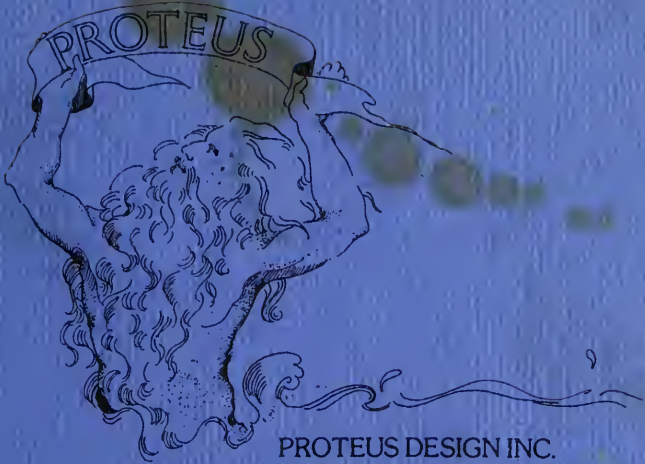


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PROTEUS DESIGN INC.

# THE PROTEUS FRAMEBUILDING BOOK

A GUIDE FOR THE NOVICE BICYCLE FRAMEBUILDER

Dr. Paul Proteus





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I would like to thank the following people for their help in writing this book.

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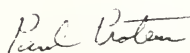
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A handwritten signature in cursive script that reads "Paul Proteus". The signature is written in dark ink and is positioned to the right of the list of names.



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## I N T R O D U C T I O N

This booklet is designed for the novice frame builder. Using this booklet for a guide, you will be able to construct a frame of reasonable integrity and alignment. The methods described herein are not recommended for a professional frame builder. Many of the techniques I describe are short cuts. I am assuming the average person has a limited number of tools and does not want to invest a large amount of money in jigs and other fixtures. However, careful attention to details can produce a frame superior to many of the finer frames produced abroad. Remember, the more time you take assembling the parts and the more practice you can get brazing will pay off greatly in the end. Above all, be patient.

Throughout the book I will say "flux and braze the joint." It should be understood to follow all procedures mentioned in "general procedure" when brazing.

As for tools, always get the best you can reasonably afford. Tools are a good investment regardless of whether they are for frame building or not. Stay away from so called "handyman" or drug store brands. If you're buying files, look for brand names like Nicholson or Simmonds. When using a new file, be very careful. The teeth are the sharpest they will ever be. In their condition they are most prone to breakage and premature wear. A little care now will pay off in the long run. When buying drills, not as much care is necessary. However, make sure the drills are made of High Speed Steel or better. High Speed Steel is often abbreviated H.S.S. If a drill breaks or dulls, it can easily be sharpened on a grinding wheel. Purchasing a tape measure or ruler is relatively simple.

Just get ones with metric, or English and metric markings. Whenever you may need a drill press (such as drilling a fork, crown, etc.) a high school metal shop may be helpful. As for getting and using torches, I am not as sure as to where you may be successful. Tool rental businesses might have them, or a friend might be helpful. In any case, read as much as possible or have someone instruct you on all points of safety. In general, a fuel gas such as acetylene or Mapp Gas in conjunction with oxygen works best. I do not recommend a propane torch even if used with silver. This is not to say that it is impossible to use, just more difficult. Before you proceed to make any frame sections, read the pertinent chapter through beforehand. This will give you a better understanding of what you are doing. When in doubt, use common sense. Good Luck.

#### G E N E R A L   P R O C E D U R E

To properly braze a joint, especially a sleeved joint such as a lug, two areas of concern should be watched carefully--cleanliness and fit. As far as cleanliness is concerned, it should be fairly obvious that the braze material will hold much better if it is attached to metal rather than the dirt or grease on top of the metal. Also the ease and neatness with which the braze material flows under or along a lug or other fitting will increase as cleanliness increases. The simplest way to insure cleanliness is to remove all foreign material from the metal. If the metal has heavy grease on it, use a solvent such as Varsol to remove the grease. Either dip the metal into the Varsol or use a rag. Then wipe dry with a clean cloth. Repeat the same procedure if the grease persists. Next, use some abrasive paper or cloth to get down to bare metal. Many

frame tubes are covered with a rust preventative, so be sure to clean down to shiny metal wherever you are going to braze. Finally, use acetone to get any residual oil off the surface. Although most flux will adequately clean very dirty surfaces, the dirt may pile up or darken the flux. This will make it very difficult to see what you are doing while brazing.

The other main concern is fit. Almost always the strength of the frame tubes and lugs exceeds the strength of the braze material. Therefore a joint with a large gap filled with braze material will be weaker than a tight joint when the braze material is used as an adhesive. In joints that are not sleeved, the tightest possible fit is the best. In sleeved joints such as lugs, too tight a fit can present a problem. The braze material, especially brass, may have difficulty getting under the lug causing an incomplete braze or overheated joint. In general, a sleeved joint should be able to be put together and taken apart by hand, and yet have no play when assembled. For some silver braze materials a slightly tighter fit will also work.

Whenever a joint is to be brazed, it must be fluxed. Flux removes dirt and allows the braze material to flow more easily. It also removes oxides not normally removed with ordinary solvents. Silver fluxes are usually pre-mixed as a paste. Bronze fluxes are usually a powder substance which can be mixed with water to form a paste. When brazing lugs, apply the flux paste to the tubes and lug interiors, then fit the joint together. On other joints, just apply flux on the exterior of the tubes and fittings.

Brazing different thicknesses of metal may require different size brazing tips. Thicker metal requires a larger diameter tip.

It is not necessary to use different dips, but it helps.

Holding metal pieces together while brazing is often necessary. Should it be necessary to clamp a piece of metal in the same area it is being brazed, only the lightest possible pressure should be used. Excessive pressure will cause the metal to collapse when it is heated.

Be sure you have properly prepared and assembled your joint before you start brazing. Once you have started brazing, making any changes will be very difficult.

## D E S I G N I N G   Y O U R   F R A M E

The first step in building your frame is to design one that will meet your needs and at the same time fit your body. You must decide whether you are going to build a racing frame or a touring frame or something in between the two. Regardless of what that decision is, you must have a positive idea of what you want to build. Racing frames generally have short wheel bases, steep head and seat tubes, short chainstays and a small amount of fork rake. Touring frames have long wheel bases, less steep head and seat tubes, long chainstays and more fork rake. In designing a frame, do not start with the idea of 39" wheel base and try to make your bike conform to that dimension. Instead, design each component of the frame individually to suit yourself. When you finish drawing your design, you can then measure the wheelbase. If that dimension is unsatisfactory, study your design and figure out the best component of the design to change. Next I will go through each piece of the frame and explain its significance:

Bottom bracket height - This is the distance from the center

of the bottom bracket to the ground. It helps determine how high the top tube will be off the ground. For example, a 21" frame with a 10 1/2" bottom bracket height will have a top tube closer to the ground than a 21" frame with a 10 3/4" bottom bracket height, assuming the seat tube angles are the same. Also, the clearance for the end of the pedals to the ground will be affected. This is more critical when long crank arms are used. Finally, the stability of the bicycle will be affected by raising or lowering the weight of the rider in relationship to the center of the wheels.

Seat tube length - This is the distance from the center of the bottom bracket to the top of the seat lug. Many people consider this length to be the most critical dimension on the frame. Perhaps that is why there are so many different theories as to how long a seat tube should be. Actually though, these theories really deal with top tube height. Remember the top tube height is a function of the bottom bracket height, seat tube length and seat tube angle. My suggestion is to pick out a top tube height you like best, either by standing over a frame that you feel most comfortable with or by using the calculations in many books dealing with crotch height, and leg length. When you've figured out the top tube height, the length of the seat tube becomes whatever length is necessary to bring the top tube to that height. If you are not concerned with top tube height you might want to consult the C.O.N.I. book, Cycling, on proper seat tube length from a given body size.

Seat tube angle - This is the angle formed by the seat tube and the ground. The angle is always less than 90°. A common seat tube angle would be 72°. The more steep the seat tube angle the more uncomfortable the ride. However, a steep seat tube may make the

frame more responsive and less energy absorbing. These are benefits to the racers. On the other hand, a less inclined seat tube is more comfortable although some sacrifice in quick handling and energy absorption may occur. This would be better for the tourists who may have comfort as their main concern, especially on long rides. The less inclined seat tube may also make the frame more stable. Another consideration for some people is the distance from the nose of the saddle, to a line drawn through the center of the bottom bracket, perpendicular to the ground. In very small frames this distance will be very short and in very large frames this distance will be very long. If you believe this distance should always fall within certain parameters, then you must make sure you can adjust your seat to fit those parameters. To accomplish this, you must know how far back the top of the seat tube should be behind a line drawn through the bottom bracket perpendicular to the ground. Since saddle position is adjustable, there should be two possible extreme settings for a seat, and therefore also the seat tube. Figure out the furthest and the closest distances the seat can be behind the bottom bracket. Then make a scale drawing. Measure the angle of the seat tube in the furthest back position and then in the furthest front position. You now have a choice of selecting either extreme angle or any angle in between. Therefore the considerations first mentioned under seat tube angle can be used since you have a choice of angles.

Top tube length - This is the length from the intersection point of the center lines of the top tube and seat tube to the intersection point of the center line of the top tube and head tube. The length of this tube relates to the length of the upper part of



your body and your arm length. Some adjustments can be made in the seat position, while most adjustments are made in the handlebar stem length. There are three simple ways to determine the proper length. First, find a bike where the length of the reach from the saddle to the handlebar feels good when you ride it. Make sure the stem is neither excessively short or long. Just measure the length of the top tube. Second, consult a chart such as those found in the C.O.N.I. cycling book. Third, go to a store that has a machine that lets you adjust different lengths of top tubes to fit you. Many Raleigh stores have such a machine. Note the measurements you get.

Head tube angle - This is the angle formed by the head tube and the ground, similar to the seat tube angle. Many of the characteristics of this angle are the same as the seat tube angle. The major difference is that the head tube serves as the basis for the steering axis. Because of this, a steep head tube angle will make steering much quicker although less stable.

Fork length - This is the distance between the center of the front axle to the center of the brake hole in the fork. The main considerations here are the type of brake and clearance you prefer. If you already have a set of brakes you plan to use, it is necessary to make sure that you plan your fork length so that the brakes will be able to hit the rim. If you are using clinchers, you will want to have the brake pads in their uppermost position. This will enable you to lower the pads in the event you may want to use tubulars or 700c tires. If you're using tubulars, set the fork length with the brake pads down. Just to be sure you're approximately in the right area, a distance of 14 3/8" is quite common.

The other consideration, clearance, is also important. Many tourists want room for clinchers and fenders. In this case you may want to have more clearance. If so, the brakes you use are not important. This is especially true when Mafac cantilever brakes are used, since they can be brazed on anywhere along the fork. One final note, longer forks flex more than shorter forks.

Fork rake - This is the distance from the center line of the head tube to the center of the front axle. The measurement must be made along a line that passes through the axle and crosses perpendicular to the head tube center line. There are two important components of fork rake, the length of the rake and the radius of the rake. Usually, the longer the rake, the softer the ride will be. A longer rake will also tend to be more stable. However the length of the fork rake should be considered with the head tube angle. For example a very steep head tube angle in conjunction with a very short rake may make a frame too quick to steer, even for racing. The radius of the rake can be considered as the radius of the bender the fork was curved with. The smaller the radius, the more shock absorbing the blades will be. Generally, you will have no control over the radius of the bend. If you ever do have a choice of radius you will be able to make a knowledgeable decision.

Front wheel clearance - This refers to the distance between the front axle and the center of the bottom bracket shell. This distance is usually the concern of tourists. A problem can arise if this distance is too short. Usually the toe clip will hit the back of the front wheel or front fender causing a momentary shock for the rider during the downstroke of the pedal. There is no set correct distance for every frame. Crank length, toe clip size, and .

whether or not you are using fenders makes a big difference. To increase the clearance distance you can do one or any combination of the following things: increase your seat tube angle, lengthen your top tube, decrease your head tube angle or increase the fork rake.

Chainstay length - This is the distance from the center of the bottom bracket shell to the intersection point of the chain and seat stays. This is a very simple variable. Larger stays create a smoother more comfortable ride and short stays make for a stiffer more responsive ride.

Now that you know how to decide on the variables of your frame, it is time to begin to draw the plan for your frame. You will need some drawing paper, a straight edge, a good protractor, a compass, a ruler and a pencil. If you have access to a real drafting board, you will have an easier time. In any case, you must begin your drawing by choosing a scale. You could draw your frame full size, but there is no real advantage to this, and at the same time, it will create problems. It's best to use a scale where 1 centimeter is equal to 1 inch.

Start by drawing in a ground line; this is the line the wheel of the cycle will rest on. Next draw a line parallel to the ground line in the center of the paper as many inches above the ground as you wish for your bottom bracket height. This line represents the center of the bottom bracket. Draw two lines parallel and about 13 1/2" above the ground line to each side of the paper. These lines represent the center of the wheels. 13 1/2" represents an average height. If you have your wheels already or are using 700c's or tubulars, you can take an exact measurement of the distance from

the axle center to the ground. (Fig. 1)

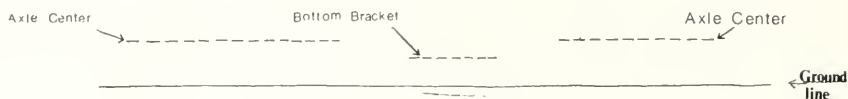
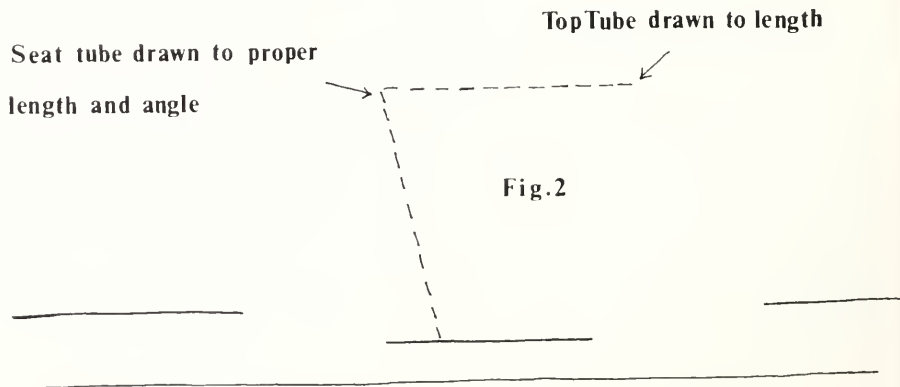


Fig.1

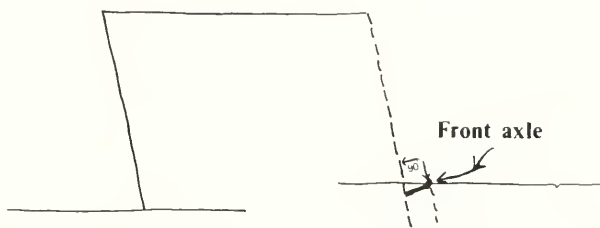
From a point on the bottom bracket line draw in the seat tube to the proper angle using your protractor. The length of the seat tube should be the length you have chosen. Next, put in the top tube. This should be drawn in parallel to the ground (there are some cases such as pursuit frames where the top tube slopes down, however, for a novice frame builder, this is an added complication) and the length you have chosen. The top tube line should connect to the seat tube about 1/2" below the top of the seat tube. This is done to account for the fact that the top tube center line is not the top of the top tube. So 1/2" allows the seat tube to be drawn to its full length where it intersects the top of the top tube. (Fig. 2)



The head tube center line is drawn in next. It should be attached to the end of the top tube and run at the angle to the ground you have chosen. Make the line longer than you need. Start a few inches above the top tube and continue down to the ground line. Set your protractor for  $90^\circ$  and draw a line perpendicular to the head tube that passes through the front axle line. The distance from the head tube to the front axle line should be equal to the fork rake length. The intersection of the fork rake length line and front axle line is the location of the front axle. (Fig. 3)

### Head tube center line at correct angle

Fig.3



From the front axle, measure a line to the head tube equal to the fork length. Make a mark on the head tube line where this occurs. This is the brake hole. About  $7/8$ " above the brake hole is the end of the head tube--make a mark there. Another inch above that is the point of the intersection of the center line of the down tube with the head tube. Again, mark this point. (Fig. 4) These distances are approximate and vary depending on headset manufacturer, style of crown, lugs and frame angles.

Above the point of intersection of the top and head tube add  $3/4$ ". This marks the upper end of the head tube. Now draw a line

connecting the center of the bottom bracket to the intersection point of the down tube and head tube. This line represents the down tube. Measure its length, and the angle it creates with the head tube. Write in this information on your drawing. (Fig. 5)

Fig.4

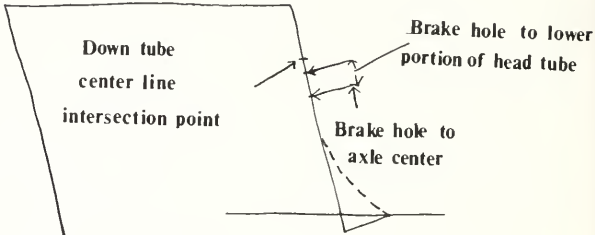
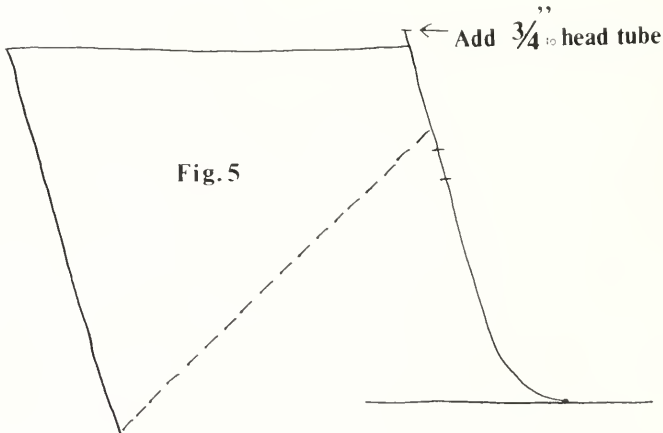


Fig.5



From your bottom bracket, draw a line that touches the rear axle line. The length of this line should be the same as your desired chain stay length. The intersection of this line and the rear axle line is the location of the rear axle. From the rear axle draw a line connecting to the top of the seat tube. This line represents the seat stays. Measure the length of the seat stays

and write it in on your plan. (Fig. 6)

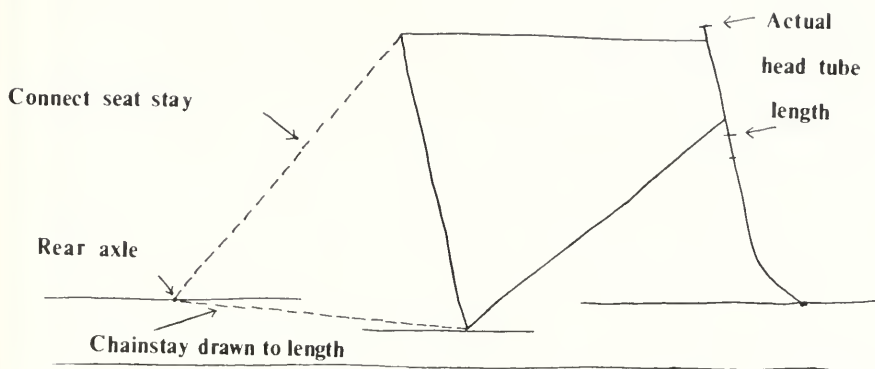


Fig. 6

You have now completed your plan and it is necessary to check a few items. Start by using your compass to mark the edges of the tires. Make sure the tires do not hit either the seat tube or the down tube. If the front wheel toe clip clearance is important to you, measure the distance between the center of the bottom bracket and the front axle to see if you have allowed enough room. Now measure your wheel base and see if you are satisfied with that length. If not, decide what you want to change and make a new drawing. Remember that the length of the head tube is actually  $1\frac{3}{4}$ " longer than the distance between the intersections of the top and down tubes. Don't forget that all measurements are center to center.

#### SELECTING FRAME MATERIALS

Another aspect of frame design is choosing the gauge of tubing most suited for your needs. One problem for a person building only one frame is his/her lack of ability to get the frame components he/she likes. This will be specially true regarding the

gauge of tubing. Most sets available in this country are: top tube 21/24, seat tube 21/24, and down tube 20/23. These are all the lightest gauges commonly available from Reynolds. Other manufacturers, such as Columbus Vitus and Ishiwata make lighter gauges. The higher the gauge number, the thinner the wall diameter. Therefore a Reynolds 20/23 down tube has the thicker 20 gauge on either end, with the thinner 23 gauge in the center. The reason the set comes with the down tube as the heaviest tube is important. This tube is usually considered the most critical tube with reference to stiffness. In many cases, manufacturers will use a Reynolds plain gauge down tube to stiffen a frame. You may also want to consider that as a possibility. Reynolds also makes a heavy and light gauge head tube. It is not butted. The most significant difference between the two is that the heavier one needs considerably more reaming to get a headset to fit into the head tube. As a general rule, a small frame can usually use the lightest tubes, whereas a large frame will need heavier ones. In choosing the gauges, keep in mind that weight is not the only factor. There exists a trade off between weight and stiffness that only you can decide upon.

A final point you may want to consider regards type and manufacturer of dropouts. There are three general styles of dropouts-- track, road and vertical. Track dropouts are for track bikes and only track bikes. It is very difficult to mount a derailleur on the rear dropouts. The only exception to this would be with the addition of a derailleur hanger (Campagnolo makes one). Road dropouts are the most common style and are used on almost every road bike except those with very short wheelbases. In the case of a very short chainstay a problem exists placing the wheel into the frame.



Usually the end of the lower lip of the dropout is about an inch forward of the position where the axle sits in the frame. Therefore it is necessary to slide the wheel about an inch forward before it can be secured into the frame. With short chainstays, one inch of space is not available. There is only one problem with vertical dropouts in general. That is, there is no horizontal adjustment of the wheel in the frame, therefore, they must be placed into the frame exactly in the proper position. If they are off slightly they can also be filed to make the wheel fit.

I consider Campagnolo track dropouts to be the best. As for road dropouts, either Campagnolo or Suntour are well made. Suntour has a unique system of offsetting the seat stay attachment tabs. This has the advantage of keeping the seat stay clear of the chain and freewheel. As far as vertical dropouts are concerned Suntour may make the best. The problem with Campagnolo verticals is that the dropouts are vertically flat. They have no raised or reinforced area for the axle attachment. As a result the chain and freewheel will almost always grind against the seat or chainstay. One way to overcome this is to braze a washer onto the inside of the rear dropouts.

#### Braze Materials

There are two categories of braze materials to consider for use on building bicycle frames--silver and bronze. Many other braze materials do exist, however, silver and bronze seem to work the best. Bronze is the most common material used. This is primarily due to its low cost and reliability. Bronze has a high tensile strength, fills gaps well and has a melting temperature around 1600 degrees F. Steel tubing and Reynolds tubing must be heated over 2000 degrees F.

before any damage will occur. So even with the use of bronze a safety factor of a few hundred degrees exists. For an experienced brazer this presents no problem. It should also present no problem to a beginner either. However, two things can make bronze difficult to work safely with on tubing. First, the main tubes of a frame are very thin. Consequently very little heat is required to bring them to brazing temperature. And since they are so thin they do not dissipate heat very quickly, which tends to make them very difficult not to overheat. Second, the flame used to braze is somewhere around 5000 degrees F. If held in one spot too long this intense heat can ruin a tube. This is especially true since bronze material needs a very sharp flame, where the ratio of oxygen to fuel gas is very high. This flame is necessary to make the bronze flow correctly. Using a cooler flame will only result in a sloppy joint and overheated tubes. This is due to trying to make the bronze flow with the wrong flame, causing the brazer to heat the tube for too long a period. If the brazer has the proper flame and keeps the torch moving, bronze is an excellent braze material. Silver braze material is usually a certain percent silver, and the rest of its components similar to bronze. The higher the silver content the lower the melting temperature, the easier it is to flow, the smaller the gap it will fill and the more expensive it becomes. Sixty percent silver may be thirty to forty times as expensive as bronze. For the lugs of bicycle frames, 45% to 60% silver works best. The melting temperature is around 1100 degrees F. and a cooler flame with a lower oxygen to fuel gas ratio is used. Because of those characteristics, damaging the tubing is almost impossible. However, using the silver on large gaps such as seat stay clusters

is almost out of the question. This is because the silver becomes so thin, it will not build up or fillet. So either a smaller silver content material is used or bronze material is used. Silver generally has a higher tensile strength than bronze. However, when a gap of over 3 thousandths of an inch occurs the silver can lose seventy-five percent of its strength. This is not true with bronze. When buying silver, be careful not to buy it if it contains cadmium. This is a deadly heavy metal. Always ask for cadmium free silver braze material.

The last consideration is the form of the material. Rods are almost always used. Usually 1/16 inch rods are preferred. However, 1/8 inch rods are sometimes used where a large buildup of material is needed. A good combination is to use silver for the lugs and bronze for all other joints.

## T H E   M A I N   F R A M E

### Mitering the Tubes

The main frame consists of the head tube, top tube, seat tube, down tube, bottom bracket shell and lugs. Having drawn up a design for your frame, you know the center to center measurements for your frame. However, this must be translated into actual tube lengths, so the frame will fit together properly. The tubes must also be mitered, that is, scalloped out at the end of the tube to the proper angle and curve, so they fit nicely against the other tube. When using machine cutters a perfect fit is attainable. More than likely, you will be using a file. In that case, a perfect fit may not be possible. Don't worry though, some of the most famous European frame makers don't do any better.

The first miter you will work on is the top tube head tube joint. First use a protractor and draw out the angle of your top tube to head tube to match your plan. This will give you a reference for checking your mitering as you go. The best file for this operation is 12" half round with a coarse cut. Before you go any further you may want to make some wood blocks for holding your tubing without damaging it. You can make this from a piece of 2" square hardwood, about 3 or 4 inches long. A larger piece is fine providing it will fit into your vise or whatever you use to hold things down. Drill a 1 1/8" hole lengthwise through the wood. Now cut the wood in half lengthwise and file the exposed edges down about 1/8". These wood blocks will be able to hold all your tubes except the head tube. Put the top tube in the wood blocks in a vise in such a manner that the Reynolds marking is up. (Fig. 1) Start filing at what you guess is the proper angle. After you've made a little headway, take the tube out of the wood blocks and hold the head tube up to the miter in your top tube. Lay the assembly against your angle drawing and note your error. Also check to see if the curve you are creating in the end of the tube matches up with the curve of the head tube. Put the top tube back in the vise with the wood blocks. Start filing, remember your errors and make the needed corrections. Keep repeating this procedure until you come as close to perfect as you think you are able. The next joint to work on will be the down tube head tube joint. It should be done the same way as the top tube except the angle will be different.

The seat tube must be mitered now and you will have to prepare the bottom bracket shell before you will do it. Preparing the

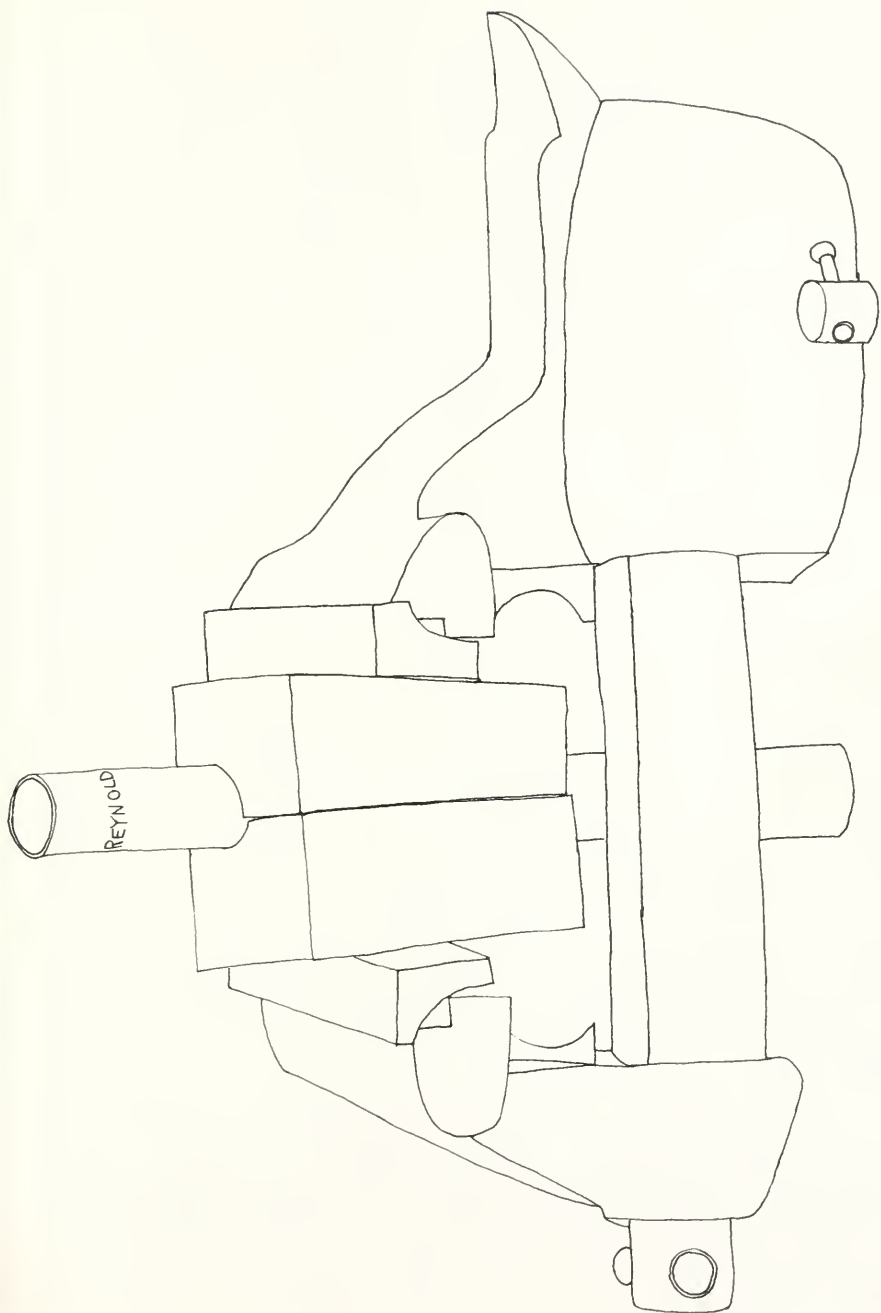


Fig.1

bottom bracket consists of filing the edges as you want them and then reaming the large tube holes so the tubes will fit. If you happen to have access to a 1 1/8" reamer, use it to ream the holes. More than likely, you will need to use a large round or small half round file. Evenly file the insides of the holes until the tubes fit. It may be necessary to sand the burrs off the edges of the tubes before they will fit. The seat tube gets mitered on the Reynolds marked end twice. Once to fit the curve of the bottom bracket shell and once to allow the down tube to slide into the bottom bracket. First miter the tube for the bottom bracket by using a 14" half round file. File perpendicular to the tube until it is mitered to your satisfaction. Sand off any burr you might have created. Put the seat tube into the bottom bracket until the curve of the miter is flush with the interior curve of the bottom bracket. Take a scribe or other marking tool and trace the outline of the down tube hole in the bottom bracket onto the part of the seat tube blocking the hole. Pull the seat tube out and file away the part which was blocking the hole. This would be done with a 10" half round file at about a 60° angle until you are even with the scribe marks you have made. Sand off any burrs and reinsert the seat tube making sure you have filed the tube properly. You are finished with the seat tube and now must miter the other end of the down tube.

The down tube will be mitered like the seat tube except it will not get the second miter. Also, the length of the down tube is very important. From your plan, ascertain the length from the center of the bottom bracket shell to the center of the intersection of the down tube to head tube. Knowing their length put the down tube into

the bottom bracket shell and hold the head tube up against the mitered end of the down tube. Measure the center to center distance and compare it against your plan. If the actual distance is too short, put the down tube a little less far into the bottom bracket. Should the distance be too long, cut the unmitered end of the down tube off by the amount the actual measurement exceeds your plan. You should now have the assembly set up so that the actual and planned center to center distances are the same. Make sure the head tube is perpendicular to the threaded bore of the bottom bracket. With everything set, make a mark with a scribe or other tool along the intersection of the down tube and inside threaded bore of the bottom bracket. Pull the down tube out and file down to the line you have made using a 14" half round file. Sand off the burrs, reinsert the down tube and check your measurements.

Mitering the other end of the top tube is the most difficult of all. You must similarly have the proper center to center measurement, angle and scallop. Put the unmitered end of the top tube against the seat tube and the mitered end against the head tube. Measure the center to center length of the intersection points of the tubes. Compare this to your plan. However much longer the distance is, cut off that amount minus  $3/4$ " from the unmitered end of the tube. For example: Actual measurement is 24", the plan calls for 22"--a difference of 2". Subtract  $3/4$ " from 2" to get  $1\ 1/4$ ", the distance you must cut from the end of the tube. The miter on each end of the tube should be parallel with each other in the plane of the head tube-seat tube. To accomplish this, take a straight edge and draw a line down the center of the tube from the low point

of both sides of the existing miter. (See Fig. 2.)

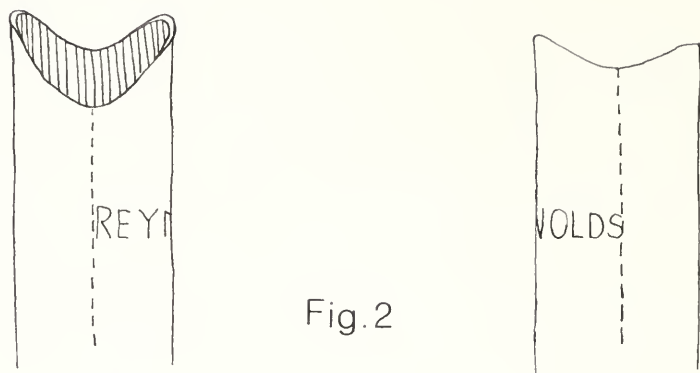


Fig.2

These lines will help you line up your miter. Don't forget that your miter should be nearly parallel as in Figure 2b. Little by little make your miter with a 10" half round file. Check your angle, cut and lines for accuracy. Proceed until your center to center measurement is the same as your plan. Your main frame tubes are now mitered. Cut your head tube about 1/8" larger than your plan calls for. This will allow for dressing the head tube ends later on. Put your top tube against the head tube the way it will fit together in the final frame. Trace around the top tube onto the head tube. Remove the top tube and drill a 1/4" hole in the head tube in the center of the traced circle. This will be the vent hole to allow expanding gases trapped in the top tube to escape. Take all your tubes and sand the ends to remove any burrs.

\*SAND AREAS lugs will cover to aid in adhesion of braze material.

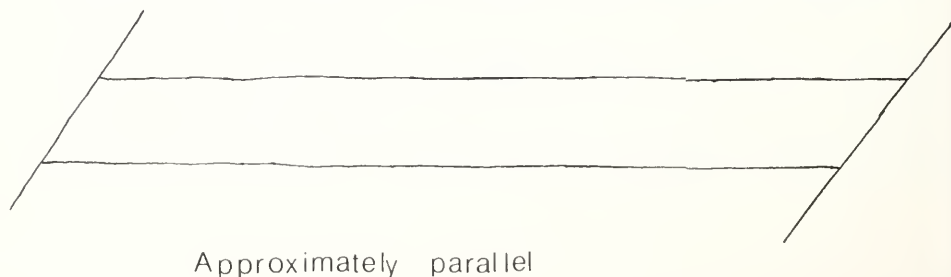


Fig. 2b

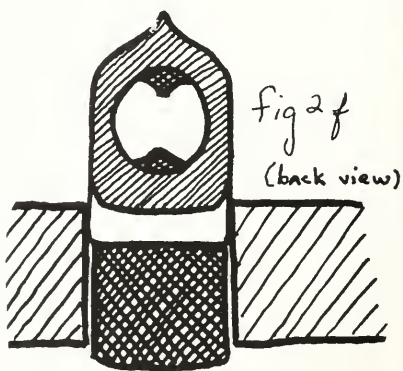
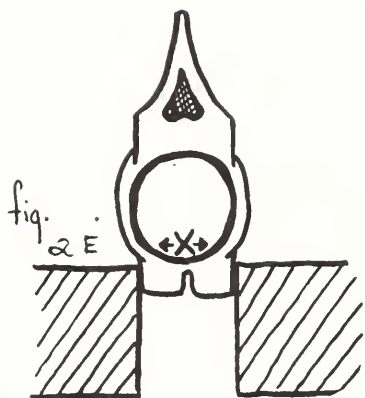
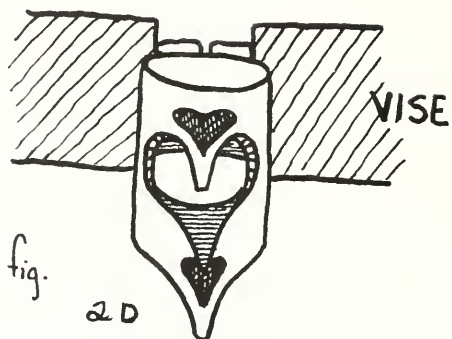
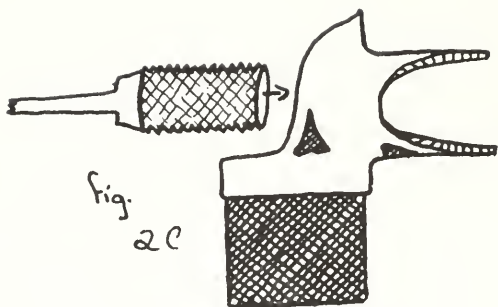


### Preparing the Lugs

The next step is to prepare the lugs. The most important thing is a proper fit. Refer to General Procedure for this description. The techniques that you can use to achieve this fit vary. Reamers the same size as the tubes the lugs are to fit over can be used. One problem with reamers is they catch on the edge of the lug. Also, if care is not taken, they may bend or distort the lugs. Filing is the next best method. A medium size coarse round file is good for this purpose. A problem encountered here is holding the lugs when filing. The lugs may be placed on a tube or held in the hand. Either way is fine. The last method is to use a small grinding stone on the end of a power tool. One advantage to this method is the small amount of pressure needed. This eliminates the difficulty in holding the lug firmly.

Top and down tube lugs may be slipped on a scrap head tube, or better yet, on a solid round the same diameter as a head tube, then placed in a vise without distorting the shape of the lug. (Fig. 2c) Seat lugs can be held in the vise by the seat bolt guides on the back of the lug. (Figs. 2d and 2e) When possible place all lugs into vise with points facing away from you. (Fig. 2f ) This prevents accidental destruction of the points by the grinder. Grind small amounts at a time, checking fit as you go, making sure you do not grind away too much.

With the Prugnat "S" series lugs--solid and cutout--no grinding is necessary on the back inside of the seat lug. (See "X" in Fig. 2b.) We use a 1/2 inch diameter carbide burr and find that larger sizes tend to catch the lug interior, causing the bit to jump about and mar the interior surface.



Filing the lug outline is the last step in preparing the lugs. This will vary depending on the style of lug used. A fine grit (1/2" x 6") grinding stone on a table-type power grinder is excellent. Make a smooth, clean, flowing, outline of the lug and remove any irregularities. Keep the appearance symmetrical with any points to center lines. For the cleanest possible lug line, grind all edges perpendicular to the tube surface that it touches.

After grinding the inside surface to fit, and after grinding the edge lines, file off any burrs which mar a smooth lug line even if the brazing is perfect. Don't worry about the surface of the lug; you will find finishing of the exterior easier after the lug has been brazed.

#### Brazing the Main Frame

The brazing of the main frame will take place in the following sequence. The top tube will be brazed to the head tube at the proper angle. Once this is done, and all the other tubes are the proper length all the other angles should come out the same as your plan.

Flux the top tube headjoint and put both tubes into the lug. Make sure the center of the top tube is in line with the center of the head tube. (See Fig. 3.) Center to center alignment is dependent upon proper mitering.

The head tube should protrude about 1/16" beyond the lug. Lay the assembly against a drawing of the proper angle you have marked on a piece of metal. If the tubes don't coincide with the drawing, bend the joint until the tubes will stay at the proper angle without being held.

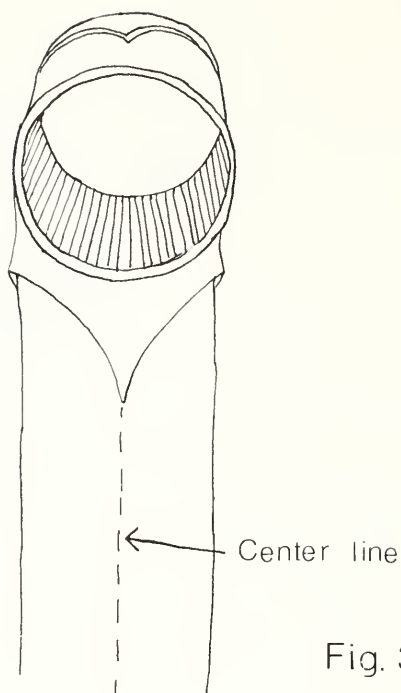


Fig. 3

If possible, use some sort of adjustable clamp.. An adjustable clamp, properly set to gently hold the lug next to the tube surface, can be of great assistance in obtaining the exact angle you desire.

If a gap exists between the lug and the head tube, clamp the lug as shown in Fig. 4. Clamp the lug with only the minimum pressure needed. Don't worry if the points of the lug are not pressed down against the top tube. If you have everything straight, proceed to braze. Start on the head portion of the lug. Slip the braze material under the lug and flow it to the top tube and end of the head tube as far as you are able without lifting the tubes. (See Fig. 5.) If you used a clamp, let the joint cool and then braze the

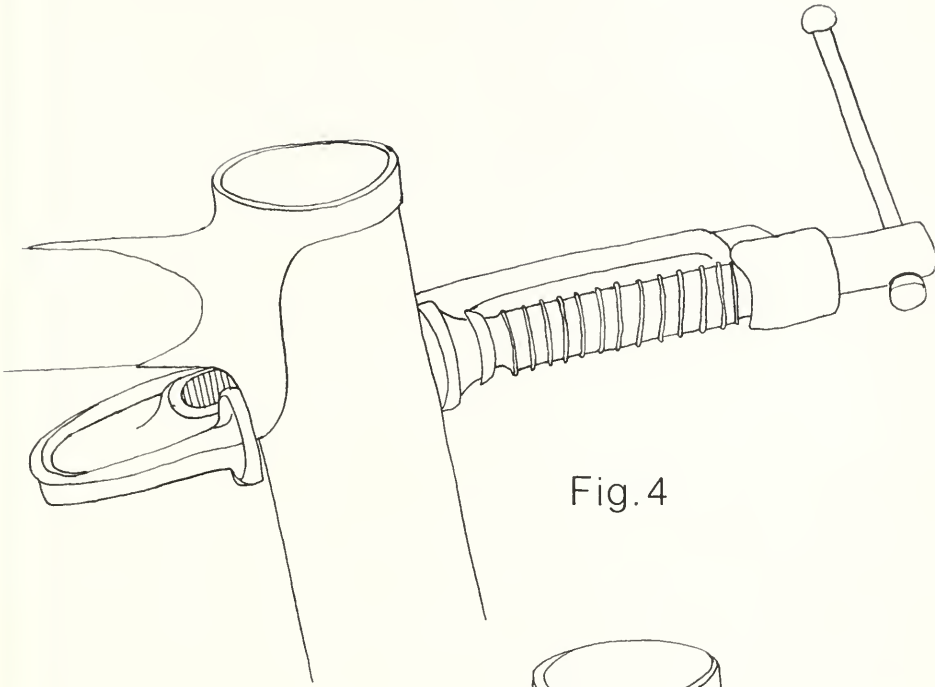


Fig. 4

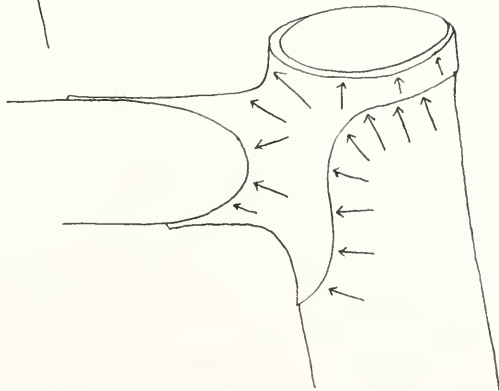


Fig. 5

area where the clamp was. Turn the joint over and braze in the same manner. Be sure to smooth out any areas where the two brazing procedures overlap. Draw excess braze material under and around lug. Try not to leave a large excess of braze material on exterior of lug line, but be sure to fill in interior as much as possible. Scrape excess flux and/or braze material off with cool brazing rod end, and smooth line with flame. To braze the lug section on the top tube bend the points of the lug down against the top tube. If they will not stay down, you have two choices. First, you can clamp them with some light pressure or heat them and tap them down. Either way could damage the top tube, so be gentle with it. Braze from the circular section of the lug out to the point of the lug. Be careful when brazing the tip. It is very thin and easily overheated. If you seem to be putting in more braze material than necessary, make sure the braze material is not going in one side and coming out the other in a big blob. One prime concern should be to avoid overheating the tubing. A big blob of braze material or gap under the lug is a minor problem compared to a cracked tube. The blob can always be filed and the gap may be insignificant to the overall strength of the joint. Having completed this joint, allow to cool slowly. Flux and assemble the whole main frame including the bottom bracket. Check all the joints to be sure their centers intersect. Line up the edge of the head tube with the edge of the seat tube to be sure the tubes of the frame are in the same plane.

If the head tube is very small, this may be very difficult. In that case, put another tube inside the head tube and lay the whole thing on a table to be sure everything is lined up. (See Fig. 6). Proceed to braze the down tube-head tube joint the same

as the top tube joint. After brazing the joint and letting it cool, check the frame to make sure everything is lined up, straightening anything that isn't. Next comes the seat tube-top tube joint. It should be brazed like the other joints with the exception that it should follow the pattern in Fig. 7.

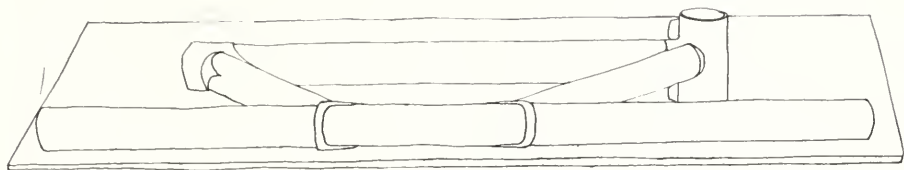


Fig.6

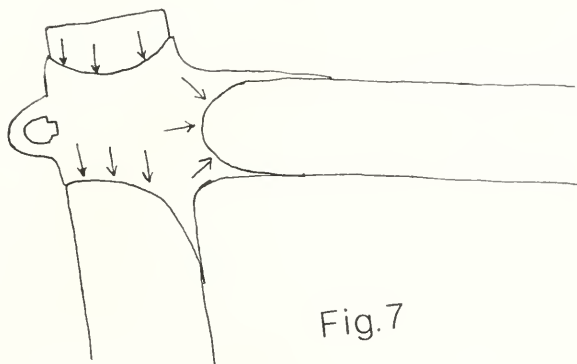


Fig.7

On small frames it is a good idea to cut off the seat tube about an inch longer than necessary. This will make the frame easier to handle and will eliminate the need of having to slide the seat lug several inches down the seat tube.

After brazing the seat tube lug, brush some flux on the joint while still warm in the areas where the seat stays meet the seat lug. It is difficult to make flux adhere to the cool joint when the frame is in a vertical position and the heat of the brazed seat lug will insure adhesion. Don't worry, by the time you apply the flux,

the frame will have cooled enough so as not to lose its annealed condition.

The final joint of the main frame assembly is the bottom bracket. The problem with the joint is lining it up without an expensive jig set up. To do this, you will need a decent pair of bottom bracket cups, an accurate straight edge and a ruler. Screw the cups into the bottom bracket shell. Only 2 or 3 turns are necessary. Be careful not to cross thread them. If the cups won't go in even 2 or 3 turns, you may have to have the threads of the bottom bracket shell cut. One way or another get the cups in a couple of turns. Hold the frame in wood blocks by the down tube as shown in Fig. 8.

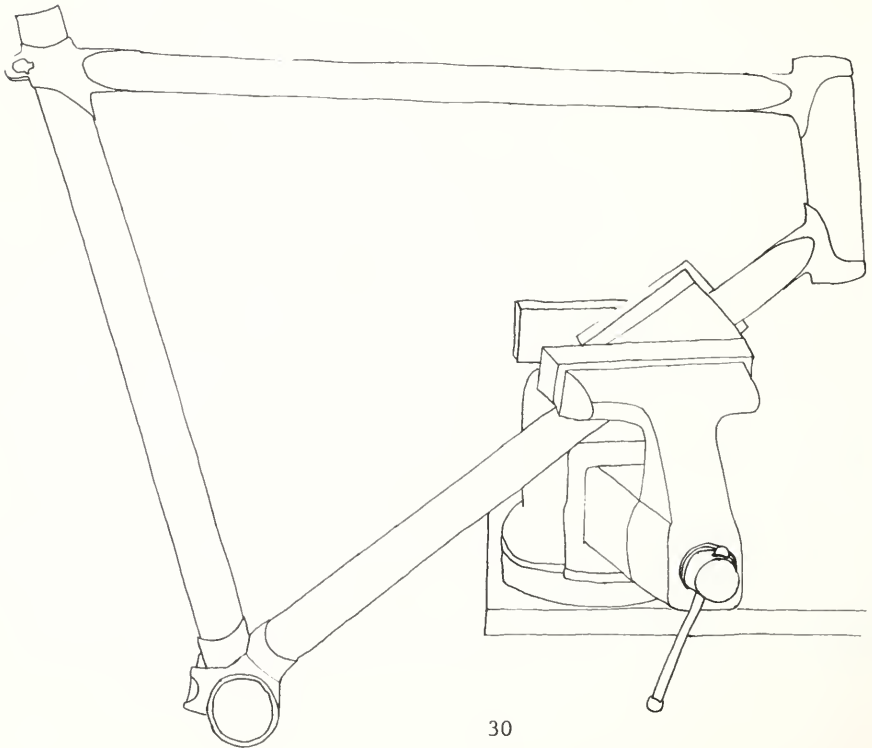


Fig.8



Place the straight edge against one of the cups and alongside the down tube. Measure the distance from the straight edge to the tube near the bottom bracket and then from as far away from the bottom bracket as possible. Adjust the bottom bracket shell until the two measurements are the same. Do the same with the seat tube. Then go back and check the down tube. (Fig. 9)

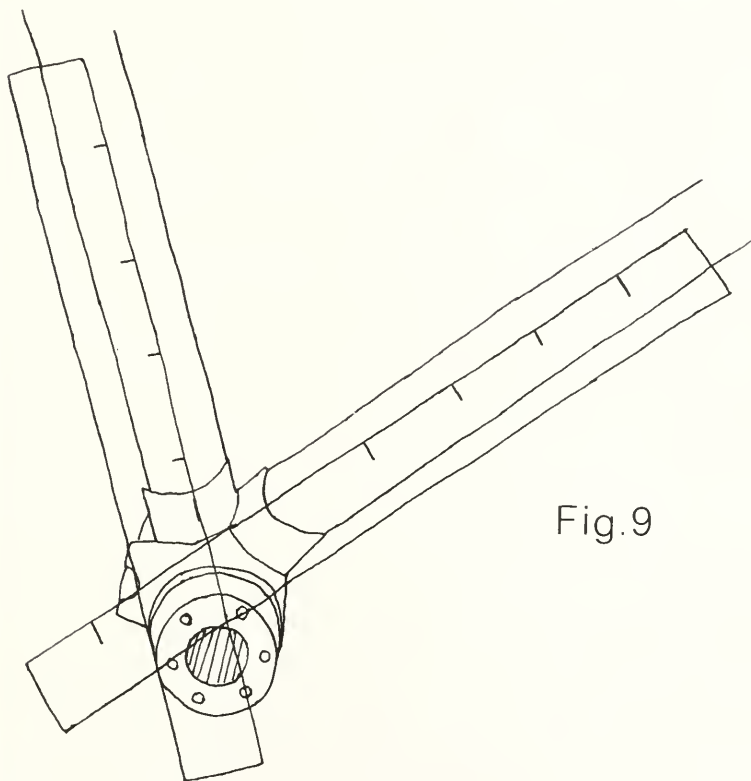


Fig.9

ruler should be  
parallel to tube

As a further check, use the other side of the bottom bracket. To get both sides of the bottom bracket perfectly parallel to the tubes may be impossible. If that is the case, do your best to even out the errors on both sides. When you have everything straight, don't

touch anything. You don't have to take out the cups, they will come out easily enough when you've finished brazing. To braze the bottom bracket, heat a broad section of the bracket about 1/4 of the way around the tube from the intersection of the bracket with the down tube to the threaded portion of the bracket. Work your way around each tube using a downward stroke to flow the braze material into the bottom bracket. After you have finished both tubes, you can take the cups out and inspect the inside of the bottom bracket. Don't be surprised if you did not get much penetration of the braze material. It takes very experienced people to get good penetration. If you want, you can add more braze material to the inside of the bracket.

Two more operations must be done with the main frame before you can proceed to the next section. First, you must perform a final check in the frame alignment. If it is not in one plane, you will have to bend the head tube in relation to the seat tube to straighten the frame. To hold the frame, put the bottom bracket in a vice and put the other end of the seat tube against a cushioned immovable object. Next, insert some cheap headset into the head tube. These headset pieces will keep the head tube from distorting. Insert a heavy pipe that fits the head tube and bend the frame until it is straight. A properly brazed frame may take two people to straighten it. (See Fig. 10.) Second, the head tube must be reamed and cut square so that a headset can be properly fitted. Almost every headset made fits the same diameter headtube bore. Even Zeus cutters which have a slight taper are good enough for any head set. This cutting operation can be performed by any reputable bike shop. The only other thing to do now is roughly finishing the back of the

seat lug. This is often done at this time since removing large amounts of material from the seat lug is difficult after the seat stays are attached.

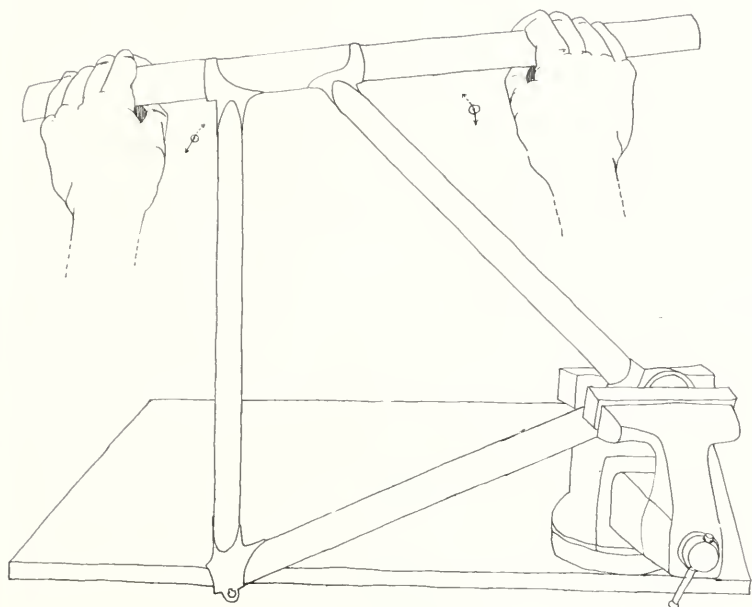


Fig 10

### THE REAR TRIANGLE

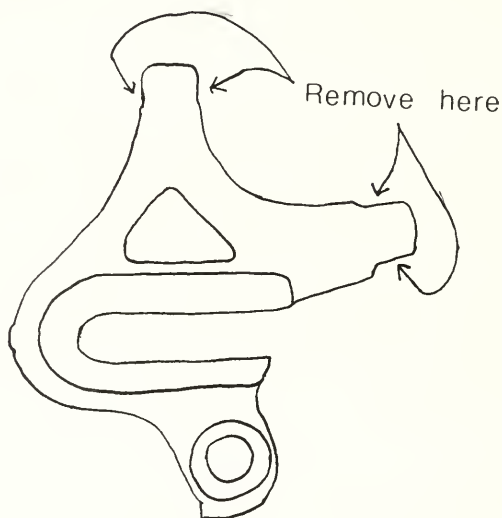
The rear triangle consists of the chainstays, seatstays, rear dropouts, chainstay bridge and seatstay bridge. The parts should be assembled and brazed in the following order. Rear dropouts are fixed to the chainstays. Seat stays are then attached to the dropouts. The chainstays are brazed to the bottom bracket while the seat stays are brazed onto the seat tube lug. Finally the seatstay and chainstay bridges are put into place.

#### Brazing Dropout to Chainstay

To attach the dropouts to the chainstays a few things must be

kept in mind. First, the style of joining the pieces must be decided upon. This style can be chosen from the section on finishing stay and fork ends. Usually the style of the chainstay ends, seatstay ends and fork blade ends all match. In most cases the dropout will be too large to fit into the chainstay end. Therefore the dropout must be filed. Remove an equal amount of material from both the top and bottom of the dropout. (Fig. 1)

Fig. 1



At the same time you should be preparing the seatstay ends so that they will fit properly. To do this, remove material from the top and bottom of the dropout where the seat stay attaches. The width of the dropout should not be changed. If it is too wide to fit into a slotted end, widen the slot. This can be done with a small file or hacksaw. A snug but not too tight fit of the dropout is preferable. If the chainstay is open ended, be very careful so when the dropout is brazed onto the stay, the sides of the oval or crimped section of the stay will be perpendicular to the ground.

(Fig. 1a) The important point in brazing the dropout onto the chainstay is to be sure that both dropouts line up exactly the same when the chainstays are laid one on top of the other. To braise the dropouts, clean and flux the parts. Place the assembly in a vice. (Fig. 2)

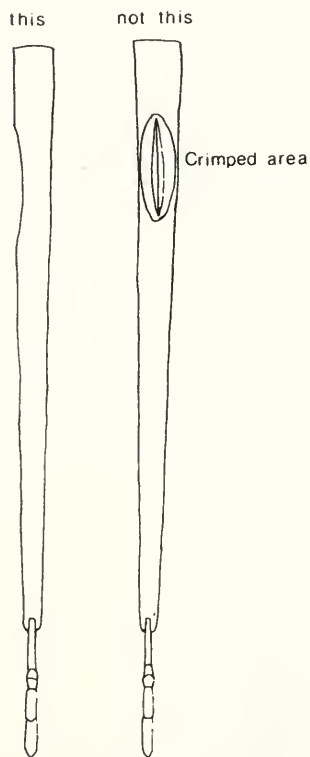


Fig. 1a

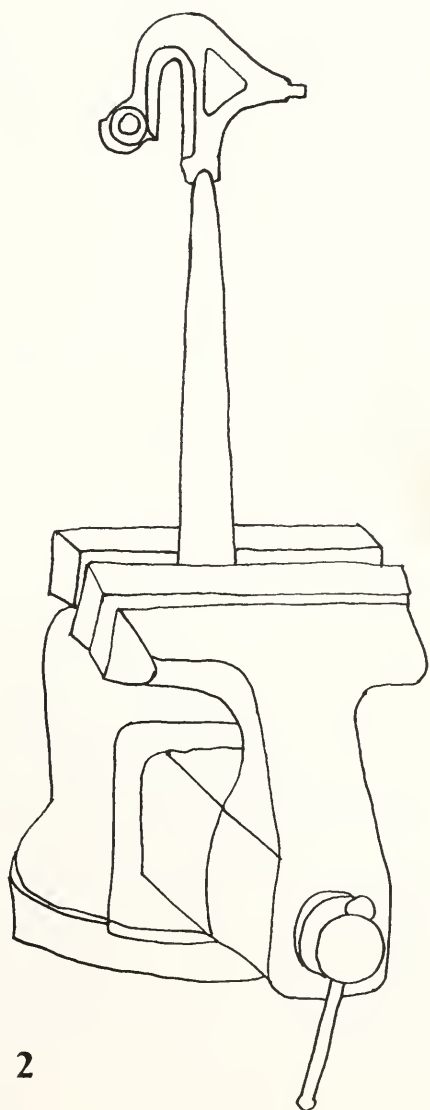


Fig. 2

The dropout may be able to swing a few degrees in either direction. Pick the midpoint of the swing as the position to braze. If your dropout is firmly held and does not swing, just braze it where it lies. To start your brazing heat your dropout to the proper temperature first, then heat the stay end and add braze material. (Fig. 3) Work the material across the joint so that it comes out the opposite side. If this seems impossible, do not continue heating the metal. Instead, add braze material from the other side. Next, do the other face of the dropout adding braze material in the same places. Finally put a little more material on the places where you started brazing. This is where pin holes most often occur and the extra material can easily be filed from there. Now the other dropout must be brazed to the other chainstay. When you do this, lay the chainstay assembly over the one you just finished brazing. Swing the dropout until it exactly matches the other one. Now carefully put the assembly into the vise. If you think it moved check it again against the brazed chainstay assembly. Now is the best time to file the assembly since

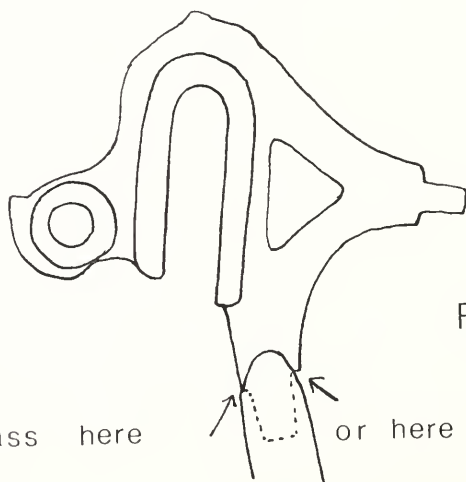


Fig. 3

Add brass here

or here

it is easy to hold and get to. Once brazed onto the frame it will be difficult to hold and the seat stay will be in the way. The other end of the chainstays must be mitered to fit in the bottom bracket shell. To do this start by preparing the bottom bracket shell stay holes. Usually the holes will be a little small. In that case you must either file the inside of the holes with a large round file or ream them with a 7/8" reamer. If the stay are too tight a fit, tap the stays in gently. Then wiggle them around a bit to loosen up the holes. Don't over do it, just relieve a little of the tightness. With the stays fitted properly, insert them the proper distance into the bottom bracket so that the measurement from your design coincides with that of your actual frame. If your stay are too long to do that, cut some material off. Even though you have measured the stays, they might be off a little, so put a perfectly dished rear wheel into the frame and gently tap one of the rear dropouts until the wheel lines up centered between the two stays. This is done with the wheel pulled all the way back in the dropouts. Get a scribe and trace the line of intersection between the inside of the bottom bracket and the chainstays.

(Fig. 4)

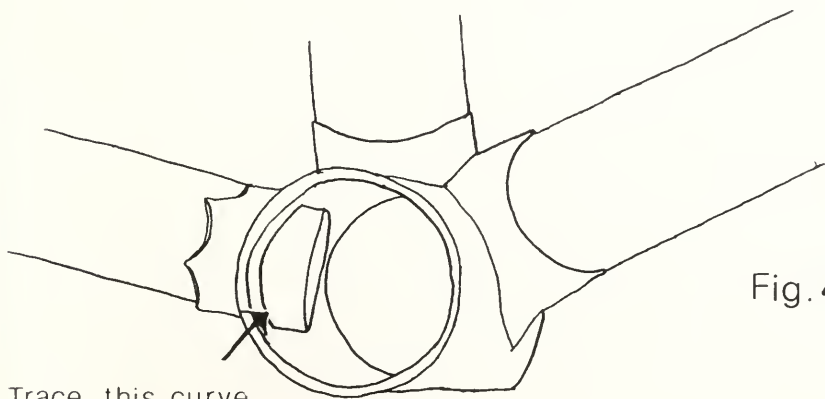


Fig. 4

Using the scribe marks as a guide, cut the stay close to the marks and then file with a large half round file until you match the marks. The ends of the stay should now be perfectly mitered. Check by filing off any burrs and reinserting the stays into the bottom bracket shelf.

#### Attaching Dropouts to Seatstays

The next major step is the attachment of the dropouts to the seat stays. I assume the ends of the dropouts and seatstays have been properly finished to fit together. Vent holes should be drilled on what will be the inside of each seat stay. These holes need not be any larger than 1/8". The best place to drill them is somewhere between where the brake bridge will go and the intersection point with the seat tube.

The frame must be set in a vise, held at the bottom bracket. (Fig. 5) The bottom bracket should be held at the bottom, so there will be room to see inside it to make sure the chainstay are flush with the inside of the shell. From your design you should know the distance from the dropout to the seat lug. Since your design drawing is only two dimensional, do not measure along the seat stay, but along a line drawn down between the two seat stays. Put a perfectly dished wheel in the frame and swing the chainstays until the dropouts are the right distance from the seat lug. Have someone hold the chainstays in that position while you slip a seat stay on each dropout. The seatstays should be held against the seat lug and at the same time the stay should be adjusted so that the wheel sits dead center between them. Using the chapter on seat stay attachments mark the seat stays and then prepare them as described in that section. Clean and flux the dropouts and seat stay ends. Put a wheel in the frame and insert the finished seat stays. Clamp them in place with two pieces of wood and a C clamp making sure that the wheel is centered between seatstays and between the chainstays. (Fig. 6)



High enough to see  
inside

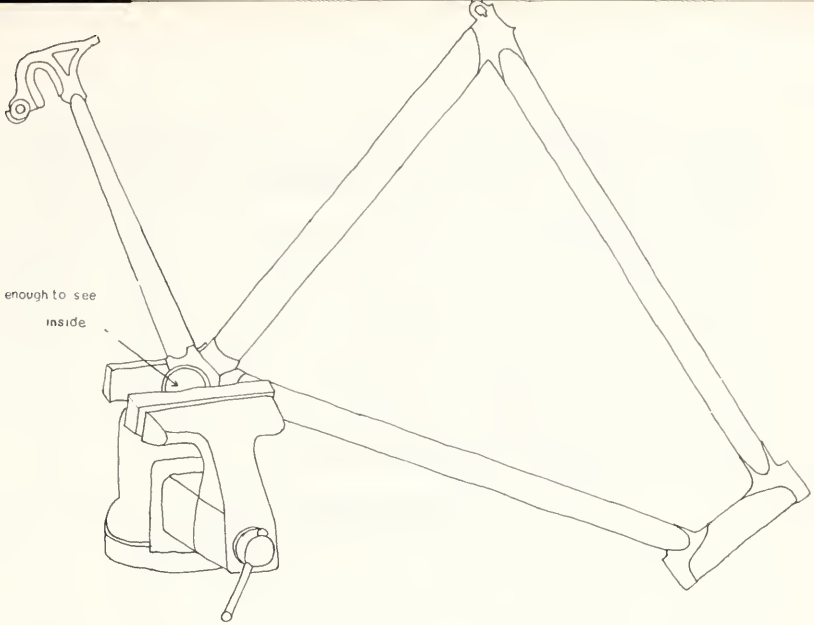


Fig 5

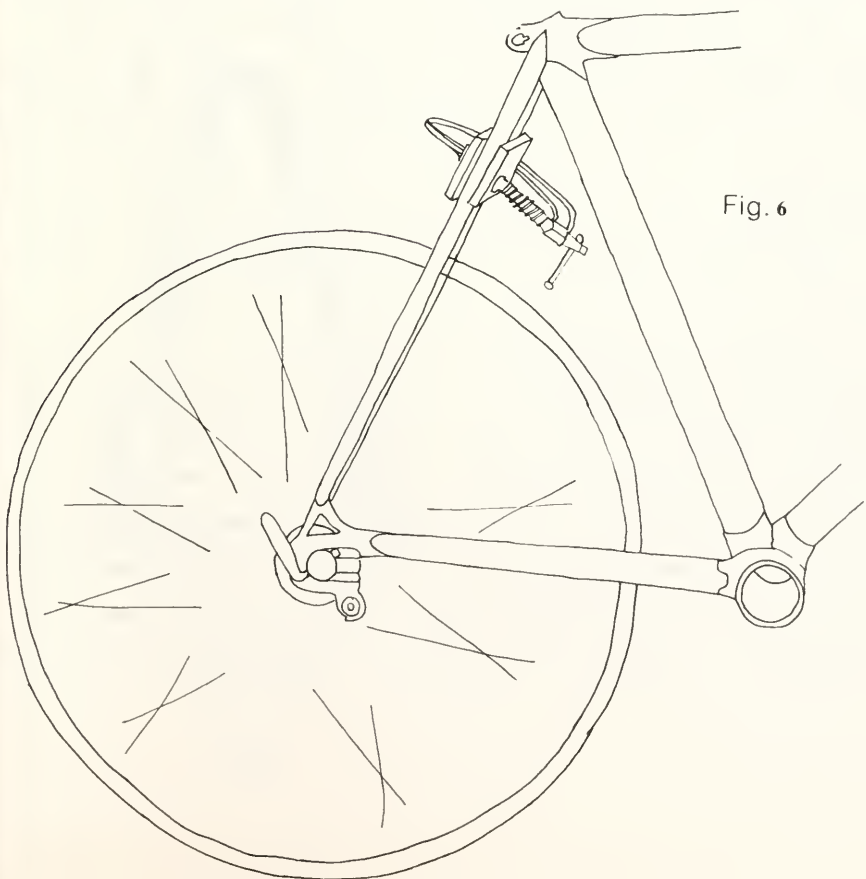


Fig. 6

Gently remove the wheel. Don't worry if the stays move together or apart a little. All that is necessary is for the angle between the seat and chainstays to remain the same. Proceed to braze the seatstay to the dropout in the same manner that you did the chainstay. Remove the clamp and take your seatstay chainstay assemblies that you have just brazed off the frame. Now is the best time to file and finish the joints. Clean and flux the holes in the bottom bracket, the ends of the seatstays and the seat lug.

#### Brazing Chainstay Seatstay Assembly to Main Frame

Reinsert the assemblies onto the frame; put the perfectly disheveled wheel all the way back into the dropouts. Tap the back of the dropouts until the wheel is both centered between the chainstays and the chainstays are flush as possible with the inside of the bottom bracket shell. Next adjust the seat stays so that the wheel is also centered between the seat stays. When this is done, clamp the seatstays with the pieces of wood and C clamp. Next, tie a string around one dropout. Run the string around the head tube and back to the other dropout. The string should be taught. An elastic string would work even better. Measure the distance the string is away from the seat tube on both the left and right side of the frame (Fig. 7). If the distance is not the same on both sides you will have to push the rear triangle assembly either to the right or left depending on your particular problem. However, when you push the assembly you may find the wheel is no longer centered between the stays. Therefore you will have to readjust the stays and then again check the string measurements. In some cases you may find that the wheel seems determined not to sit in the proper place. This is usually caused by a bent dropout. To correct this remove the chainstay seatstay assembly

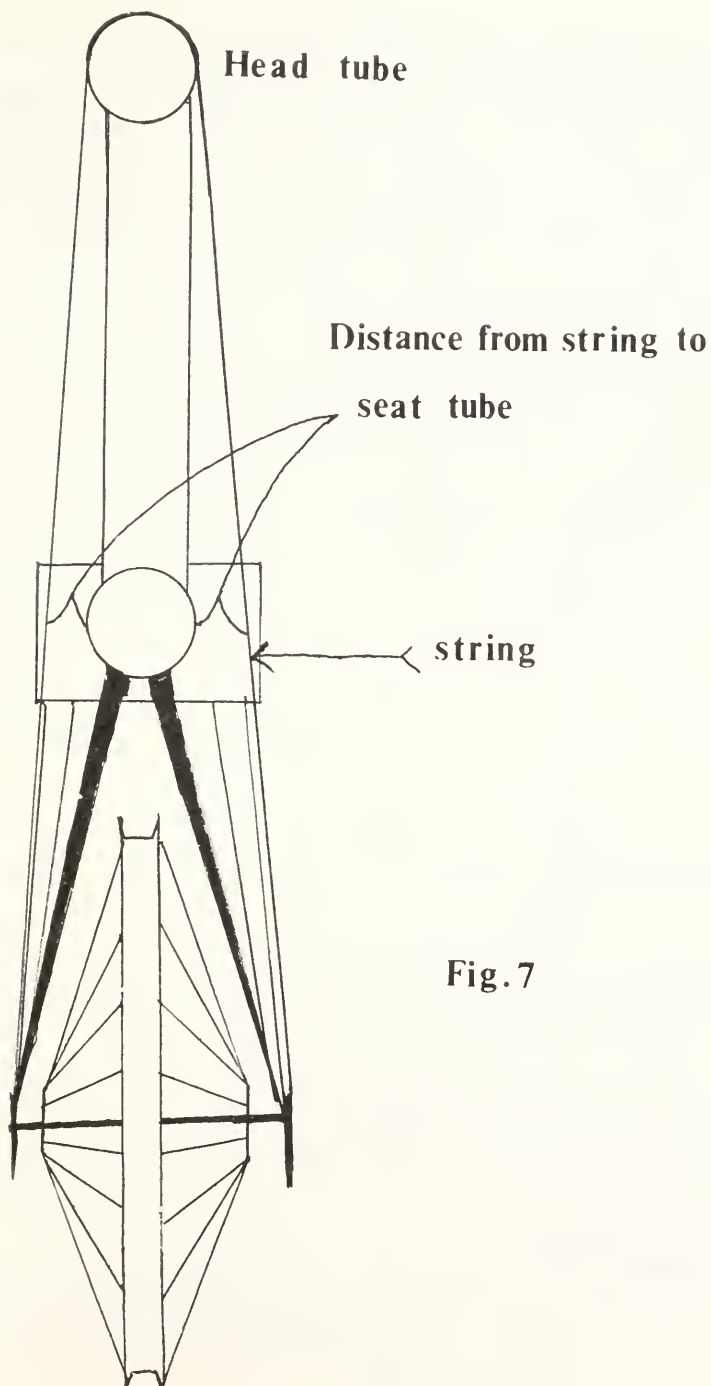
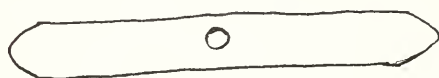
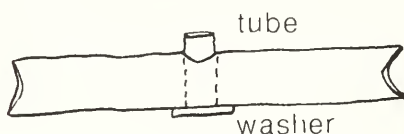


Fig.7

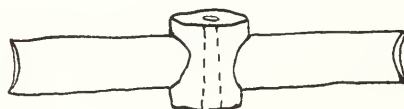
and bend the dropout to correct the problem. In the end, you must have the wheel centered between the stays and the string measurements must be the same. To braze the assembly in place, start by brazing the seat stay attachment. Then, braze the stays into the bottom bracket. Braze the outside portion of each stay last. The technique should be the same as brazing the main tubes into the bottom bracket. Let the frame cool. Take the wheel out and check the string measurements. Not only should the string measurements be the same, but the dropouts should be the same distance apart as the axle. Bend the stays so that they meet those requirements. Insert a hub between the dropouts so that they will remain the right distance apart. Now you are ready to put in your bridges. Choose the style bridge you want from the drawing in Fig. 8. The construction of each style



Simple heavy gauge



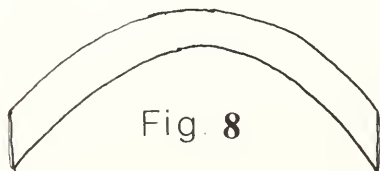
Reinforced light gauge



Tube over bridge



Tube over bridge



Curved bridge may use any of above add-ons

Fig. 8

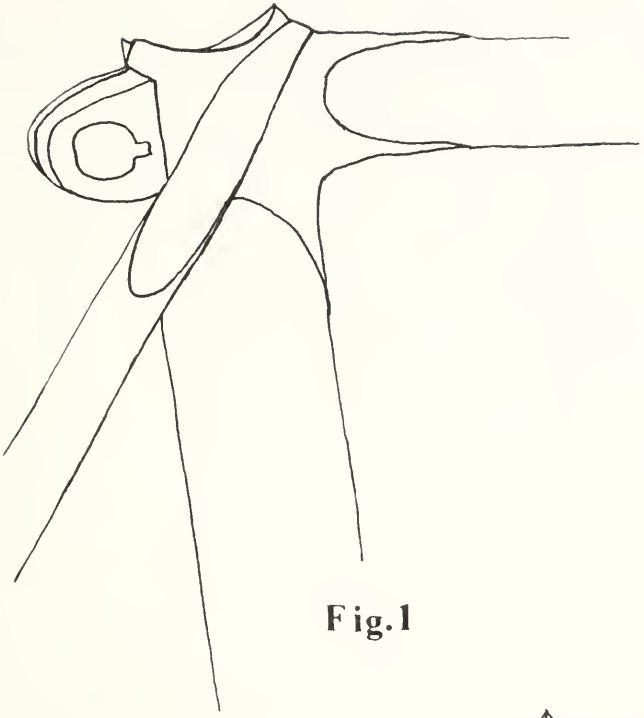
is self evident. To make the bridge, you must first decide where you want to put it. On most racing frames, measure 36mm from the center of the dropout to the center of the bridge, where the brake bridge intersects the seatstay. For touring frames 37mm should do. Measure the distance between the stays at that point and add 1/2". This is the length you should cut your bridge tubing. Use a large round file and miter the bridge a little at a time checking to see when it fits in the proper position. Once this is done put whatever additional fittings you are going to use on the bridge in place. For example, you might braze a washer onto the bridge now. Drill a 1/4" hole for the brake to mount in. If you are making a track bike, you will still need a small vent hole in the bridge. Braze the bridge in place making sure that it is not crooked. This is done by heating the intersection of the brake bridge and seat stay, about half way around the bridge. Apply braze material and then do the other half. Finish by brazing the bridge to the other seat stay. Next, you must braze the chainstay bridge. It is done the same way as the brake bridge except that it only gets a vent hole. Also, it is a different distance from the dropout. The way to find this distance is to put the wheel into the frame that you are going to use when you finally equip the frame. As you put it in, notice how far towards the bottom bracket the wheel goes. This is where you put the chainstay bridge. If you are going to use fenders your bridge should be another 1/2" closer to the bottom bracket. Now heat the outsides of the seatstays and chainstays opposite the bridges, just enough to turn the metal slightly red. This should relieve some stress from the stays. Let everything cool. Proceed with a string test to make sure everything is straight. This is called tracking the stays and does not mean

that you are ruining your frame. The last step is to use some drop-out alignment tools to straighten the dropouts. Most good bike shops can do this for you. If you have not already done so, slot the seat tube lug so it can clamp onto the seat post. To do this, put two blades in your hacksaw to make the slot wide enough.

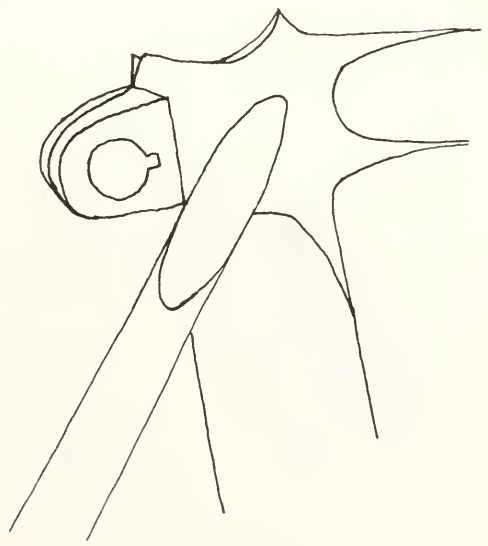
#### S E A T S T A Y   A T T A C H M E N T

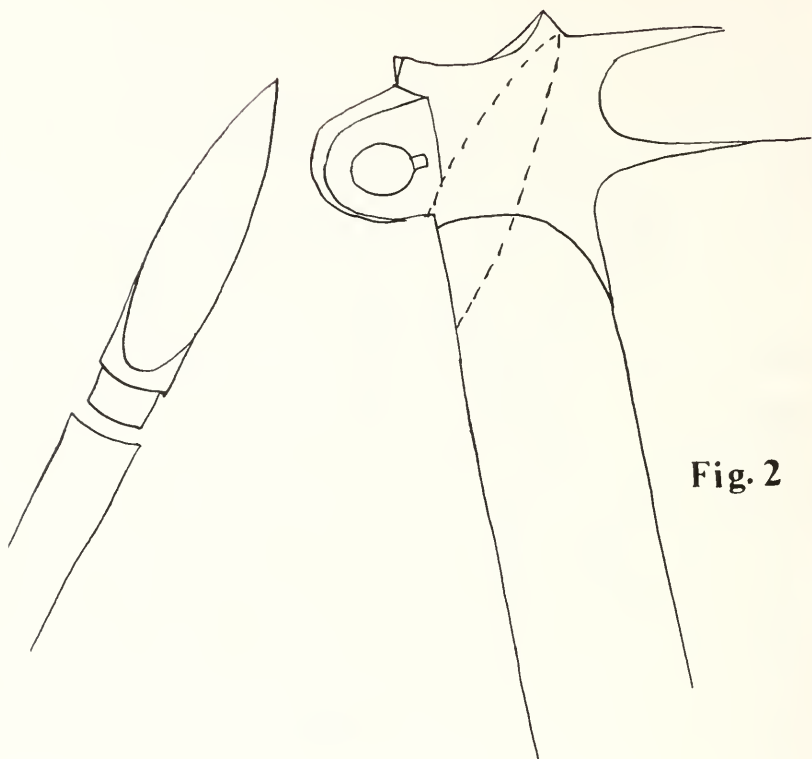
Probably the most variation in frame styles occurs in the way the seat stays are attached to the seat lug or seat tube. Though there are many different styles, I will only discuss a few of the basic ones--the wrap over, the fast back and the scalloped attachment.

The plain wrap over is a fairly simple technique. Sometimes the wrapover is joined on either side and called a wraparound. These styles look like Fig. 1. There are two ways to achieve the chamfer on the end of the stay. First, the stay may be cut square, and a chamfered piece (Fig. 2) may be added. This is the simplest. The only precaution here, is to make sure that the piece is brazed on at the proper length and relationship to the other end of the stay. This is especially true if the stay has already been domed and slotted. The other technique is to cut the end of the stay at an angle and then braze a plate onto the stay. The plate is then filed to match the curve of the stay. (Fig. 3) Which ever technique you use the stay should be cut so the very tip of stay is even with the center of the side of the seat lug (when you don't intend to curve the stay end around the seat lug) or about 1/2" longer than that if you do plan to curve the end around. On the ones that do not curve around the brazing procedure is to position the stays where you want

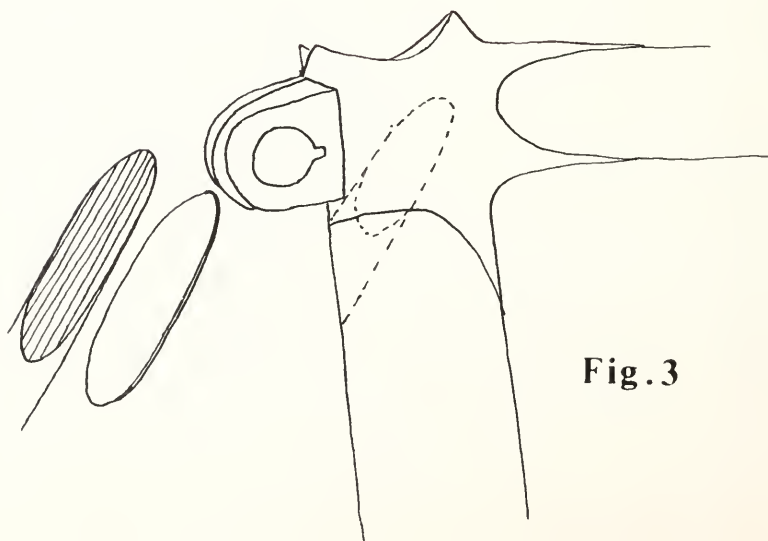


**Fig.1**





**Fig. 2**



**Fig. 3**



them (holding them as described in the rear triangle section). Make sure that one stay is not higher than the other when looking at them from above the top tube. Flux the area to be brazed and heat the joint. Give more heat to the seat lug than to the thinner stay, when brazing the plate type. More heat can be given to the stay where the solid add on is used. Use a thicker brazing rod in this joint so the braze material won't run way so fast. Braze the section under the stays first, because the upper section is more visible and should have its appearance unmarred by the lower brazing. The frame should be held in such a manner that the stays are parallel to the ground. This will help keep the braze material from running. When heating the lug keep the flame away from the bare seat tube because it is very thin, and will easily crack. Work from the back to the tip of the stay. On the ones where the tips curve around the seat lug the only difference is the first step. In that case, heat the tips of the stay and gently tap them with a hammer to curve them over. If you wish to make a complete wraparound, first fill the gaps between the end of the tips with a big blob of brass. Then just file to make it look as if it were one piece.

The next style is the scalloped attachment. Everything is done the same as the wrapover except a scalloped add on is used. If you can not get a scalloped add on, simply cut the stay the same as for the wrapover. Save the piece you cut off the stay. Then, file the stay so it will accept the cut off portion of the stay. (Fig. 4)

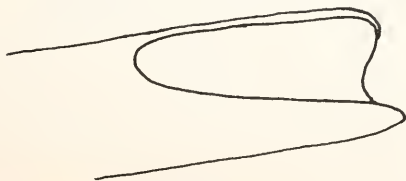
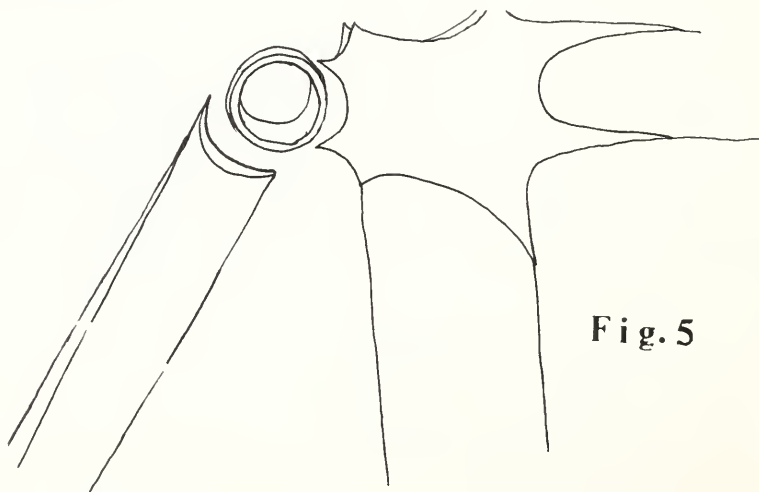


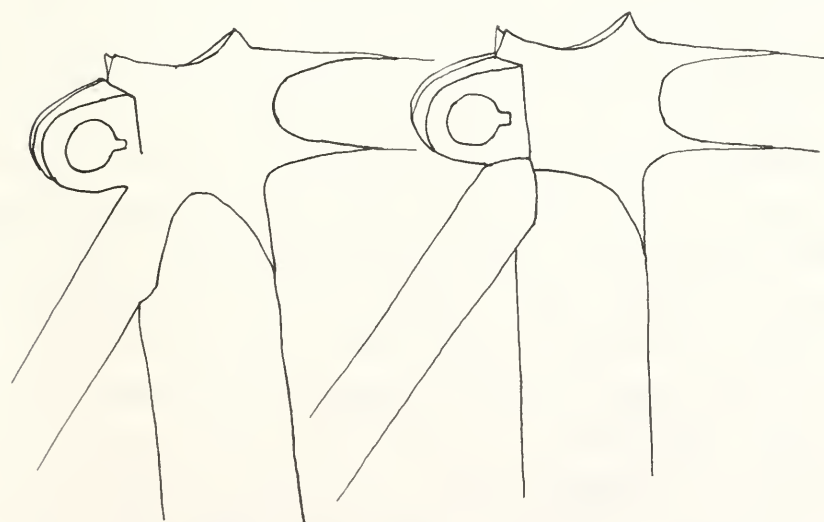
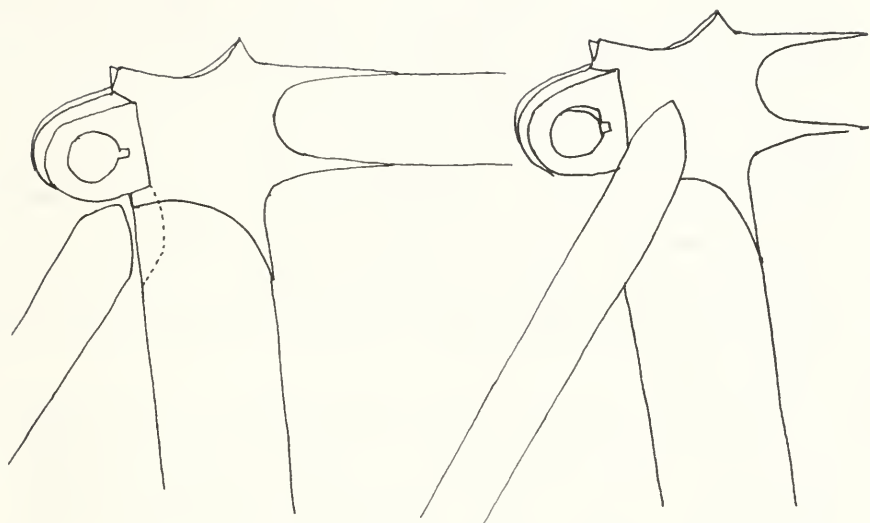
Fig. 4

Use a small round file for this. Then file the excess material off. Colnago used this technique.

One of the most popular styles of attachment is the fast back. To make this you will need an additional piece. This piece is a cylinder drilled out to accept an allen key fitting. (Fig. 5) This piece can be made from thick walled tubing or purchased from a frame components supplier. This cylinder is usually 1/2" to 5/8" in diameter and about 1 1/4" long. The center is drilled out to various sizes depending upon which type of seat bolt you will use. The first step is to file the seat bolt ears off the back of the seat lug. Then braze the cylinder onto the back of the seat lug. This should be done carefully using a large amount of braze material to build up around the cylinder. Next the seat stays should be marked so they can be cut at about the center of the cylinder. Then they should be scalloped on the end to fit against the cylinder. (Fig. 5) Flux the ends of the stays and the cylinder. Braze this area, giving more heat to the cylinder than the stays. File the area to liking. The next page shows various other styles of seat attachments and their components.



**Fig. 5**



## F I N I S H I N G   B L A D E   A N D   S T A Y   E N D S

The ends of blades and stay can be finished in an infinite number of ways. I am only going to discuss a few of the techniques. From these discussions you should be able to make any variations you might like. There really doesn't exist much difference between blades and stays, so I'll just discuss them as one group. In any case always be sure that you finish the end so the other end of the stay or blade will line up as necessary. For example, a fork blade can only fit on a crown on one possible position. Therefore the slot for the front dropout must be precisely positioned on the end of the blade.

The first possibility is getting a tube set with the ends domed and slotted by the manufacturer. In this case there is usually only one problem, the slot is not wide enough to accept the dropout. The simple solution is to file the slot wider. It is almost always more advisable to widen the slot rather than thin out the width of the dropout. Even if your set was predominated and slotted it may be necessary to cut off the end of the blade or stay to shorten the length or rake. In that case you will need to finish the ends yourself. First you must decide on how deep you want the slot. This is a matter of personal taste. To make the slot you can use a file or hacksaw. The hacksaw will work faster and the file will be easier to control. On either case the largest you should make the slot is 5mm. The best idea is to start with a smaller slot and then widen it. Make your slot. (Fig. 1) Next close the end of the slot by squeezing it in a vice or tapping closed with a soft faced hammer. It should look like Fig. 2. Again file or hacksaw the slot. It should only be necessary to cut the slot where the ends have been

crushed. At this point the end should look trapezoidal. (Fig. 3)

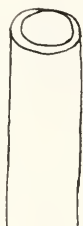


Fig. 1



Fig. 2

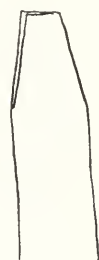
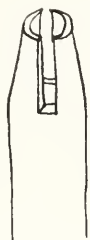
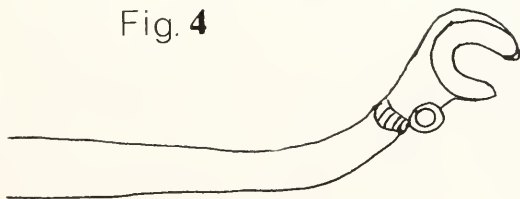


Fig. 3

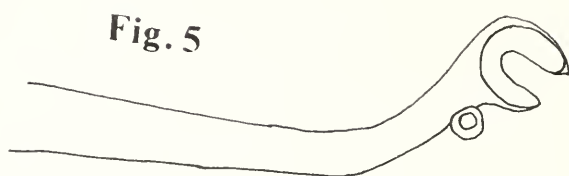
If you want you can stop at this point and finish with some emery cloth. To get the full domed and slotted look it will be necessary to squeeze the end at least one more time and then slot it again.

The next style of finishing is done with the end of the blade or stay chopped off. Usually the end is described as just-open. Again it is necessary to slot the open end. This time the brazing is done to fill in the large gap between the curved inner wall of the stay and the flat sides of the dropout. The braze material should be built up slightly above the end of the stay. To smooth the brazing a small round file should be used. The end should be filed perpendicular to the end of center line of the stay. It should look like Fig. 4. The side of the dropout should be blended into the stay.

Fig. 4



Another method of finishing a stay end is to blend it into the dropout. This is done by building up braze material over either a domed and slotted or open end. Then, using long file strokes blend the braze material into both the dropout and stay. (Fig. 5)



To check your work, you might spray some fast drying black lacquer on the end. The dropout and stay should appear as one piece. If not, add some more braze material and file.

Most other styles of ends are just variations on the above techniques.

#### T H E F O R K

To build a fork, you should break the operation down to three steps. First braze the steering column to the crown. Then, braze the fork tips to the blades, and finally fix the blades to the crown assembly. Make sure you have carefully designed the fork for proper clearance, rake and allowed enough length on the steering column. Besides the length of the head tube, the steering column needs about 20mm, for the crown and 40mm, to protrude above the head tube.

In most cases the rough steering column will not be a very good fit with the crown. That is, a fit satisfactory for good brazing. Such a fit should be neither too tight nor too loose. Remember, too tight a fit and you will have difficulty getting braze material to flow, too loose and you will sacrifice strength (this is

especially true with silver, which loses a major portion of its strength as the gap between the objects being joined widens). To make a proper fit, you have two areas of attack. Either ream the hole in the crown or file the steering column to fit. It is most common that crown holes will be slightly undersized and steering columns oversized. This is not always the situation but it occurs in the majority of cases. If you happen to have access to a one inch reamer, go ahead and ream the steering column hole. If not, use a large round file to remove any irregularities on the inner portion of the hole. Should the steering column now fit, you can disregard the following instructions.

More than likely it doesn't fit. That's ok, because it will help you position the crown. File an area all the way around the thick walled end of the steering column (on threaded steering columns this will always be the unthreaded end) from the end to a distance equal to the girth of the main crown body. (See Fig. 1.) By doing this, the crown (if filed adequately) will fit on the steering column so that the end of the steering column will be flush with the inside of the crown. If your crown happened to fit the steering

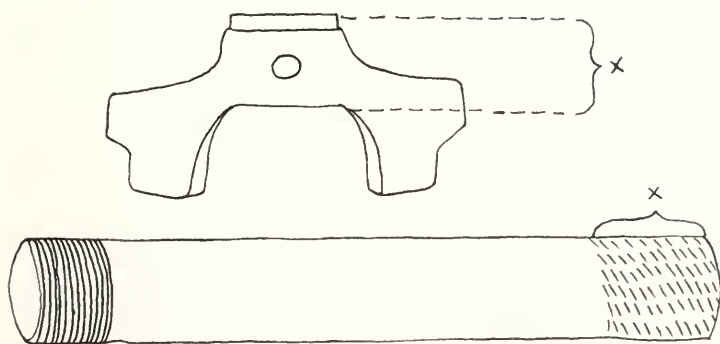


Fig. 1

column, without filing the end, you will need a way to make sure the crown remains at the right place on the column. Should the column protrude beyond the crown you can always file the excess off. Never recess the column into the crown because this will substantially weaken the joint. The fit between the two pieces should be such that they can be put together and taken apart by hand and at the same time have as little play as possible. Now you are ready to set up for brazing. If you filed your steering column place the column in a vise thread side down, thick walled side up. Be careful not to hurt the threads. Now put a coating of flux on the inside of the crown and on the outside of the column, (See Fig. 2) and assemble the pieces. Using this set up the crown will

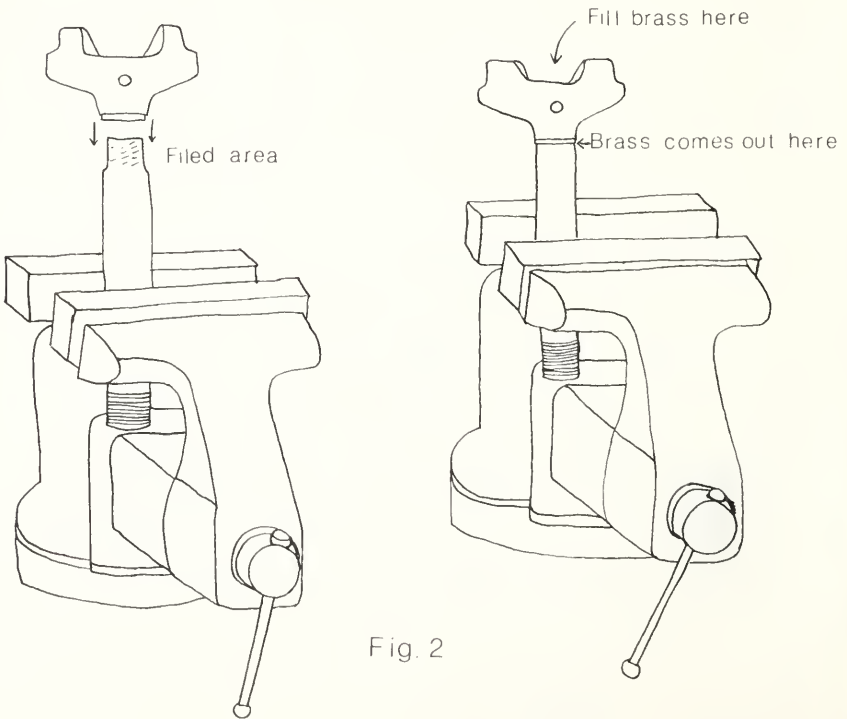


Fig. 2



remain in the right place and you can use gravity to your advantage to help flow the braze material through the crown. Heat your crown on one side until most of the area around the steering column is hot enough. Usually this is when the flux on the top and bottom of the crown begins to turn watery. Feed the brass or silver in from the top and, using a stroking motion, bring it down to bottom of the crown. Keep adding braze material until it runs out from the bottom of the crown. This way you are assured of having completely filled the joint. Work your way from the center to the sides of the crown using the stroking motion downward. Then do the same procedure on the other side of the crown. Allow the assembly to cool slowly, avoiding drafts.

If your steering column did not need filing, use the same procedure except lay the assembly on the side. If you try to do the same procedure as on the filed column, you may find that the crown will slide down the column as you heat it. Another alternative is to pin the crown in place. To do this, position the crown as I described previously. Then drill a hole through the crown and into the steering column. Put a nail in the hole and this will hold the crown in place while you braze. On crowns that do not have pre-drilled brake holes the pin hole should be drilled where the brake hole is finally drilled, leaving a cleaner looking piece. Any excess braze material, flux, or protrusion of the steering column should be removed now.

The next step is to attach the drop outs to the fork blades. First, having decided on the rake, you will either leave the blade the way it is, or cut off enough to make the correct rake. Be careful not to cut off so much that the fork blades will be too short.

Second you must select the style of attachment you want from the section "finishing stay and fork ends." Prepare the blades as described in that section. Now the dropouts must be filed to fit the blades. In some cases the bore of the fork blade will be large enough to fit the dropouts in the blade end with no filing. If you had to slot the end of the blade make sure that the slot is parallel to the oval end of the fork blade. Should filing of the dropouts be necessary you should decide whether to file the front and/or the back of the dropouts. This decision is based on the aesthetics of how the dropout looks when attached to the blade. In any case, as little metal as possible should be filed off. A tight fit is okay. It is extremely important that both dropouts be filed exactly the same. This will help insure that the dropouts line up the same way on each blade. Flux the inside of the end of the blades making sure the two blade assemblies line up. To make sure, place one blade assembly on top of the other. The outlines of both assemblies should match. Place the blade in the vice. (Fig. 3) Heat the mid-section one side of the dropout first. Remember, the dropout is much thicker than the fork blade and consequently needs considerably more heat. After the dropout has gotten hot enough (watery flux) heat the end of the fork blade. Now bring the brazing rod into the crevice. You should be able by stroking across the blade end, to flow the braze material along the end of the blade. The crevice should fill up without making too much of a mess of the dropout. Repeat the same operation on the other side of the dropout. Before brazing the other dropout make sure it still lines up with the first blade assembly. Then proceed as above. Let the dropouts cool slowly. Final finishing of the dropouts to the blades should be done now. It

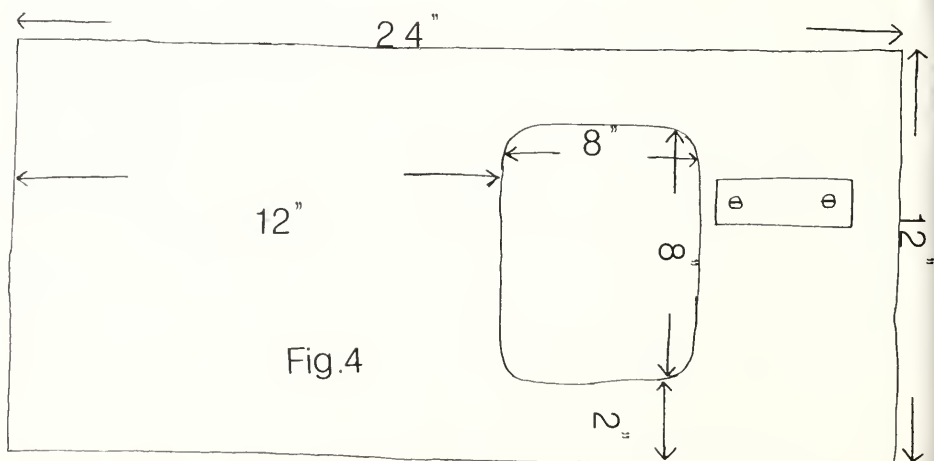


Fig. 3

is much easier to work on them when they are loose. Once fitted to the crown it will be more difficult to work on them. When filing be careful to remove as little material as possible from the blade.

Having designed your work, I assume you know how long to make your fork blades. The length can be measured more accurately using the center of the dropout (which is now attached) to the end of the blade. However, leave the blades a little longer (about 1/4") than you need. You can never add material, so it is best to leave some room for error. About two inches below the open end of the fork blade, drill a bent hole. Make sure this hole will be on the inside of the fork when the blades are fixed to the crown. This hole allows hot expanding gases to escape during brazing. No hole, would force the air to escape at the same place you are putting braze material, limiting the penetration of the brazing.

Before you can do any more brazing, it will be necessary to prepare a jig. (Fig. 4) The purpose of the jig will be to hold the



three pieces of the fork together so that the wheel sits in the center of the fork blades and the steering column lies on a line which intersects the center of the axle. To make the jig you will need a piece of plywood, two short pieces of 2" x 4" or something close to that, a C clamp and a front Quick Release axle assembly. A measuring tape and straight edge will also be handy. Cut the plywood to the outer dimensions shown and then cut the hole in the center of the board. Next nail or screw a piece of 2 x 4 above the hole as shown. Measure 1/2" in from the side of 2" x 4" and draw a line (using a straight edge) through the 1/2" mark, parallel to the 2" x 4" all the way down the board. This is center line of the fork. All parts of the fork will be equally to the right and left of the line. Lay the crown assembly on the board (Fig. 5) with the crown over the hole in the board and the C clamp holding the steering column tightly against the 2" x 4". Put the fork blades into the crown (regular crowns) or over the crown (Italian style sloping crown). If the fork blades won't fit, file the outside of the blades (regular crown) or the inside of the blade and outside of the crown inserts (Italian sloping crown). Sometimes the insides of the regular crowns must also be filed. It is not important to get the blades all the way onto the crown at the time. They need go only in far enough so they won't fall off when you let go of the blade. With the blade in the crown, place a straight edge across the blades right where they meet the crown. Now adjust the crown so that the distance from the bottom of the straight edge to the board is the same on the right and left side of the crown. When the measurement is the same, the crown will be parallel to

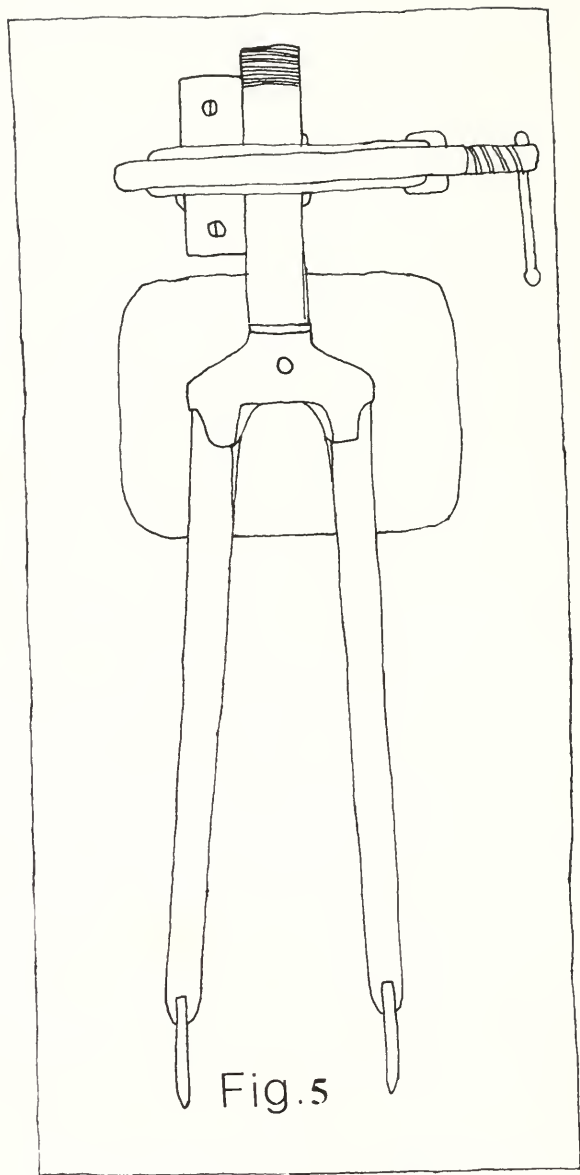


Fig. 5

the board. (See Fig. 5B.)

Lay the straight edge across the hole in the board (Fig. 6), and measure the distance from the board to the center of the blade or crown. Keeping that measurement in mind, prop one of the fork blades up at the dropout end until the distance from the center of the fork blade to the board at the point just before the bend in the fork blade equals the distance between the center of the fork blade and the board at the crown. Hold a quick release axle in the dropout of the fork blade you have propped up. Measure the distance from the hole in the center of the axle to the board. Write down the measurement which you call X. Cut a piece of 2" x 4" about 3 inches long. Decide which side of the 2" x 4" should be placed up against the board (a good flat side). Now measuring from the edge of the 2" x 4", you decided to place against the

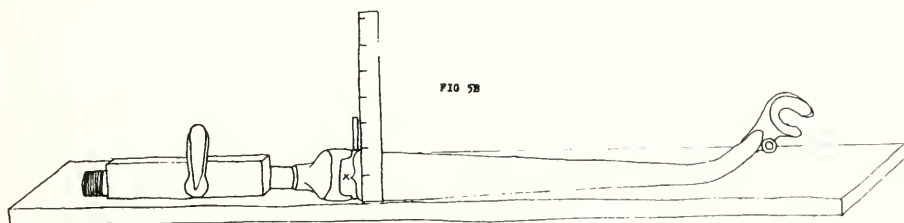


FIG 5B

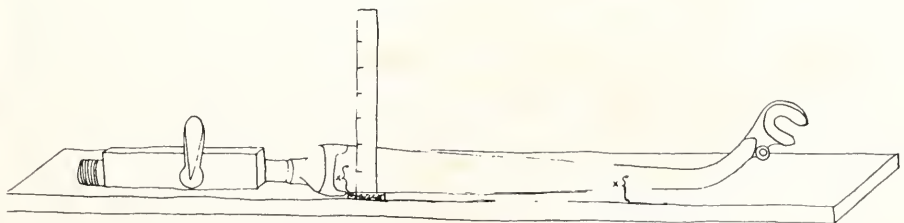
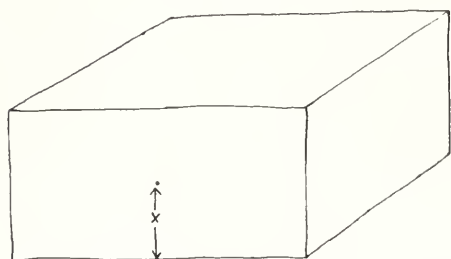


Fig. 6 (x=x)

board, make a mark X distance away. (See Fig. 7.) Drill a hole through the mark large enough for your axle (in the 2" x 4"). Put your axle in the hole and center it in the block of wood. Glue the axle in place with a water soluble glue so that you can remove it later. Put the cones and lock-nuts back on the axle and adjust them so that the axle will be as wide as the front hub. Determine the exact center between the ends of the locknuts of the axle and draw a line through the center on the 2" x 4". Your 2" x 4" piece should look like Fig. 8.

2x4 can be placed either way depending on rake of fork



This side to be placed against board

Fig. 7

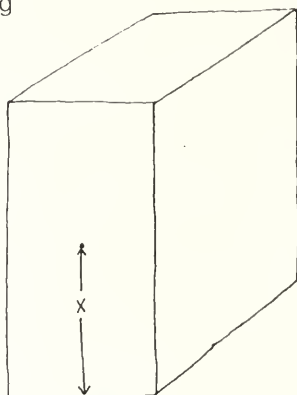
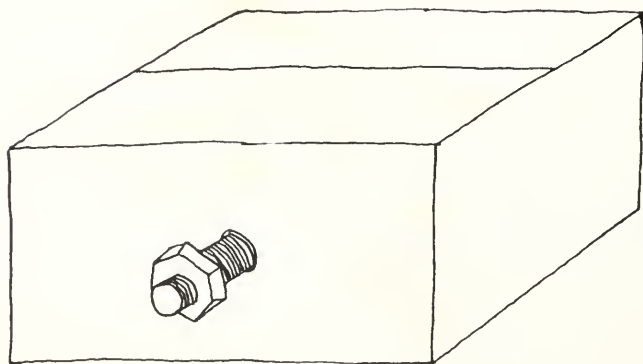


Fig. 8





Fixing the 2" x 4" axle assembly to the board is the most critical step in setting up the jig. The piece must be attached so that it meets these three centers. First, the center line drawn on the board must be in line with the center line on the 2" x 4". Second, the 2" x 4" must be positioned so that the area on the crown to be brazed will be centered over the hole in the board. Third, the edge of each side of the axle must be equally distant from a point picked somewhere along the center line. (Fig. 9) Before you attach the 2" x 4" check to see if the axle is the same distance off the board on both sides. If not, plane the 2" x 4" or glue on a shim so that it is the same. Making sure everything is right, attach the 2" x 4". If you've done everything right, the jig should be ready to use. To check the jig, clamp a top tube where the steering column should go. The end of the tube should be as close as possible to the axle. See if the axle seems to be bisected by the top tube (use your eye or measure). If everything checks out, put the jig aside while you prepare the fork pieces.

The crown should be finished so that it will accept the fork blades without much difficulty. If your crown is an integral crown (the crown fits into the fork blades) follow this procedure. Slide the blades onto the crown as far as they will go. On some English made integral crowns, the crown is finished enough so that the blades will slide all the way. In that case you are set. If you have difficulty, first file any burrs off the inside of the fork blades. If that doesn't work you will have to file the crown. On some crowns you will notice that the crown protrusions are not perpendicular to the crown. (Fig. 10) While filing to make the blades fit, remove material in the areas that will tend to make the

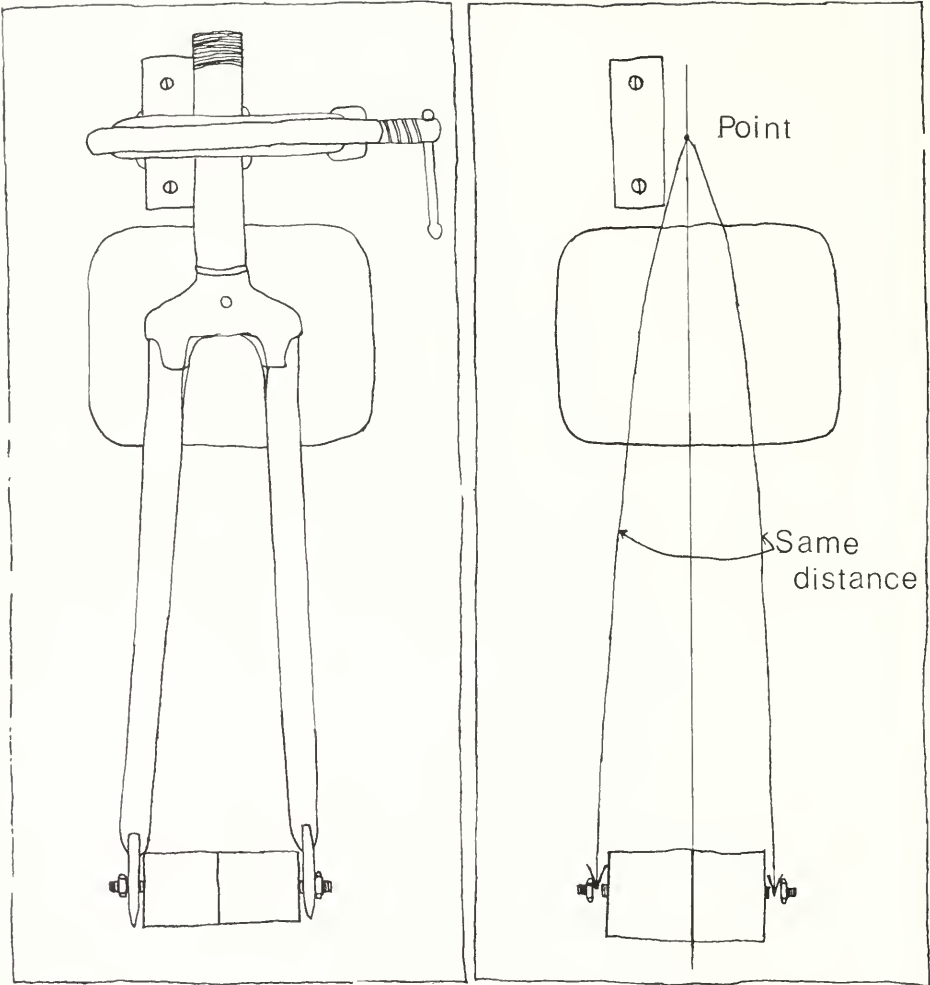


Fig. 9

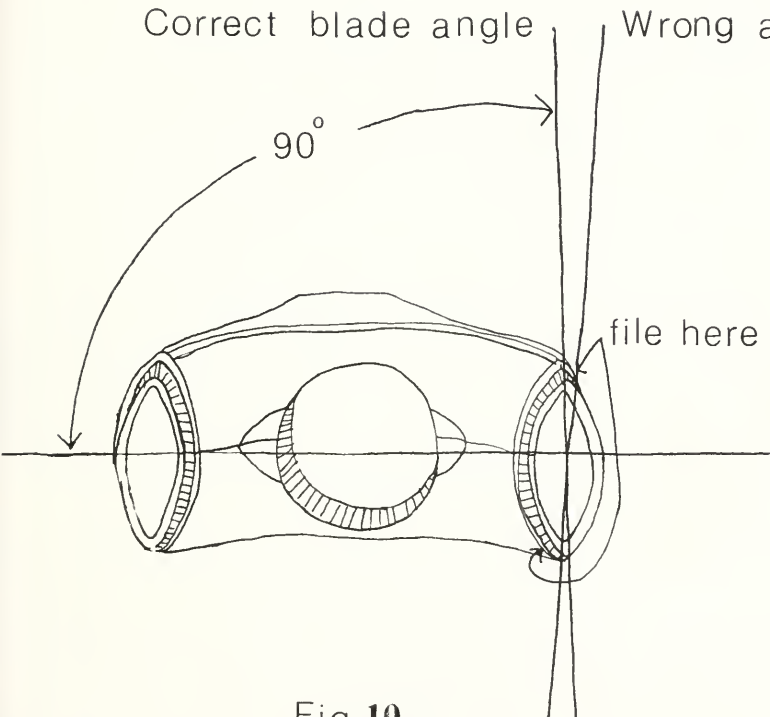
Correct blade angle

Wrong angle

90°

file here

Fig. 10



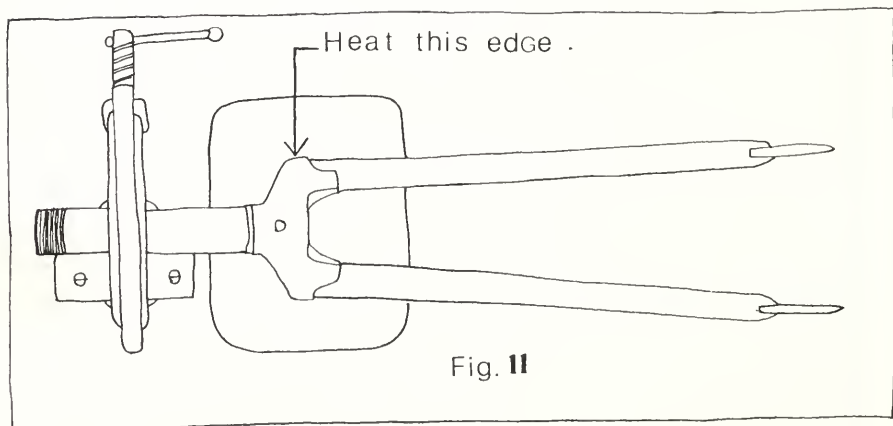
protrusions perpendicular to the crown body. If your crown is the shell type (blades fit into the crown) you must file the inside of the crown and the outside of the blades. Usually shell crowns are made accurately with the blades recessed at proper angles. In either type of crown you may find that after you have put the blades all the way into the crown the tips of the blades are too close together. When this happens, there is only one thing to do. Bend the blades apart making sure to do this equally on each blade. Putting the steering column in a vice will help you bend them more evenly. Put the fork tips on their place in the axle of the jig. Lower the steering column slowly downward onto the surface of the jig. The steering column should end up right against the 2" x 4". More than likely this is not the case. Either one fork blade is longer than the other or the crown is slightly cocked. In any case, the adjustment must be made by removing material from the end of one of the fork blades. This is why I told you to leave the fork blades a little longer than necessary. The process of removing material from the blades to even them out should be done along with measuring the length of the fork. By removing a little material at a time and measuring the fork, you will be able to leave blades of equal and proper length. You're going to have to remove the fork blades to flux them, so don't mix up the right from the left. Flux the inside of the shell crown and outside of the blades, the outside of the integral crown and inside of the blades. Clamp the steering column loosely against the plywood and 2" x 4". Again, place a straight edge across the blades where they meet the crown. Measure the distance from the bottom of the straight edge to the board on both the left and right side of the fork. Adjust the crown so that

the right and left measurements are the same. When adjusted this way, the crown should be parallel to the board and parallel to the axle. You are finally ready to braze the blades onto the crown. Regardless of the type of crown you are using, some general principles apply. First, the crown is much thicker than the fork blades and therefore they must be heated much more. Second a problem of heat distortion occurs. When a blade is heated on the outside of a crown, the blade tends to be forced inward during heating and then outward during cooling. Usually these forces cancel themselves out to some degree. However, the difference between the two forces is significant. To minimize the effect of these differences, each blade must be brazed in a certain order. This order is the outside of the blade first and then the inside of the same blade. Next the outside of the other blade and the inside of that blade. By brazing in this order, any difference in the heating forces will be the same on both blades. Because you're brazing the inside last, both blades will probably be pulling slightly inward.

To braze the integral crown, follow this procedure: Support the jig so that the steering column is at the top and the fork tips at the bottom. This will allow gravity to pull the braze material down into the fork blades. Heat the outer shoulder of the crown just above the fork blade. Be careful not to heat the fork blade at this time. The crown is very thick and so is the protrusion into the fork blade. Not enough pre-heating of the crown will result in a cold braze, that is a braze in which the braze material is bonded to the blade (which was hot enough) and not the crown. So make sure the crown is as hot as it can safely be. At this point feed the braze material into the crevice between the crown and fork blade.

Keep the flame on the shoulder of the crown--not the fork blade. When the crevice fills up, move the torch to the blade and using a downward motion bring the braze material further down into the blade. There will be more room in the crevice for braze material so repeat the procedure until you feel you've put in enough braze material. Now you have to do the same thing to the inside of the same fork blade. Point the torch upward so that the inside of the crown is heated and not the blade. Do the same procedure as on the outside of the blade. After you think you filled the blade, check the crevice to be sure it is filled. Don't worry about being sloppy, because this type of crown is very easy to file.

To braze the shell crown, support the jig so that the fork tips are pointing up and the steering column pointing down. Again it is important to heat the crown first. Begin by heating the outside of the crown near the edge. (Fig. 11) When hot enough work your way up to where the blade meets the crown. The last thing to heat is the blade. Add the braze material a little at a time and work it as far down into the crown as possible. If the crown is cut out with



lots of points, you may want to start from the sides and work towards the center. Using this method you will make the best use of gravity as the center portion of the crown is lower than the sides. (Fig. 12) Repeat the same procedure on the inside of the blade and then on the other blade. Let the assembly cool.

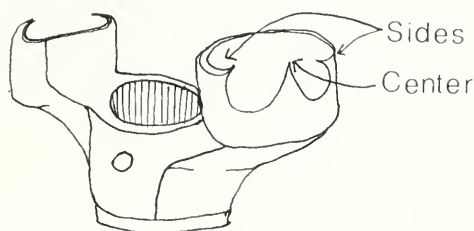


Fig. 12

After everything has cooled, pull the fork out of the jig. Now put the fork back in the jig. Notice if the fork fits properly. If not, bend the blade to make it fit. Hopefully that won't be the case. Next, get a perfectly dished wheel. Don't assume that your bike shop or you did a good job. Ask a bike shop to check your wheel with a dishings gauge or do it yourself if you have a gauge. Put the wheel into your fork and look down the inside of the steering column. Don't worry about the wheel being closer to one blade than another. The only thing that counts is looking down the steering column. If the wheel is on center, that is great. If the wheel is only somewhat off center, file the insides of one of the dropouts so that the wheel will center itself. If the wheel sits way over to one side, the best cure is to remove the necessary dropout and re-braze it further into the blade. Next, you must align the dropouts. The best way to do this is with dropout aligning tools usually made by Campagnolo, Zeus or Var. It is a very simple job that any bike shop can do. Decide what type of head set you are going to use.

This is important, because the seat on the top of the crown for the crown race must be cut to the proper size. Most good bike shops have a tool to cut the race; unfortunately, they're almost all for Campagnolo, Zeus headsets. So if you have decided that you want a Strong-light headset you will have to find someone with the proper cutter. The Campagnolo cutter will not work for Strong-light. If your steering column has to be threaded, make sure the person who threads it uses a cutter that has a pilot or guide ahead of it. Just a die in a holder is not enough. The threads will be cut crooked and the fork will be ruined. The hole for the brake must be drilled now. Some fork crowns have pre-drilled or pre-centered holes. In this case, use a 1/4" drill. Drill from one side, turn the fork over and drill the other hole. Never drill the hole all the way through unless you have a drill press. Even then be very careful. On crowns not pre-drilled use a center punch to mark the spot. Be cautious about centering the hole too high because the brake may hit the crown race. Finally, ream the steering column with a 7/8" reamer or large round file. Only the very end of the column where the stem goes needs to be reamed.

#### F I N I S H I N G

The first consideration in finishing a frame is being prepared for a lot of tedious labor. Proper finishing is the end result of many hours of patience and elbow grease. Unless you are contemplating becoming a full time frame builder, your tools, due to cost, should be limited to a good selection of files, abrasive cloth and a wire brush. For rough shaping a large coarse file works quite well. A flat file is all that is necessary for rough shaping of



the lugs and fork crown. For final shaping and general finishing a good half round medium file (Nicholson Swiss pattern #6 half round) will do most of the work, but a few small diameter round files will be needed for close clearance work. Final finishing can be done with #80 grit aluminum oxide abrasive cloth and a good set of jewelers files. To start things off right, the first step in this process is to take a stiff wire brush and clean the flux from all brazed areas. A slow process at best, but essential for the best results. On the other hand, access to a sandblaster would be must faster and easier. Proceeding with logical order the next step is to recheck frame alignment. Make sure front and rear brake holes are correct and the head tube and bottom bracket have been machined to insure the fit of the headset and bottom bracket cups respectively. This is necessary at this point as adjustments made later would end up as surface irregularities which would require extra finishing steps. The frame and fork are now structurally prepared and ready to be put in finished shape. A good place to start is the lugs. Good lug definition is a trait found on all top quality frames, although some tend to blend the lug edges into the frame. That is usually done to hide an uneven lug line. The lugs at this point probably have a small bead of braze material on the lug and the tube immediately adjacent to the brazed joint. This can be cleaned up with a small curved square file (or radius file). Take the tool and carefully file the excess braze material on the tube until it is flush (Fig. 1) with the edge of the lug. The tip of a

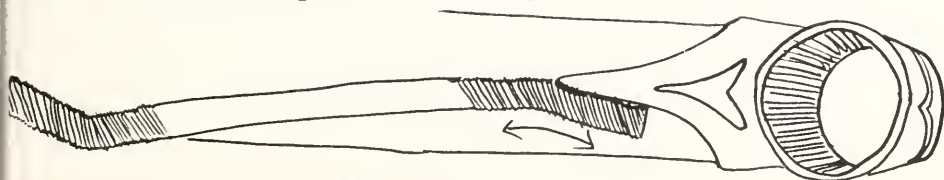
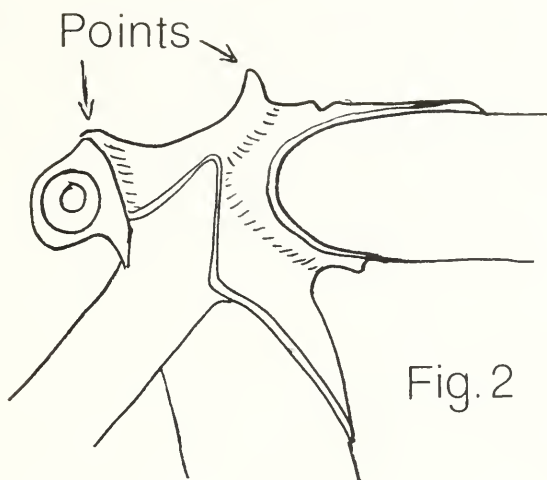


Fig. 1

half round file is useful to get in spots too close for the radius file. Carefully do this to both head lugs, the bottom bracket and the top tube-seat tube joints on the seat lug. Occasionally there will be a large blob of braze material in a radius too small in which to operate a file. The best remedy is to carefully reheat the lug in the area of the blob carefully working the torch so the excess material is flowed into the joint leaving a relatively clean lug line. This heating process used in small radius cut outs is all that can be done in the absence of power deburring tools.

Next on the agenda is to make sure all the lugs are smooth, even curves. Most lugs as formed in the factory have irregular edges which need to be smoothed. Once again the radius file is called to action. File the worst irregularities until you have a relatively smooth radius. Slowly proceed to file the lug edges to where they will be symmetrical when viewed from all angles. This process is most important on the head lugs as they are the most distorted, and also quite obvious. The bottom bracket is usually pretty good to start with, but the seat tube joint of the seat lug usually requires a lot of attention. Seat lugs are generally considered the ugliest lugs on the bicycle. On the other hand, creative shaping of the seat lug gives a custom appearance to a frame. The different number of seat lug styles are as many as the number of manufacturers. In shaping the seat lug the first step is to use the large file to establish the lines of the seat opening. A large round file may be useful if you decide on a style with curved sides. The following steps are specifically for shaping a pointed seat lug but will generally apply to all styles. (Fig. 2) The first step is to file the excess seat tube flush with the edge of the seat lug.

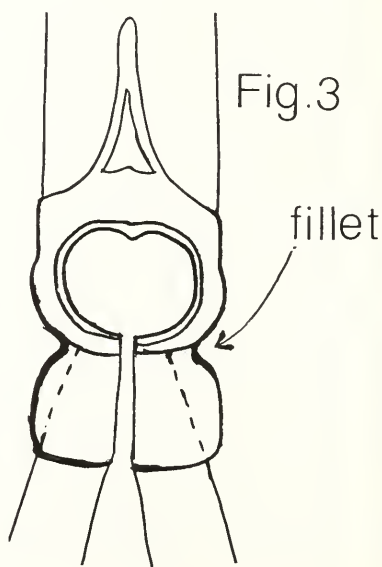


Next, using a curved or large flat file start taking down the edges of the seat lug until you have a point on both the front and back of the seat hole. Looking from the front of the head lugs, sight down the top tube and carefully file the point until it is centered in line with the top tube. The rear point may be rounded off to about an 1/8" above the seat lug ears. The lugs are now in their rough shape ready for final finishing. Optional at this point is thinning the lugs. Some builders think the thinner the better, but unless carefully done it can weaken the overall frame. Although some thinning is necessary, it is due to the fact that the lugs are not of consistent thickness to begin with. As they come from the factory most are thinner near the point and much thicker close to the joint. Take the large flat file starting at the high part of the lug edge and work your way towards the points. Use less pressure

as you get to the points to insure a uniform line. When filing a round surface such as a lug, always move the file away from you on the cutting stroke, raising the tip while lowering the handle in a manner which would avoid flat spots. Repeat this process until you've done all the lug edges, bottom brackets and fork crowns. Now take the half round and medium round files and remove all irregularities from the lug surfaces, after which they should be ready for sanding and painting.

Methods of finishing seat stays follow a basic pattern, but different techniques are necessary for different styles. The integral fastback will be an example as it is the most popular and most difficult to make perfect. All other attachments mostly require little more than having the edges of the stay cleaned up. For the integral fastback take the large flat file and mold the end of the cylinder till it continues the stay line. (Fig. 3) The next step uses a small round file to even the fillets between the cylinder and the lug. After this is done carefully round off the edges of the cylinder giving the seat lug and stays a smooth one piece look.

One area quite difficult to finish is the stay and fork ends. This process is very important to developing an overall look to a



frame. Two popular styles are domed stay ends with round dropout edges and flat angles stay ends with squared off dropouts. The first method is usually used on Reynolds frames as the stays and forks are usually domed and slotted to begin with. After brazing dropouts to stay ends there is usually a lot of excess braze material all around the joints. Regardless of which style you choose, the first step is to blend the dropout line with the stay line. Start-  
ing about the middle of the top inside edge of the dropout, use rounded strokes of the flat or half round files to blend the dropout into the stay. Hold the file parallel to the stay as you file. Repeat this on all dropout edges so that when you look at the frame from the side all the curves are smooth and continuous. The dropout edges should be round at this point so if you desire flat edges use the same file using flat strokes letting up before you get to the stays. All outside edges of the dropouts should be finished accordingly before proceeding. To flat finish stay ends, take the flat side of the file holding it at about the 45 degree angle to the dropout surface, and using flat strokes file the ends until they look like Fig. 4. Be sure you finish the inside and outside



Fig.4

ends the same length down the dropout. The doming procedure takes a lot of effort but the results are worth the extra effort. First take the file, flat side flush on the dropout surface and using the edge establish a curve which extends fully to the end of the dropouts. This will leave a small groove between the stay and the dropout. To continue, hold the flat side of the file at a 90 degree angle to the dropout. Using rounded strokes, file the stay end until the groove has been removed. Your stay end will now have a definite dome shape. If the dome is not centered on the stay or the curve is not regular, repeat the last two steps until you are satisfied with the results. Once again it is important to have both sides of the same stay even. To complete the process file the ends of the stays using round strokes holding the file at a lesser angle for each series of strokes while you have roughly rounded the stay end into a dome. Once again the final smoothness will be determined by sanding.

The purpose of final sanding is to insure all surfaces are smooth and prepared for painting. The first consideration is the lugs. Use your fingers as sanding blocks on the irregular surfaces of the lugs. You should sand off all filing marks, left over flux, excess braze material and generally leave the smoothest possible finish.

Use the small round jewelers file to smooth any roughness in the brake bridge and chainstay bridge joints. Then tear some abrasive cloth into 1/4" strips and sand until a one piece smoothness is attained. Continue this sanding process on the dropouts and stay ends, sanding at every angle until the desired results are achieved. After you have finished the hand sanding carefully

rub your fingers over all lugs and other critical surfaces to be absolutely sure of the smoothness.

The frame is now ready for painting and you're one step closer to having a custom frame.

## P A I N T I N G

Painting a bicycle frame consists of three basic steps. Metal preparation, priming, and applying the top coat(s). Each step will be discussed separately.

### Metal Preparation

A very common mistake of both amateur and professional frame painters is inadequate preparation for priming. The frame must be absolutely free from excess braze material, flux, grease, carbon

and other deposits. The most common (and preferred) method of preparing a frame for painting is to sandblast the entire frame. A .50 grit blast will give the frame a nice even roughening that provides excellent paint adhesion yet is smooth enough to be covered by the primer coat. Sandblasting will also remove braze material, flux, and carbon from the frame and is especially convenient in those areas that are relatively inaccessible to files and sandpaper. If you, as most amateur frame-builders, do not have a sandblaster at your disposal the best technique is to sand the metal by hand with 80 grit strip sandpaper which comes in long rolls of various widths. A one inch wide roll is generally best.

Clamp the frame firmly in a vice using wood blocks and tear off a 12 inch strip of sandpaper. If you can buy wet/dry sandpaper it's best to use it wet as it sands more efficiently. Drape the sandpaper over a tube and pull it back and forth much like you would a rag when polishing shoes. (See Fig. 1.) As you sand, move the strip toward the other end of the tube. With 3 or 4 passes over the tube you should be able to sand its entire surface. If you're using wet sandpaper wipe each tube clean as you finish it. The main tube sections should go quite quickly. Care is necessary when working around the lugs. A common mistake is to sand the tips of the lugs first, often to the point where they blend into the main frame completely. Once this is done it's very difficult to regain the definition of the lug. A better technique is to use a 1/2 inch strip made by tearing your 1 inch strip lengthwise, and carefully work from the center of the lug out. (This method will allow you to thin the lug without inadvertently going too far. If you want to blend in the lug tips this is best done as a final step.) It will be



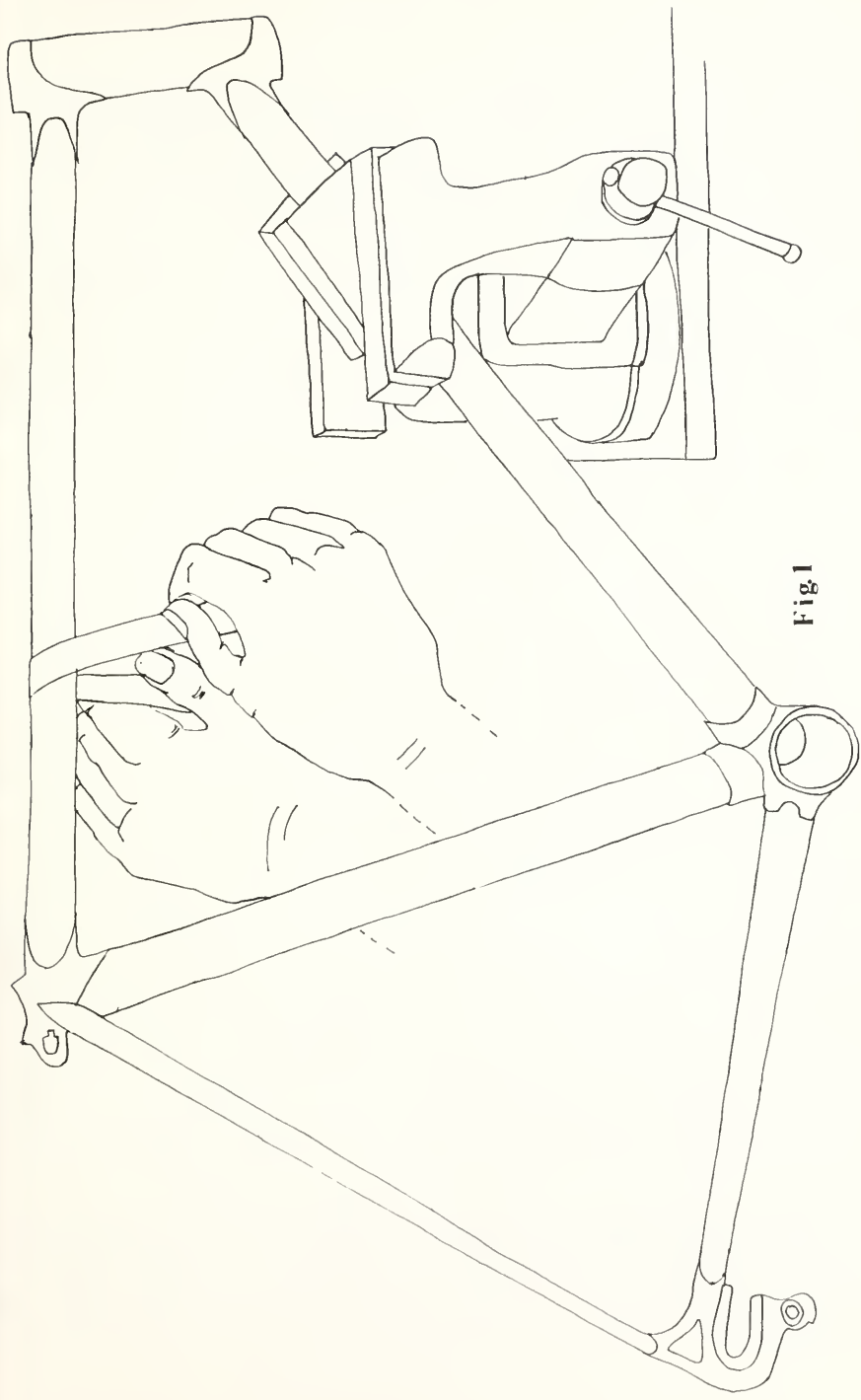


Fig 1

necessary to use small pieces of sandpaper when sanding areas such as drop out surfaces or the bottom bracket. Often a short piece held with your forefinger and rubbed (rather tediously) back and forth is the best method. In other areas such as between the chainstays, a strip 1/4" - 1/2" wide (again torn from a 1" strip) provides the most efficient method.

After sanding, the frame should be examined carefully to make sure no surfaces have been missed. Any method of checking the frame is acceptable but you should do it systematically, going over it one area at a time so that when you've finished you know you looked at every part of the frame. It's usually easiest to look at the frame as three triangles, the main front triangle and the two triangles formed by the stays and the seat tube. For example, start at a dropout, look down the chainstay, up the seat tube, and down the seat stay back to the dropout. Repeat this process 4-6 times turning the frame to a different angle for each examination. You should be visually overlapping the first check with the second so that you'll be sure no area is missed. Cover the other stay dropout combination and the main front triangle in a similar fashion. Check the bridges and then make a final check of all brazed areas following the line of the joint. The fork may be checked by examining it one blade at a time and then checking the crown. While such a search (for what you might ask) may seem ridiculous it's very easy to miss a rough or dirty spot if you just casually look the frame over.

After examining the frame it should be wiped off using clean rags of paper towels to remove the sanding grit and other dirt. A good method is to hang the frame from one of the rear dropouts. Take

spoke and put it through the hole intended for the dropout adjusters (which should not be installed yet). The part of the spoke which attaches to the hub will stop it from passing completely through. This part of the spoke should face the inside of the dropout as whatever you use to hang the frame from could later mess up your paint finish. Bend about the last 2 inches of the spoke over (see Fig. 2) into a hook and hang the frame from it. Hold the fork by hand. After you've hung up your frame find a tube or piece of wood that will go through the head tube. Put a cap or collar on one end or simply wedge it to the head tube so that you can use this stick as a handle to turn the frame without touching it. (Fig. 3)

Wipe the frame with whatever you're using (I like Bounty paper towels) to remove most of the grit. Next take a clean towel and wet it down with whatever thinner is going to be used in your primer coat. Special metal conditioners can also be used to wipe the frame, although they are probably an unnecessary expense. If you choose to use a conditioner (they are usually a mild acid which does contribute slightly to the frame's paint adhesion ability) it's best to follow that step by wiping the frame with whatever thinner your primer requires to avoid a possible reaction between the paint and the acid. If you're using a pre-mixed primer such as an aerosol, simply use a compatible thinner. If your primer is enamel use enamel thinner, for lacquer use lacquer thinner, etc. Finally, wipe the frame gently with a clean white towel; if any dirt stains the towel repeat the last process and again wipe with another towel until you're quite sure no dirt or grease is on the frame. Wipe the frame in a systematic fashion just as you checked that the sanding

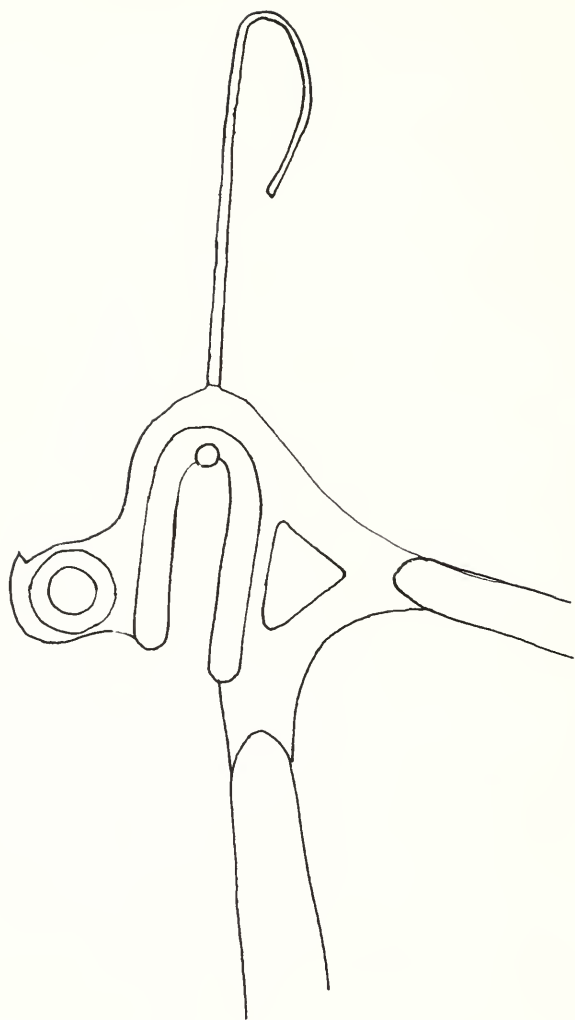


Fig. 2

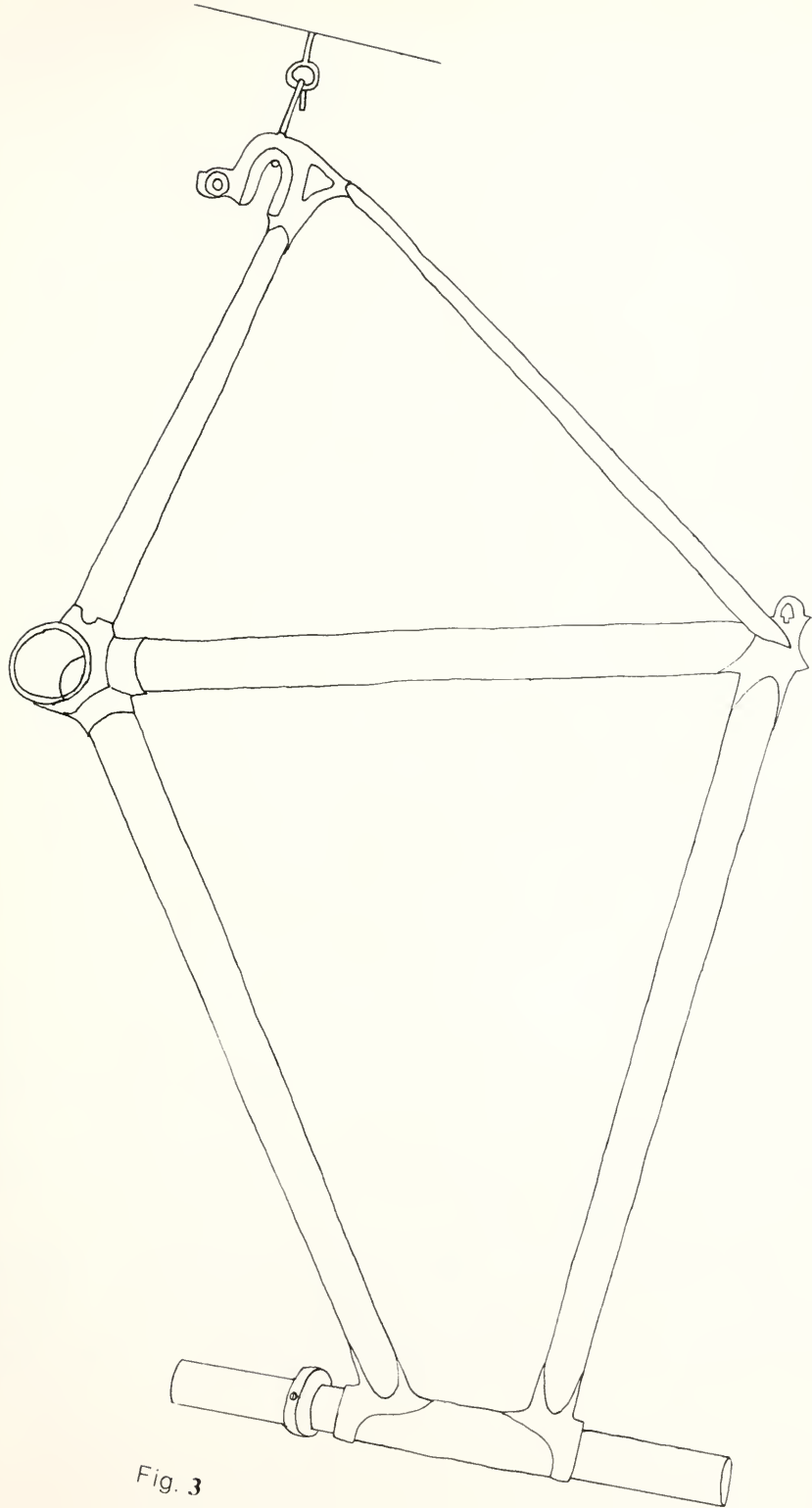


Fig. 3

was complete.

### Applying the Primer

A primer coat is required to achieve good adhesion between your paint and your frame. The chemistry of paint is such that the best paint for adhering to metal will not have the gloss, hardness, or other finish characteristics desirable in a topcoat. Primers are designed to adhere to metal and provide a good adhesion surface for the topcoat. As there are countless methods, materials, and opinions on painting, I've decided to describe a method similar to the one we've found best, rather than attempt a complete guide to painting techniques. This method which requires the use of a compressor and spray gun, will be followed by a short supplementary discussion for those who choose because of cost, facilities, or preference, to use another painting system.

Deciding where to paint your frame is somewhat of a problem. Ideally, you should have a professional paint room with adequate ventilation, lighting, and filters cleaning both incoming air and outgoing fumes. Often it's best and safest to paint outdoors. Light is almost always better outdoors and paint fumes present much less of a problem than in an enclosed space. It's not generally wise to paint outdoors if it's windy, rainy, dusty, or if the temperature is below 50° F. Most paints are designed for application at 72° F., although this is not critical. If you do choose to work indoors try and find a brightly lit room and mount an exhaust fan in a window to extract fumes.

Wherever you choose to paint (although this isn't as important outdoors) the area should first be cleaned and wet down. If you're painting in a dirty cement wall and floor basement you should first

sweep the entire area and then hose down the walls, floors, and ceiling. (Before starting to paint, mop the excess water off the ceiling to prevent water from dropping on the frame.) Wet down an area as large as possible around your painting area. This will not only hold down the dust already in the immediate area but also catch some of the dust particles in the air. This brings up a dilemma in painting indoors, as the flow of air and the flow of dust are directly related. The more ventilation you provide the more fresh, potentially dust-carrying air, you bring into the painting area.

Even with good ventilation a two stage air filter (usually utilizing an activated charcoal filter) is necessary to give you the best protection from the fumes. While a one-time use of these paints probably presents little danger, our recommended paints are more toxic than conventional paints and you should use all the care that is possible. If buying or borrowing a filter presents too great a problem, it's best to simply work outdoors, where fumes disperse naturally.

Once your painting area is cleaned and wet down, the frame should be hung in place from its spoke hanger. You should not touch the frame with your hands at this stage as dirt or even skin oils can interfere with good adhesion. It's best to wear rubber gloves to protect your hands from paint and to handle the frame by its hanger and whatever you've rigged through the head tube. After hanging the frame, bend the hook of the spoke in a manner preventing it from falling off whatever you're hooking it onto (an eyelet, hook, rope, etc.) no matter how you turn the frame.

Since you've recently wiped your frame with a clean towel, you'd

think it'd be clean. Chances are though, that as you wiped off the dirt, you wiped on some lint. The last step of metal preparation, which should be done immediately prior to applying the primer, is to blow off the frame with compressed air. This is best done at a high pressure setting, using the valve at the end of the hose rather than the gun.

The paint I'm recommending is DuPont's zinc chromate Corla epoxy primer. It's a 2 part paint that utilizes a chemical reaction as part of its hardening process. As paints which depend solely on solvent evaporation take months to reach full hardness this chemical reaction is a distinct advantage over non-epoxy primers. This paint is generally available from whatever paint distributor serves the automobile body shops in your area. You can check the yellow pages under Automobile body shop equipment and supplies. Mix the paint according to the instructions using the recommended 3871 thinner. Be careful to note the way the manufacturer uses percentages. Thin 25% means use 25% as much thinner as paint or 4 parts paint to 1 part thinner. A standard household measuring cup is good for this purpose. Prepare approximately 8 oz. of final thinner paint. This will be more than enough but since you've probably been forced to buy large quantities anyway it's better to make a little extra. As you pour the paint into the cup of your spray gun filter it through a paper filter funnel available at paint distributors. This will remove any dirt or coagulated paint. Also, before filling your gun with paint, run about 2 oz. of the 3871 thinner through the gun, making sure the thinner flows and atomizes easily and evenly. You might also want to rinse out the cup (with thinner) to make sure no foreign particles will get into the paint. I use a Devilbiss EGA



502 gun. While generally considered a touch up gun, this gun and others of a similar size are well-suited to bicycle frame painting. Larger ones can also be used but usually are a little more difficult to control. The spray pattern knob should be closed all the way to provide a circular spray pattern. The paint volume knob should be closed down to yield a very fine mist. Spray pressure should be set if possible at the recommended 55 lbs. As when you sanded and cleaned the frame, paint should also be applied systematically to avoid missing spots or applying too much paint to some areas.

Before spraying the frame test the gun on something like a piece of cardboard to make sure that there isn't too much paint coming from the gun and that it's working smoothly. Definitely begin with a conservative volume setting, as you can open it as you gain some practice. If the paint volume is set too high, your first sweep will probably cause a run and you'll have to wipe down the frame a second time. The gun should be kept as upright as possible, a constant distance from the frame (usually about 6", but use whatever distance seems to work best), and directly at right angles to the area being painted. Start at a particular point, again, a dropout is a good choice. Begin to spray about 6" above the dropout and move the gun at a nice even pace toward the dropout and down the chainstay to just before the bottom bracket where you should move the gun to the side. By starting to spray while the gun is pointed at the air you avoid applying an excessive amount of paint as the gun starts up. By having the gun moving before you reach the frame and moving away from the frame before you stop spraying you apply an even coat. Next spray the seat stay in

a similar method. At this point it's best to spray the insides of the other chain and seat stays. Then turn the frame to each angle spraying those parts of the stays that become visible. Overlap each pass by about 50%. Be careful not to spray any area too much more than another. You might want to deliberately miss some sections such as the dropout on some passes. The most important thing to realize is the necessity of an even coat and the advantage of systematically covering each area of the frame. Common sense should provide you with the actual order and rate of application. Initially it's best to apply too little paint and gradually open up your volume as you get the feel of it. Generally you'll sweep over each spot 2 - 3 times before the paint begins to flow out, which is when you know you've applied the proper thickness. Too little paint looks dull, the proper thickness flows out and looks wet and shiny, and too much paint runs and sags. Applying primers is good practice for topcoats as both dull spots and runs can generally be sanded or scuffed to a smooth finish suitable for applying the topcoat. With the topcoat more care is required as the frame cannot be sanded afterwards.

As you paint you'll be manipulating the frame's position with the "stick" you've placed through the head tube. Care should be taken not to miss the following areas: bridges, especially the top of the brake bridge, the undersides of the top and down tubes, and the sides of the seat tube facing the head tube. Of course after you've gotten a full wet coat over the entire frame you should conduct careful visual search of the frame turning it to various angles and running your eyes down each tube or around each triangle as described in the sanding section. It's also usually a wise idea to

stand on a chair and look over the frame from above.

Once you're sure the entire frame has been painted adequately, you should paint the fork. Blow off the fork with compressed air before starting and simply hold the fork in your hand by the steering column. Close down the volume control a little as you'll generally be working with a little closer spraying distance when you hand-hold the fork. Spray the dropouts first as you'll usually miss their inside surfaces when spraying the blades and attempting to spray them after the blades often results in runs. After the fork is painted give it a careful visual check and set it to dry being held by its steering column. You could either set the steering column in a vice or slide it over a convenient post or dowel. Alternately you can choose to hang the fork prior to painting. One method is to tightly jam a piece of wood with a hook on one end into the steering column. This method is also useful if you plan to hand-hold the fork but hang it after painting. Another possibility is to put a spoke through the steering column and bend it around the underside of the crown so it won't fall out.

It's best to let the primer dry for at least 24 hours despite manufacturers' claims. Of course if you have access to an oven you should bake on the primer, one hour at 200° seems about right.

#### Applying the Topcoat

The first step is to again give a careful visual check of the frame. At this point it's common to notice brazing holes, spots of brass, runs, thin spots, etc. Small spots of brass can be filed and sanded. Runs can also be sanded usually starting with 220 grit sandpaper and finishing with 600 grit. If you've had to expose large areas of bare metal it's best to reprime the frame. If you've

only exposed a few tiny spots of bare metal repriming is not necessary. After checking the frame you should scuff or sand the entire frame (and fork) using a Scotch General Purpose Pad. These are available at your commercial paint distributors. Another alternative is to use 600 grit sandpaper. In either case you're only trying to smooth out the paint surface; do not sand away a major amount of paint.

After scuff sanding you have to wipe off the paint dust. Here Bounty paper towels work very well, although anything clean will do. After wiping the frame a few times, (you're finished when the towel no longer picks up red dust) set the frame aside and hose down the room or area around the frame.

Replace the frame on its hook and blow it off with compressed air going down the tubes and turning the frame just as when you paint.

The recommended topcoat is DuPont Imron polyurethane enamel. This is also a 2 part paint. To a greater degree than the primer it hardens by a chemical reaction. The paint must be mixed immediately prior to use as it will harden into a solid mass even if covered usually within a day. The paints should not be used more than 3 hours after mixing as hardening will reduce its finish characteristics. This type of paint (polyurethane enamel) is one of the few paints that provides a professional quality finish without baking.

Mix the Imron (or any other polyurethane enamel such as Sherwin Williams Polare) according to the manufacturers' instructions. Imron uses 3 parts color to one part activator. If you do not have an oven or hot place to dry the frame after painting you may want to add some 189S accelerator to the paint to decrease the drying time and increase hardness. This is not completely necessary as Imron

is designed to air dry. Especially if you're willing to wait a week before building up the frame, it's probably an unnecessary expense. Next run an ounce or two of the recommended topcoat thinner (in this case 3979S) through your spray gun to make sure it's clean and avoid any reaction between the Imron and whatever was in the gun last (probably the primer). After cleaning the gun, pour out any 3979S left in the cup and fill it with the Imron. Do not reduce the Imron at all at this point. It's usually best to use it without thinning although occasionally a small amount of 3979S will allow it to flow out easier and produce a smooth finish. The danger in reducing the paint is that it increases the likelihood of runs. When you fill your cup with the Imron, filter it through a paper filter funnel.

Set your air pressure at 50 lbs. (at the gun) to start spraying. If your pressure gauge is not at the gun allow 1 lb. pressure drop for each foot of distance between the gun and the gauge. A gauge at the end of a 10 foot hose should be set at 60 lbs. Spray a test on any available surface and adjust the pressure and volume to your liking. The spray pattern should be circular, which means the knob adjusting the pattern should be fully closed.

The frame should be given 2 complete coats. First give the frame a light coat. This coat should cover the entire primer with color but should look fairly thin and dull. Paint the fork first, set it aside, then paint the frame. While you've been painting the frame, the fork should have "tacked up" or begun to dry. This is necessary before applying the second coat, or runs will result. Usually 10 minutes is more than enough time for the paint to tack up. Now apply a full wet coat to the fork. This is just enough

paint to give a bright, shiny, wet appearance. When you're done painting all surfaces should look (as well as be) wet. Don't think some spots are dry because they're dull, since Imron looks fairly wet even after it's completely dry. A dull spot needs more paint. Be careful though not to apply too much paint. You can always let it sit and tack up a while and if it still has dull spots apply a third coat before you let it dry. A run, however, is usually not fixable. People often try to wipe off a run and spray that part over. Imron, however, shows dust easily and usually such repairs in the middle of a paint job hurt more than they help. After painting the fork give it a careful check before setting it to dry.

Once the main frame has had 10 minutes to tack up apply its second coat. Again, a full, wet coat. The gun should create a bright liquid path of color as you move it across the frame. If the color does not look liquid you should increase the volume or move the gun closer to the frame. If, however, the color seems to create little waves of liquid flowing out away from the center you're applying too much paint and should decrease the volume, or increase the distance between the gun and the frame. You want the least paint that will give you a smooth, liquid look. It's usually a good idea for beginners to spray the bridges first on their second coat. Often they will be forgotten until the end and the novice painter will cause the paint to run when attempting to paint a bridge near an already fully painted stay. The line between a really good glossy paint job and a runny mess is very fine so be careful, and once it looks finished, leave it finished. As when you applied the primer a systematic pattern is the best way to

spray your topcoat.

After you've given the entire frame its second coat check it carefully for dull spots. Avoid touching up large areas or entire tubes to make small dull spots glossy. Many times, however, you will be forced to spray the entire length of a tube to fix one small dull spot as wherever you stop spraying you cause another dull spot. Also avoid waiting too long to fix a dull spot. Once I noticed a dull spot 15 minutes after painting a frame. Because it had all started to dry, wherever I stopped spraying after painting over the dull spot, I created a new dull spot. Also, the edge of the spray path was dull. This is called overspray and results whenever small amounts of fresh wet paint fall on paint too dry to allow the wet paint to flow into it. Overspray can also result from too high a pressure setting or too great a distance between the frame and the gun. In this particular case I had to apply another full wet coat over the entire frame as the result of trying to fix a single dull spot.

Now that you've checked the entire frame and touched up those areas that needed it, just leave it where it is until it's dry. If possible turn off the fan as less dust will be drawn across the wet frame. After 3 hours the frame can be handled gently. At this time place it in a hot place (a car parked in the sun is good) for a day or two. It's best to wait about a week (longer if you don't mind) before building up the frame. While Imron is reasonably hard after 3 hours, its hardness does improve with more time. This is called curing. Standard enamels require 3 months curing time for best results in hardness without an oven. If you have an oven, bake on the paint for one hour at 200°. This cures the paint immediately

and the frame can be built up 30 minutes after cooling.

### Using Aerosol Sprays or Other Paints

After checking with various distributors I've found that it's extremely hard to buy the paints I've recommended in small quantities. For this reason the method I've described may require \$40.00 or so in paint supplies. One way around this problem is to ask the paint distributor to tell you the name of a professional painter that uses Imron and who may be willing to sell you some small quantities of the paints. For most people though, it seems that either an aerosol paint or any more commonly used paint will be a more reasonable method. Paints for painting of this sort are usually enamels or lacquers. Lacquers dry fast and are the easiest to use. Enamels dry more slowly and run more easily. However, there seems to be a direct relationship between drying time and durability; the shorter the drying time the more brittle the paint. Lacquers are definitely more brittle than enamels. Before completely dismissing the possibility of using lacquer you should know that lacquer usually gives you the best finish in terms of appearance. Lacquer goes on smoothly, furthermore, it can be sanded with 600 grit sandpaper between coats, and given a final compounding job resulting in a "custom car" style finish. Enamel will always have a slight orange peel, or unevenness. This unevenness is not noticeable to most people. Almost all bicycle factories use some form of enamel to paint their frames.

My recommendation for a topcoat is to use an enamel or epoxy paint (usually better if an oven is not available). Acrylic enamels are generally superior to normal enamel but they are not generally available in spray cans. If the paint you choose has optional hardeners use them unless you have an oven. The primer should be a



zinc chromate or zinc primer. The primer should also be an enamel rather than lacquer type primer. Check your local stores by phone. Many primers make great claims but all the primers I've seen that work well were either zinc or chromate. Do not use any topcoat on bare metal even if the manufacturer recommends it.

Whatever paint you choose to use, the previous description of the "Imron" method should be used as your general guide along with the manufacturers' instructions. As for blowing off the frame with compressed air, if you don't have the air simply wipe the frame lightly with the cleanest, most lint-free thing you can find before spraying. Some paint stores sell tack rags for this purpose. Some (usually sticky to the touch) leave deposits worse than the dust they remove, others (usually dry to the touch) are okay.

My last words are: don't try short cuts, be careful, have patience, and good luck.

P.S. If you should decide you'd rather not paint your frame, we will paint it for you. A paint job using a slightly more sophisticated versions of the "Imron" method costs \$35.00 including sand-blasting, priming, the Imron topcoat, baking, and return shipping. Other painting services such as panels, contrasting head tubes, etc. are available. Please frames or inquiries to:

PROTEUS DESIGN  
9225 Baltimore Blvd.  
College Park, Maryland 20740  
Attn. Frame Building Department

#### F R A M E   R E P A I R S

Probably the most difficult aspect of working with bicycle frames is frame repairs. This is because all the problems of frame building are encountered along with the additional problems of taking

the frame members apart. The difficulty of taking a frame apart should not be underestimated. While building a frame the stress of fitting parts together is done before the actual heating of the metal. In frame repairing the stress is usually applied to the metal while it is at its highest temperature. Also complicating the problem is the possibility the frame was built poorly in the first place. This causes problems when the frame components were fitted together too tightly. Sometimes they may have been hammered together. Even worse they may have been pinned together. All these conditions are going to create problems for you. When the metal is heated to make the braze material molten enough to allow the joint to be pulled apart, the metal is prone to distortion and fracture. This should be kept in mind while doing any frame repair. Any time a frame repair requires pulling something apart that is attached in more than one place, the part must be cut to allow each joint to be heated separately. Trying to simultaneously heat and pull apart two joints will give you nothing but trouble. For example, a dropout has this problem. It is attached to both the seat stay and chainstay. The first step in replacing a damaged dropout is to cut it in half so that one half is connected to the seat stay and the other portion to the chainstay. When cut the dropout usually releases some tension in the frame so that the two parts of the dropout no longer line up. This allows some room for pulling each part of the dropout from the respective stay. This room is necessary because you want to pull the dropout straight out of the stay, not at an angle. Pulling the dropout at an angle will break off the end of the stay. If the dropout is tight it should be wiggled around ever so slightly to help loosen it. If it still doesn't come out try

heating the stay a little further back. If that doesn't work you can use more heat. Don't get frustrated and pull the piece out prematurely. After the piece is out the stay ends must be cleaned to accept the new dropout. Usually a small round file will do a good job. Next the new dropout must be lined up to match the old one. If put in crooked the wheel will never sit straight in the frame, or will sit straight in only one position. Sliding the wheel forward or back will cause the wheel to sit cocked in the frame. Take your time lining up the dropouts. Put a dab of brass on the dropout to hold it in place. Then put a wheel in the frame to check it. If adjustment is needed, bend to correct. Then finish brazing.

Another example is a main frame tube. Since it is brazed at both ends the tube must be cut to allow both ends to be worked on individually. Cut out an eight to ten inch section of the tube. This will give you room to pull out each section. Pulling a tube out of a lug is extremely difficult. Before starting you should check to see if the frame was pinned together. If it was it will be necessary to remove the pin. There are two ways to see if there is a pin. First, a visual inspection by looking into the tube. Here a pin will appear as a nail sticking into the center of the tube. Second sand the paint off the lug to see if you can detect the pin. This should appear as a small ring of brass about the size of a nail head. If there is a pin it should be drilled out. Where a main tube is connected to a head tube or seat tube, extreme care should be taken not to distort those tubes. Sometimes inserting another tube into the head or seat tube will help them keep their shape and dissipate the heat better. To pull the seat or down tube out of the

bottom bracket or the seat tube out of the seat lug, a trick can be used so you will not have to heat the frame at those points. Do this by cutting the tubes as close as possible either to the seat lug or bottom bracket. Then grind or file the remaining tube out of the lugs or bottom bracket until you are down to the brass. Then use a 1 1/8" reamer to round out the hole. Any time you are pulling a main tube joint apart it will be necessary to heat the joint all the way around. This is difficult with one torch because the side not being heated by the torch will cool down before the other side has gotten hot enough. If you use two torches or a torch that spreads the flame around the tube you will be much better off. However, a single torch can do a frame repair, you just have to be quicker. Just as in the case of the dropout, be sure to pull the tube straight out. When replacing a part you have removed be sure to avoid any tension being on the part you are brazing. As in the dropout, the seat stay and chainstay must line up. If they do not, they must be bent until they do line up. Failure to do so will cause one of the stays to crack apart when sufficient heat is applied.

Another helpful hint is to sand or sandblast the area you are going to repair. This will help cut down on fumes from burning paint and also make it easier to see what you are doing.

#### C H E C K I N G   Y O U R   F R A M E

**by Arthur Rudman**

#### Know How to Check Your Frame Tubes for Conformance to the Best Reynolds Sticker Guarantee

Did you know that while your choice racing or touring frame has a sticker affixed to the seat tube which says "Guaranteed Built With Reynolds 531, Butted Tubes, Forks, and Stays," it may not have what it is guaranteed to have?

The Reynolds Tube Company manufactures only a seamless variety of bicycle tubing. The seam tube has a pronounced raised longitudinal seam of electric weld on the interior of the tube, (This is the least expensive tubing material) as distinct from the smooth interior of the Reynolds tube. Welded tubes are heavier in weight and tend to crack or break when over stressed at the weld, hence, welded frame tubes are the least desirable tubes from the cyclists' viewpoint.

What should concern the cycling community is that so often the aspiring cyclist believes that label and does not know enough about frame short-comings to keep the frame builders honest. The biggest bike manufacturers have been notorious about promoting all 531 throughout with additional builder guarantees but still the frames lack what is promised.

Welded head tubes are found frequently in disassembled and broken frames. There are not that much additional profits, one would think, by substituting a piece of welded tubing in place of the seamless variety. More likely, either production depleted the seamless head tube stock, (It comes in random lengths of about 20 feet) or the wrong size tubing was ordered or delivered, making it impossible to press the head set bearings in position or to braze the head lugs. Maybe there is that much extra profit in it, after all, if the buying public does not care or does not know the difference.

Let's remember that there are twelve pieces of tubing for which that top level thoroughbred Reynolds sticker guarantee applies.

Head Tube	1 piece
Main Tubes	3
Forks	2

Seat & Chain Stays	4 pieces
Fork Column	1
Brake Bridge	1
(Chain Stay Bridge)	Optional

It's up to the bike builder to build it properly. Reynolds makes the right kind of bike tubing!

Head tubes may be conveniently inspected by removing the fork from the main frame. You should then be able to inspect the interior of the straight gage head tube for the existence or nonexistence of a weld and the fork column interior for a single butt.

Other short comings are sometimes the use of seamed stock for one of the other eleven pieces of tubing of a cycle frame, or the use of a non-buttet straight gage variety, where it is not expected. One or two butts are expected for the main tubes. It is common to have a double butted top tube.

An explanation for the term butting is now necessary. The term butt is an English term meaning a controlled change in tube wall thickness. Butted cycle tubes are thicker at its ends for strength, stability, and weight. Reynolds has a brochure, which is available to anyone with whom the Reynolds have an inclination to respond, that admirably explains the mechanics of butting. Here in the U.S.A., our tube manufacturers refer to this process as "upsetting." At one time, U. S. manufacturers produced single butted tubing. Another interesting process applies to the forks and stays and that is "tube reduction." Were it not for this process, the smaller ends of the forks and stays would have thicker walls than the larger end. The English refer to this "tube reduction" process as butting too.

The three main Reynolds tubes are impression stamped. If the paint is not too thick and if the impression was not removed during any grit blasting or filing by the frame builder, this identification can show what kind of tubing it is. Some tube manufacturers sometimes stamp the other tubes of the set.

Low quality forks and stays can be easily spread apart or together without the expected spring back. Reynolds fork blades are impression stamped and they respond properly to this test. This is a simple test to perform.

If the bottom bracket axle assembly is removed, then the seat and down tubes may then be inspected for any seams and any butts. Seams are obvious. The butts are small but perceptible. Look into the chain stay while you're at it. Remove the seat pin to aid in viewing the seat tube interior.

The three main tubes may sometimes be tapped with a coin to detect tube changes in thickness. Remove the seat pin for this test too. The seat stays and front forks are difficult to inspect without any expense beyond the spring back test mentioned earlier. Should the widest section of the seat stays be greater than 5/8", it most likely is not Reynolds.

Know what you're buying! That Reynolds sticker and Guarantee are an inducement to buy. Should you have such a bogus frame, you may find it difficult to obtain satisfaction. The big cycle manufacturers will fight you off and may even intimidate you for they know better! Only pay for what you know you are getting--first quality tubing from a first quality builder--and let's keep them honest by inspecting for conformance what they sell before you write that check.

Proteus Design framebuilders are professionals who use involved techniques and thousands of dollars in machinery and fixtures. While writing this book we have kept in mind the basics of frame building. However, we may have written some passages or made some drawings that may be confusing. If you feel that this has occurred or we have omitted material that may have been of help to you, please let us know. This information will be of great help to us in compiling future editions.





