down the middle. The main rails are supported by two cross members that run perpendicular to the main axis and if you don't have a level table to set the jig on you can add leveling bolts at the ends of the cross members. I've also built a lighter jig from 1.5x2x.120 tubing with only a 1.5" space between the tubes and it is substantially easier to move around the shop if you have to.

Figure 1 below shows the basic arrangement of the rails, support cross members and a temporary vertical upright I had been using as a spacer.

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The table shown in the snap shot is perfectly level so I didn't need to add any mechanism for leveling the jig itself.

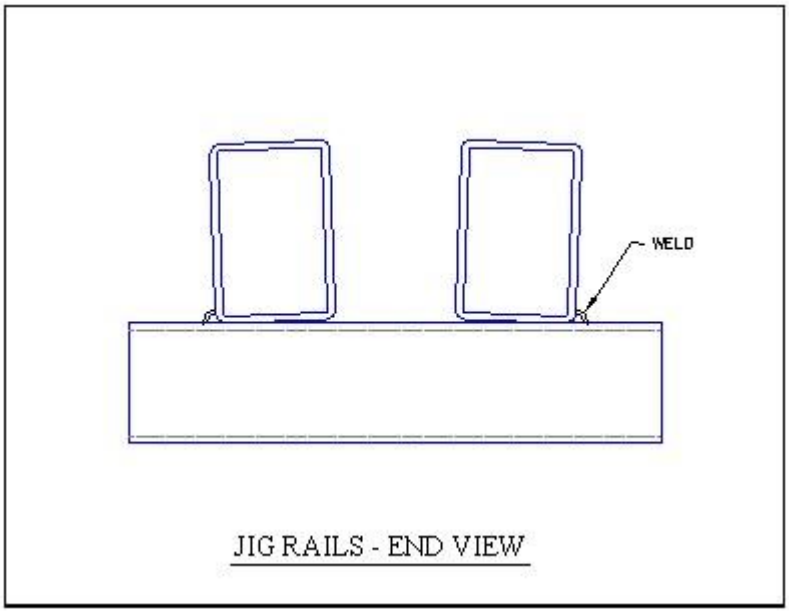
One of the advantages of this particular design is that you can build fixtures that fit in between the rails in the gap or assemble fixtures that span both main rails and lock into position on the outside of the base rails. Using a combination of the two fixture types you can work from the centerline out or from the outside in.

The jig illustrated in this article is welded but it could have been bolted together just as easily if you need to break it down for storage when it's not in use. My unit is just six feet long but it weighs around one hundred and fifteen pounds so its not the easiest thing to be moving around to make room for other projects.

This same concept can be adapted to using 'C' or channel sections for the rails but in general such jigs are heavier and have less stiffness unless you go to a deeper section.

The rails have to be perfectly parallel but more importantly they have to be perfectly square with one another and the cross members. In other words the rails cannot exhibit any type of 'twist' or 'sag' for the length of their run.

If you try to simply weld the rails to the cross members they will have a tendency to twist or 'roll' towards the side being tack welded and if this happens the top surface of the rail will not be 'flat' so it won't make a very good reference point to measure from later on down the road. Figure 2 illustrated at an exaggerated scale shows what can happen.



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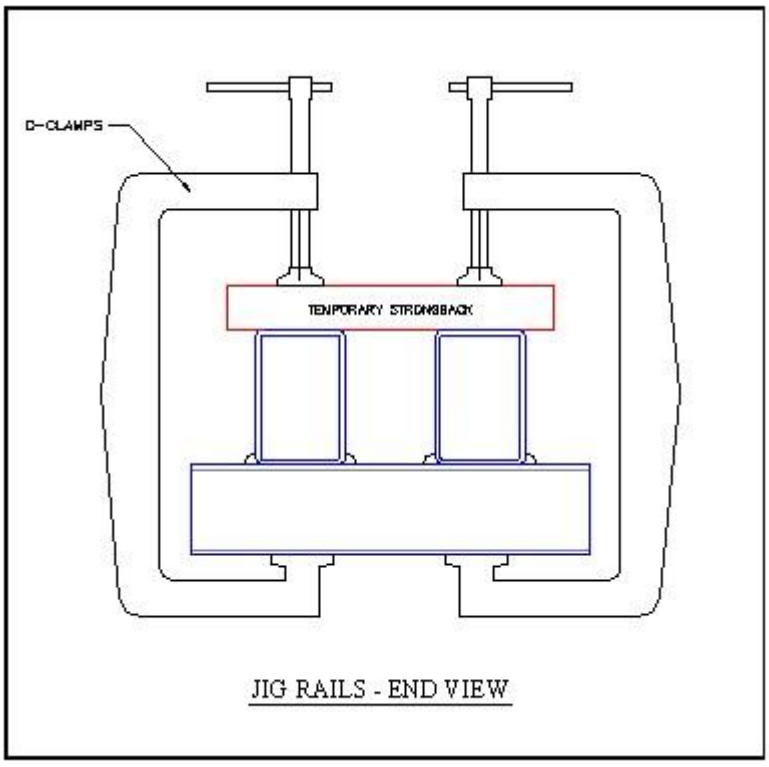
To avoid this potential problem it is best to clamp the rails down using a strongback to distribute the load as shown in Figure 3 and to use very small tacks during the initial assembly stage to keep heat distortion to a minimum.

The objective throughout the construction process is to build a jig assembly that has every single piece square and plumb so that measurements and/or angles taken from anywhere on the jig are exactly the same throughout. You can get much better accuracy for assembly by using a very long bubble level and large carpenters square. The little nine-inch levels and machinists squares most of us welders use are far to short to give good readings over the relatively long distances we'll encounter on the jig base.



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What's not shown in the illustration above are the two-inch wide temporary spacers I put between the two main rails as they're being tacked. The gap between the rails should be narrow enough so that a piece of two-inch (or 1.5") tubing slid vertically down between them should be a tight fit and not exhibit any lateral wobble. At the same time however the fit shouldn't be so tight that you have to use a mallet to drive the uprights into place.

I've found that a couple of 12 inch long 2x3 (or 1.5x2") temporary tube spacers shimmed out by another 32nd of an inch will give an almost perfect gap between the main rails once they are fully welded to the cross members.

The cross members, or legs are positioned about 18 inches in from the ends of the main rails on my jig which leaves a clear span of only 36 inches in middle so there is no measurable deflection in the middle of the rails even when a substantial load is applied.

If you're building a long full-bike jig you'll probably want to add a third cross member in the middle of the rail run.

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I've found that I can better control the accuracy of placing the fixtures and vertical uprights if I work from the rear of the jig towards the front. Figure 4 is another snapshot of the jig with a vertical upright welded in place that serves to hold a piece of tube stock for the rear axle placement.

On this particular jig I wasn't concerned with actually mounting a rear wheel but if you want to do this the rear axle fixture will have to be a 'U' shaped affair with two uprights, one on each side, to hold the ends of the axle and the axle plates. And again like all other parts this upright has to be perfectly plumb and square to the bed rails.

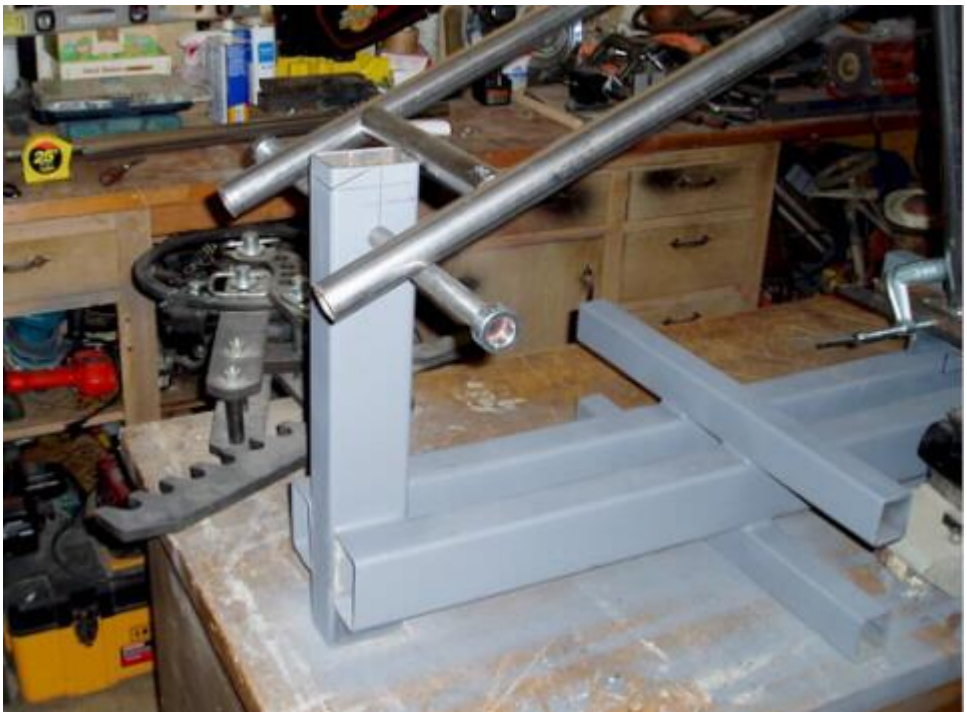

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Figure 5 is a close-up of the rear axle upright showing that it's nothing fancy, just a piece of rectangular tubing with a hole bored to house a piece of bar stock. The axle plates are sandwiched between two shaft collars on each side. That little piece of tubing at the ends of the wishbones is just a temporary spacer to aid in alignment.

You'll also notice on this particular jig a piece of 1x2 inch rectangular tubing running perpendicular to, and on top of, the main base rails. I call these members the transverse frame rails and these will actually carry the lower frame side rails. The actual dimension of these cross members, spacers or offsets as they are sometimes called will vary in dimension from one frame design to another. For some frames they will be mounted on the flat while for others they will need to be upright.

When you going about designing, planning and doing the initial layout for your proposed jig you have to spend some time in determining your goals and objectives for the unit. You have to take into consideration the types and styles of frames you intend on building, and where you already have frame plans, you have to examine them closely to determine exactly how you want to set your particular jig up to that particular frame. This article is only intended to provide some broad guidelines for jig building and not specific hard and fast rules or frame building dimensions. Every jig is tailored to build a specific frame or several frames depending upon how you decide to set it up.

To Be Continued……