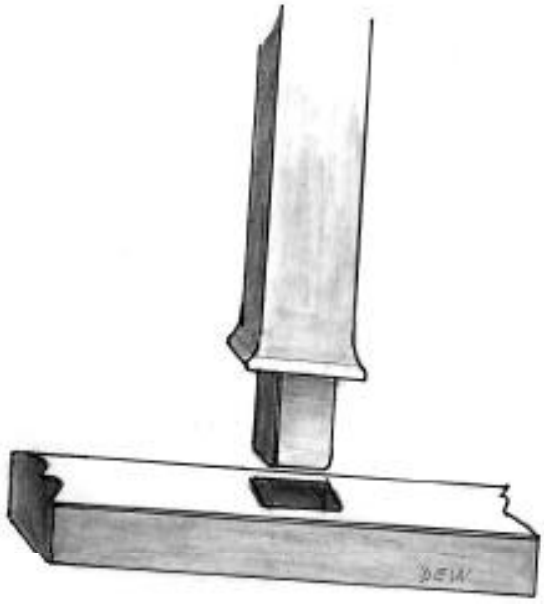
## Controlled Hand Forging Lessons 9 & 10

# Mortise and Tenon Joinery

**Text and Illustrations by Doug Wilson**



*#1. Example of technique*

**Lesson Number Nine–**
**Mortise and tenon joinery**
**Definition:** Making a mechanical joint with two or more pieces
**Intent:** The smith will learn to forge a tenon and assemble a mortise and tenon joint.
**Tools** Side set – top and bottom (drawing #2) Note that the cutting edges aren't sharp. The cutting edges are slightly radiused. Set hammer Monkey tool or bolster plate with 1/4" x 3/4" hole (drawing #3) (This is a tool block with a 1/4" x 3/4" hole in center.)
**Materials**: 1/2" x 1" x 18" mild steel bar.
**Method: Step One**: Upset end of bar and forge to 1 1/8" x 5/8", 3/4" from end. End tapers down to 3/8" x 3/4". (drawing #4) Mark bar on hot cut 3/4" from end.
**Step Two:** Take a full yellow heat. Place the bar over the bottom side set. Hit a light blow. The bottom surface of the bar will be cut. Turn the bar up on its corner. Strike another light blow.

Turn bar onto uncut next surface. Strike again. This marks the second side of the bar. (drawing #5) Repeat and cut the remaining two corners and sides with light blows.

*#2. A top and bottom side set*

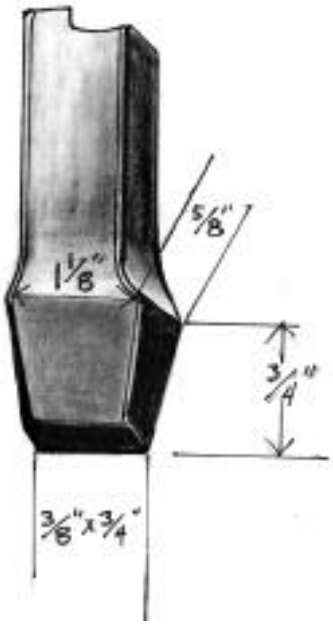
*#3. A bolster plate*

**Notes:** The light blows on the corners help to insure proper tool alignment.

Misaligned cuts or double cuts cause hot shuts, then cracks. Proper tool alignment is critical here. Any mis-cuts should be filed out immediately.

Once marked, the bar can be supported on a stand or your hip. Use top tool to continue. (See previous lesson for bar support.)

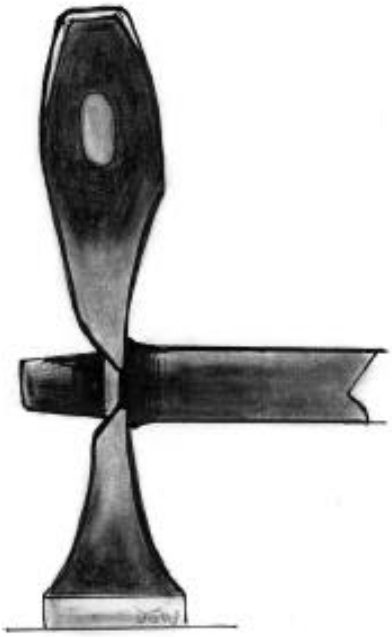
Reheat bar if necessary. Continue cutting until the core of the bar is just a bit oversize, in this case about 5/16" x 13/16".




*#4. Upsetting and forging dimensions*

**Notes:** If the tenon is a bit too fat that's ok. Too thin won't do. A striker's assistance helps with drawing down the tenon.

**Step Three:** Reheat bar to full yellow. Place bar over sharp edge of anvil face. Place set hammer directly over it. (drawing #6)
Strike a heavy blow. Turn the bar 1/4 turn. Strike again. Turn again in the same rotation. Strike again. You are drawing out the tenon.



*#5. Marking the second side of the bar*

Continue until you have drawn down the tenon to 1/4" x 3/4"; length as far as it goes. Finally, lightly forge down the corners.

**Note:** As you forge down the tenon, the set hammer and the anvil must be parallel. Check size of tenon by inserting end of tenon into bolster.

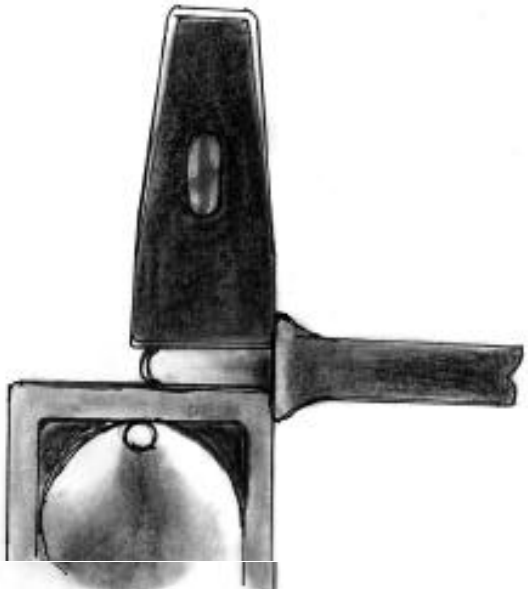
**Step Four:** Upset square shoulders. Reheat to full yellow. Heat should extend about an inch up from tenon shoulder.

**Note:** Quench the tenon to prevent burning if necessary. Pull the bar from the fire. Set bolster over the hardie hole. Insert tenon. Upset and square by hitting hard on top end of bar. (drawing #7)

Straighten bar as necessary. Square shoulders to bar with light hits on anvil face.

**Note:** Tenon should be centered on the bar.

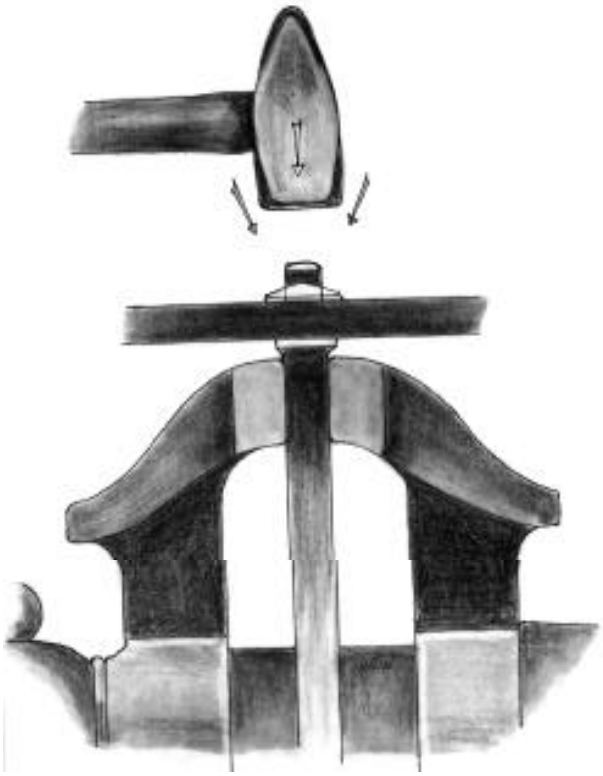
Centerlines of bar should be straight. Shoulders should be straight and square.



*#6. Using the set hammer*

**Step Five:** Cut tenon to length on cutoff hardy. In this case, length should be 1 1/4" from shoulder.
**Note:** Beveled edges on the end of the tenon help prevent thin, sharp or cracked edges on the finished tenon head.

*#7. Using the bolster plate*



*8. Upsetting the tenon*

**Step Six**: Finishing the joint. Heat tenon and about 1" above shoulder to full yellow.

Quickly set bar in vise. Set mortise onto it. Tap it down so it sits firmly on tenon shoulders. With rapid hammer blows, upset the tenon. (drawing #8) First hammer blows are straight down. Finish with angled blows.
**Note:** The entire tenon and a bit of the shoulder must be at a bright heat to insure a tight joint.

Forge the head of the tenon into a symmetrical shape with smooth edges. It should be centered on the face of the bar it has joined.
**Note:** If you run out of heat, you can use a torch to reheat the tenon head. It is best to finish this operation in one heat. A second heat should only heat the tenon, not the bar with the mortise. (drawing #9)
**Troubleshooting:** If the tenon has cracks at the shoulder, this was caused by (1) cutting too

deep in step two, (2) misaligned or double cuts, or (3) forging tenon at black heat. Note: File out hot shuts before and during forging of the tenon. If the tenon head is not centered on the bar it joins, your upsetting blows may not have been straight down or the mortise was not centered in the bar the tenon joins.

*#9. The lesson completed*

**Targets, Time:** Upsetting bar, one heat. Cutting shoulder and drawing out tenon, two to three heats. Trimming end of tenon, one heat. Assembling pieces and heading tenon, one heat.
**Targets, Dimensional:** Tenon head should be symmetrical, without sharp edges and centered on the bar it joins. Tenon shoulder should be the same dimension

# Forge Welding

By Dan Nauman Illustrations by Tom Latané
Photos by Dan Nauman
**Lesson Number 10**– Forge Welding
**Definition:** Fusing two or more bars together by bringing them to a high heat in a forge, and applying pressure to the area being fused by hammer blows.
**Lesson:** Upsetting, scarfing (see Definitions, right), and forge welding the ends of two bars of equal size together to make one bar. Intent: The smith will learn the technique of welding two bars of equal size together, accurately maintaining the original stock size and shape after welding.
**Materials:** Two 15" bars of 1/2" square mild steel. Tools needed: Basic tools include standard cross peen hammer and anvil. Flux (see Definitions, right), either borax or EZ Weld. Calipers and a square can be used to evaluate your work.
**Method:** Forge welding is used in several circumstances: to produce a smooth transition of adjoining elements; to secure several elements into a bundle (i.e., leaves, grapes, acorns, bas-

*A forge-welded sample from Cyril Colnik*

ket twist); to join a bundle to another element; to close the ends of a single bar shaped in a ring, oval, or rectangular shape (as in a frame); to join mild steel to high carbon steel (as in an ax bit); or to laminate several bars together to form a billet (as in Damascus laminate).

**Definitions:**

1.) Scarf (scarfing): Preparation or preparing a portion, often the end of a bar for welding, by tapering to a thin edge which can be blended into the mating material.

2.) Flux: The product applied to the areas to be fused to reduce oxidation, and lower the melting temperature of the scale. (Examples: borax, EZ weld, etc.)

3.) Clinker: The hard, gritty, often glassy mass that congeals in the bottom of the firepit.

4.) Coke: Soft coal that has had the bulk of its impurities burned out. Coke's appearance is puffy. As good-quality soft coal burns, it expands and congeals to the neighboring coal nugget, forming a larger mass. Almost entirely carbon in its makeup.

**Note:** Just as there are different approaches to other aspects of forging, the same is true for forge welding. It cannot be said that any one way is best, as there are many experienced smiths who produce consistently sound welds in a different manner than explained here. Different scarf forms, different fluxes, and several other aspects of forge welding can be learned and utilized. To introduce these differences in this lesson would prove confusing to the student. Thus, this lesson will concentrate on the method taught to me in the 1970s. Differences aside, the fundamentals usually prove to be similar or identical.

In all cases, a high heat is needed at the point of fusion to successfully weld the bars together. The color of the bars should be yellow to yellow/white when removed from the fire. The only exception to this would be when welding high carbon steel to mild steel. A lower heat of orange/yellow should be the highest heat applied so as not to burn the carbon out of the carbon steel.

The gray scale that forms on a bar when heated is the enemy of the forge weld. The bars will not fuse properly when scale is present. Scale forms on the outside of the bar in the presence of oxygen. Flux forms a barrier around the areas to be fused, protecting it from oxidation. It is applied to the bars at an orange heat. Flux is not glue, or a bonding agent, rather it lowers the melting temperature of this scale, and prevents more scale from forming while heating in the fire. Some smiths theorize that to some degree flux also raises the burning temperature of the metal.

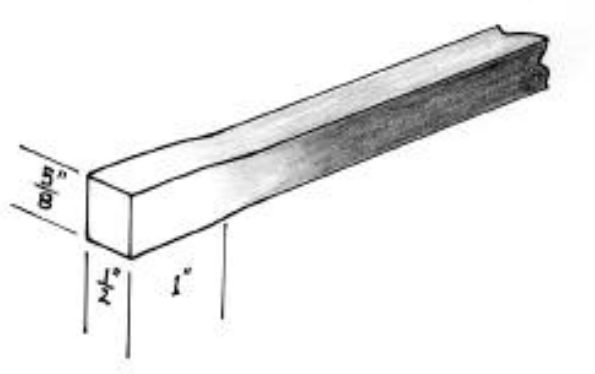



*Figure 1: Upset end preparation*

Another important aspect of welding is to be absolutely sure you have a "clean," domed fire. A clean fire is free of a clinker in the firepit, and has no fresh coal burning in the center of the fire. A good welding fire also has an abundance of coke domed and banked in the firepit. Should the fire "hollow out" while heating the bars, only coke should be added to the fire to replenish the fuel. Fresh coal cools the fire, and also introduces impurities naturally found in coal. These impurities are largely burned out as the coal becomes coke.

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When taking a welding heat, a good deep fire with the bar in the center of the fire under a good two or so inches of coke will reduce (but not eliminate) the amount of scale which forms on the bar during heating.

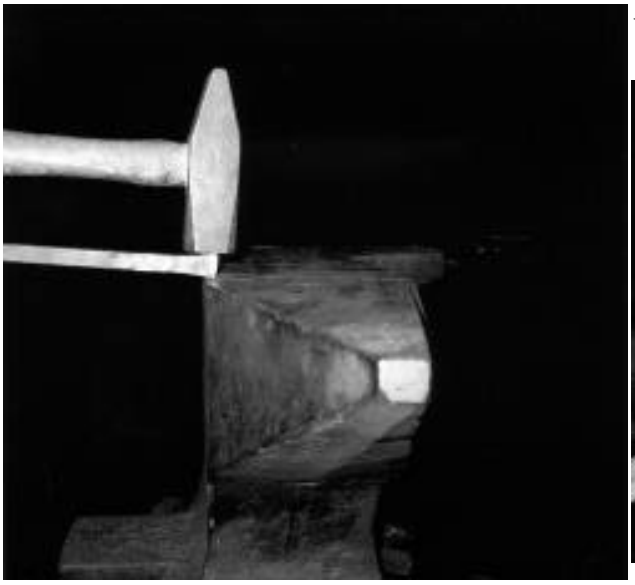


*Figure 2: A half-face blow.*

**Step One–**Preparing the scarf:
Taking a short high (yellow) heat on the last 1" of the bar. Then upset about 1" of the end of the bar so that the bar measures at least 9/16" square. (See previous lesson Number 7) Next, forge one dimension back to 1/2", producing a cross section measuring 1/2" x 5/8".

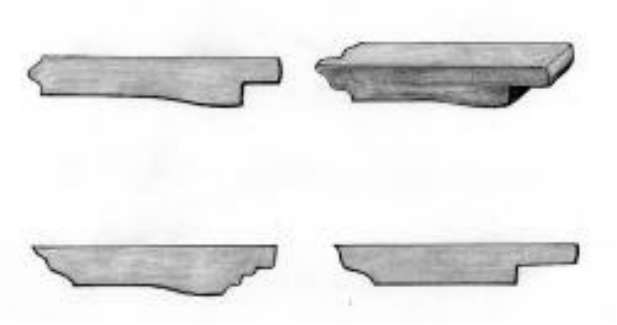


*Figure 3: Above, correct. Below, incorrect. Left– initial shoulder backed off anvil too soon. Right– no upset remains for scarf to be laid upon during weld.*

**Step Two:** Take another yellow heat on the end of the bar, again on the last 1" of the bar, place the end of the bar (with the 5/8" sides vertical) squarely on the anvil's face with the end of the bar 1/4" from the inside edge of the anvil. The edge of the anvil should be somewhat sharp for this step. Hitting straight down with the hammer's face halfway above the an-

*Figure 4*

vil face and halfway beyond the anvil face (Figure 2, photo), reduce the cross section to about 1/2 the thickness of the material, in this case to 5/16".

**Tip:** In order to create a clean shoulder in this operation, put a slight downward pressure on the bar so the bar stays where you put it. Then after the first or second blow add a slight forward pressure to keep the bar from "stepping" off the anvil.

**Step Three:** The forging dynamics of the material will cause the area of the bar on top of the anvil to slightly spread wider than desired. In the same heat from step two, turn the bar 90 degrees, and forge this area back down to 1/2" in thickness.

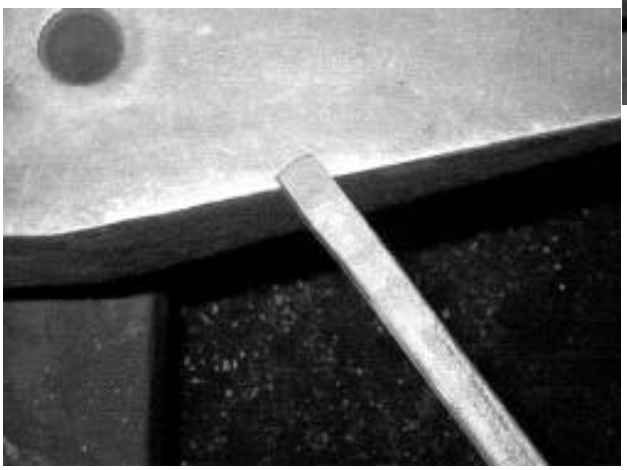


*Figure 5*

**Step Four:** Take another yellow heat on the last inch of the bar. Place the shoulder produced on a sharp edge of the anvil, pressing the shoulder squarely against the side of the anvil. The hand the bar is holding should be lowered slightly so the face of the scarf is off the anvil face. (Figure 4, photo). Move the hand holding the bar to the left of square, and take a blow. Moving the bar back and forth at a 90-degree angle (right to left), and using each step produced by the previous blow to brace against the side of the anvil, slowly step the bar off the anvil. (Figure 5, photo). In this same process, the profile of the bar should be drawn out to a flat point. (Figure 6, photo). If done correctly, the face of the scarf should have steps as shown in Figure 7. When the scarf is drawn out, forge a slight curve at the end of the scarf. You should be able to do all of step four in one heat.

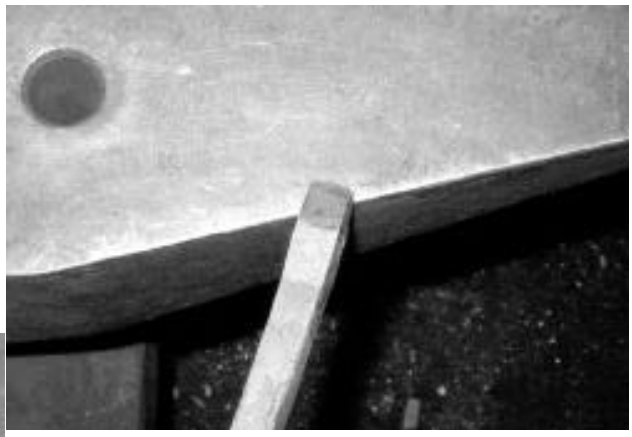


*Figure 6*

**Notes on scarves:** The reason for the curve at the end of the scarf is simple. The anvil acts as a heat sink when hot metal is applied to it. If the end of the scarf is not off the anvil when welding, it might cool too rapidly, and the weld will not be properly fused in this area. The curve keeps the thin edge of the scarf off the anvil before the first blow, retaining the heat longer to produce a sound weld. The thin tapered edge of the scarf is formed to produce a smooth weld joint. A scarf with a thick edge will produce a weld with a very visible seam (Drawing, figure 8).

**Step Five:** Repeat steps one through four on the second bar.

**Step Six:** Fluxing the scarves.

*SAFETY! - Some fluxes may emit noxious fumes when heated. Make sure your forge and building are vented properly.*

Reduce the air blast in the fire if you have an electric blower. If you are manually applying the air blast, reduce the force of the blast to

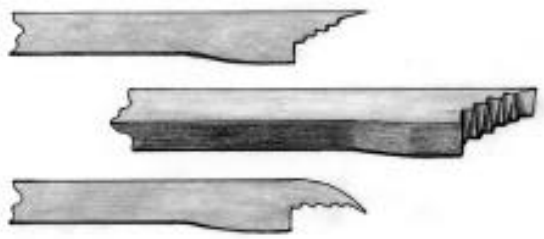


*Figure 7: Top– shouldered and stepped scarf. Bottom– Curved tip. Shoulder prevents scarf from overlapping beyond upset area when scarves are quickly placed together.*

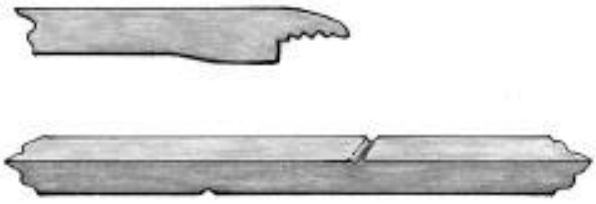


*Figure 8: Blunt scarf makes seam difficult to blend.*

more of a whisper. This will reduce the chances of burning the scarves while fluxing by reducing the available oxygen in the fire.

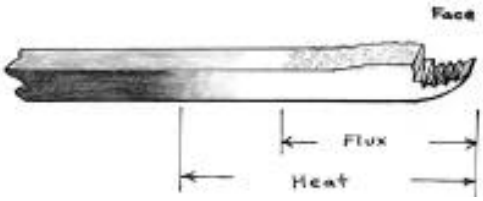



*Figure 9: Fluxed face heated from below.*

Making sure you have a clean and deep fire, place the scarves into the center of the fire, face up. If the bars are not covered with coke, cover them. When the bars reach a bright orange, with the bars remaining in the fire, take your fire rake make a hole in the fire over the scarves so flux may be sprinkled on the face of the scarves. With a small spoon with a long handle (so you do not burn your hand), apply enough flux to cover the scarf, as well as beyond the scarf where the other scarf will join. (Figure 9, drawing). Cover the bars once again with coke. When you are finished fluxing the scarves, position them so they are facing down in the fire.

**Notes:** One of the biggest mistakes beginners make in welding is not applying the flux back far enough on the bar where the bars will be fused.

Some smiths prefer to flux all sides of the scarves, while others simply apply flux to the scarf faces. The theory behind fluxing all sides of the bar is to insure that all surfaces are free from scale, as well as to increase the burning temperature of the bar. The bar can and will burn if allowed to get to a full sparkling white heat, at which point the flux will also burn off. The bars likely will not weld at this high temperature. Also, the molecular structure of the material will break down, creating a weaker joint, and often an unsightly weld.

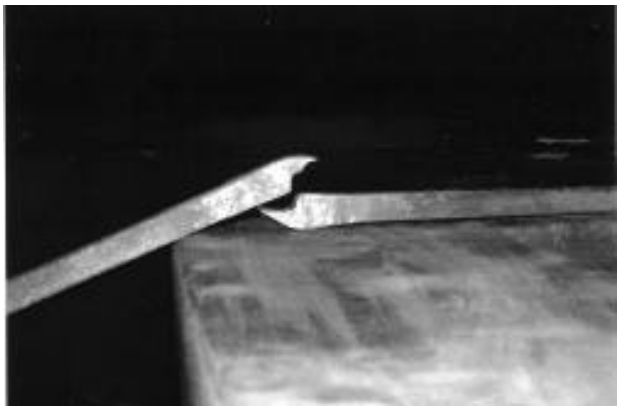
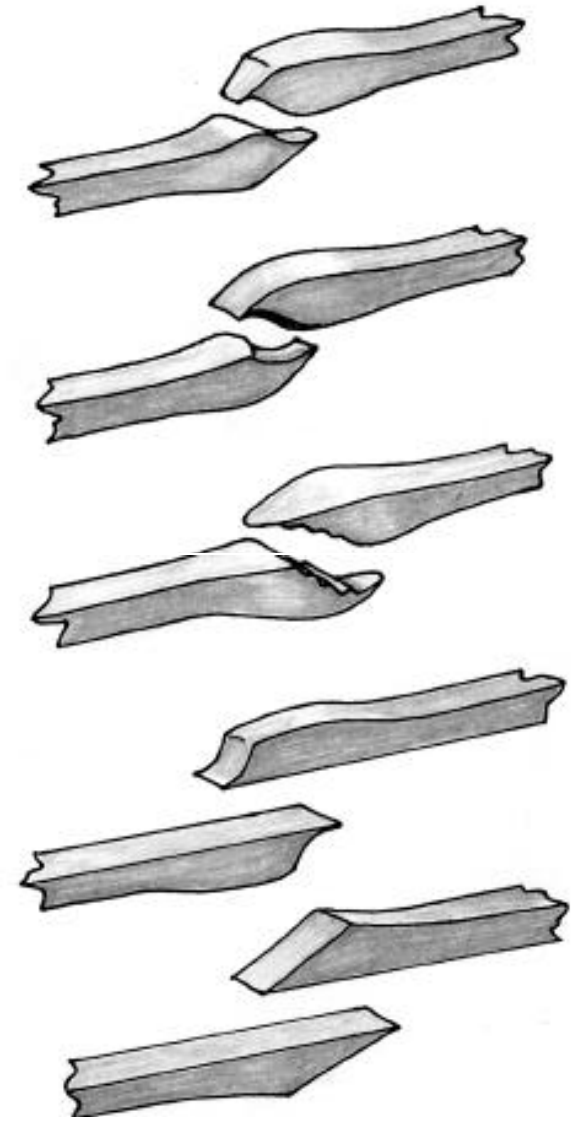


*Figure 10*

If you choose to flux all sides of the scarves, turn the bar 90 degrees only after you are certain the flux has adhered to the scarf surface. You will know when this happens, as the flux will be the same color as the bar. If one bar gets hotter than the other, move it to the side of the fire where the fire is cooler, or reduce the air blast further.



*Some other forms of bar end scarfs. The 90º shoulder on the scarf described in the text will aid in quick alignment of bars to be welded, preventing overlap beyond upset material*

Fluxing the scarves in the fire keeps them hot, and reduces the amount of scale formed, therefore shortening the time it takes to produce the weld. Removing the bars from the fire to flux the scarves is not necessarily wrong, as many smiths prefer this procedure, and do so successfully. Sometimes, fluxing in the fire is virtually impossible (i.e., welding a wagon wheel tire.) In these cases, removing the bar from the fire is necessary.

Always keep coke on top of the bars when not in the act of fluxing.

**Tip:** Rub soapstone or chalk on the face side of the bar to indicate direction of the scarf face when pulling the bars from the fire.

*Figure 11*

**Step Seven:** Welding the bars

Have your hammer at the anvil in a position to grab it quickly. The scarves are at a welding heat when they are at a yellow-white appearance in color (often referred to as a "welding heat"). Make sure the scarves are heated well beyond the shoulder where the mating bar will join. Some smiths wait to see just a few sparks coming from the fire, indicating the piece is just starting to burn. This is not necessary, and can lead to burning the tips off of the scarves.

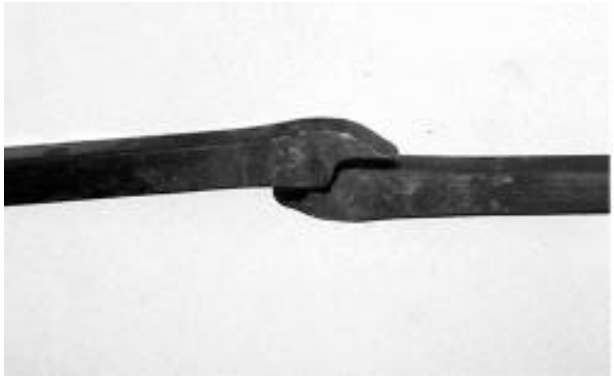


*Figure 12*

**Tip:** If you are not sure if the pieces are at a welding heat, gently touch the pieces together in the fire. If they want to stick, almost like a magnet, they are probably ready to weld. With experience, this touching in the fire will not be necessary.

**SAFETY:** *When welding, molten sparks fly from the bars which can burn others, as well as you. Alert others in the area when performing a weld, and make sure other items in the shop that are flammable are protected from the sparks. Some smiths wear a protective leather apron when welding to prevent their clothes from burning. You and anyone else present should be wearing eye protection with side shields at all times. After welding, be aware of the possibility of fire caused from stray sparks in the surrounding area, i.e., shop rags, charcoal, dry wood, etc. These items and others ignite easily from molten metal and flux spattered from the forge-welding process.*

Bring the pieces out of the fire, rotating one piece 180 degrees so that the scarf is facing up. Place the bar with the face up on the center of the face of the anvil, coming in from the far side of the anvil. (This bar should be in your hammer hand.) Place the other bar on the near edge of the anvil, with the scarf off the face, pointing up at about a 45-degree angle. (Figure 10, photo). In a hinging fashion, lower the scarf down onto the opposing scarf, keeping contact with the edge of the anvil to control the accuracy of the placement of the scarf (Figure 11, photo) and press down on the opposing scarf. The heels of the scarves should be placed together as shown. (Figure 12, photo). Press down hard enough so you can release the bar in your hammer hand.

Release the bar in your hammer hand, grab the hammer, and strike firmly in the center of the joint. Forge the entire joint rapidly with six or seven blows. Make sure you forge the thin tip of the scarf as it will cool rapidly. Next, flip the now-welded bar 180 degrees to forge the opposite side. Hit six or seven blows on the entire joint and then turn the bar 90 degrees and repeat five or six more blows on the joint. Flip the bar 180 degrees and hit the joint once again five or six blows. Repeat as necessary, never forging colder than a medium orange heat.

*Figure 13: Bars for practice weld– no alignment of scarves.*

**Note:** Dark spots on the joint indicate cooling of the material and will not weld there. This may be caused by too low a heat, or inadequate fluxing. These areas must be fluxed again, returned to a welding heat, and forged to fuse the joint.

While welding, keep in mind that you do not want to forge the cross section of the joint down beyond the parent stock size. Also, be careful not to forge beyond the joint as this will also reduce the cross section of the bar beyond the parent stock size.

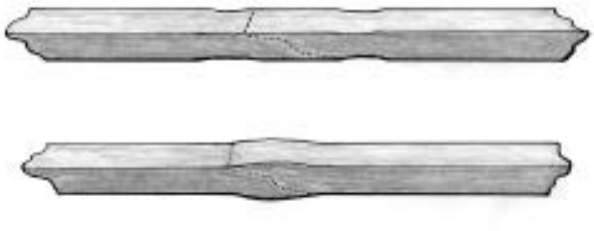


Figure 14: Top– thin areas due to loss of material from burning, too little upset, or over-hammering, must be upset. Bottom– remaining bulge must be drawn down to dimension.

With a properly executed weld there will not be any "dark spots" or evidence of a scarf. If there is evidence that the weld is not complete, flux the open seams of the joint, and take another welding heat. Remove the bar from the fire, and forge down carefully, so as not to greatly reduce the cross section of the bar beyond the parent stock size.

**Note:** Timing is important. If you take too much time getting the pieces from the fire to the anvil, you may lose too much heat to weld the bars together. To increase your proficiency, you may want to take a few "practice runs" by removing the bars while cold from the firepit, positioning them on the anvil as described in step seven. Do this until you are comfortable with the procedure. You will then be able to release the bar from your hammer hand and grasp the hammer without the bar falling to the ground.

**Tips:** -Some fluxes, such as EZ Weld brand, are very aggressive and may adhere to the metal after the weld has been completed. To remove it, take another welding heat, remove the bar from the fire, and scrub vigorously with a stiff wire brush. Flux is harder than a file, so do not try to file the flux off, as it can ruin your file.

-A lighter hammer of 1 1/2 to 2 pounds may work better than a larger hammer. With a lighter hammer, the hammer can be swung faster and more accurately. Also, the chance of forging down beyond parent stock size is reduced with a smaller hammer, as you will not have the heavier force of the larger hammer.

-You may want to first practice a more simple weld to get used to the properties of forge welding. The faggot weld is a simple, crude weld which has no end preparation (no scarves.) Try bending a 3/16" x 3/4" piece in half and weld the last 3/4" of the end of the bars together. (Figure 13, drawing). Be extra careful when performing this type of weld, because the larger surface area causes more molten flux and sparks to fly from the joint.

**Step Eight:** Refining the weld (If necessary) If the cross section of the joint is still larger than the parent stock size, place the bar back in the fire and bring the joint to a welding heat. Remove the bar from the fire, and carefully forge the joint back down to the parent stock size.

**Potential problems and solutions:** If the weld is properly executed, the joint is invisible, the bar has no bulges or "necked-in" spots, and has sharp 90-degree corners. (Figure 14, see drawing of bulge and necked-in spots). To refine the bulge, proceed as described in step eight.

If the bar is necked in, it will be more difficult to fix. The portion of the bar where it is necked in is taken to a welding heat, and then upset (refer to Lesson Seven, Hammer's Blow, volume 12, #1, Winter 2004) back to the parent stock size. A poorly executed weld will begin to come apart or fail entirely in the upsetting process.

If a parallelogram was formed at the joint, first upset the joint, then take another heat and forge down the acute angles slightly. (As explained in Lesson One, Hammer's Blow, volume 11, #1, Winter 2003.) Then carefully reduce to the parent stock size.

**Targets:** -The scarf is produced in one heat. -The weld is completed in one to two heats, and the joint returned to the parent stock size.

-The joint is to be square in section with sharp corners, no necked-in areas, and no bulges. You can check your accuracy with a pair of calipers. Check for squareness with a steel square.

-The welded bar is to be straight, have no twist, be free of flux residue and the bar should have no visual evidence of a seam.

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**259 Muddy Fork Road,**
**Jonesborough, TN 37659**
**Phone: 423-913-1022**
**Fax: 423-913-1023** Website; www.abana.org Email; centraloffice@abana.org

ABANA

| | |
|---|---|
| ___ Regular Member | $55.00 |
| ___ Senior Citizen (Age 65+) | $50.00 |
| ___ Full Time Student | $45.00 |
| ___ Foreign Member | $65.00 |
| __ Public Library-USA | $45.00 |
| ___ Contributory | $150.00 |

MASTERCARD OR VISA ACCOUNT NUMBER

_____-_____-_____-_____

EXPIRATION DATE _____ _____

# Join ABANA or Check out other area chapters!

## Northeast Blacksmiths Association

Northeast Blacksmiths holds its meets twice a year at the Ashokan Center in New York State.
The Ashokan Center is located in Olivebridge, N.Y., several miles west of Kingston, N.Y. The meets are held the first weekend in May and in the first weekend in October every year. The main demonstration is in the blacksmith shop and there is a "Hands On" workshop for beginners. A main demonstrator is brought in for each meet, food and bunk-house style lodging are provided as part of the cost of the weekend long meet.

**Contact** :
Jonathan Nedbor for more information
Phone:(845) 687-7130
jonned@hvc.rr.com

For more info and to register for meets, check out the web site; http://www.northeastblacksmiths.org/

## Join The Pennsylvania Blacksmiths Association!

_____
Name

_____
Address

_____
City, State, Zip code

_____
Home / work Phone # E-mail (optional)

New Member ____ Renewal ____

Do you have any particular skills (welder, accountant, carpenter, doctor) that may be helpful to the group or membership?

_____

_____
Suggestions for PABA demonstrations

What is your skill level?
O Beginner O Intermediate O Advanced O Professional

Membership paid by ___Cash ___Check # _____

Send your completed application with $ 25 ( one year dues) to;
PABA Treasurer, Doug Dayger
492 Quaker Lake Rd
Binghamton, NY 13903
(make Checks payable to PABA)

### PABA Membership Application

Membership is from *Jan. 1 — Dec. 31*

**New Jersey Blacksmiths Association**
**Attn: Larry Brown, Editor**
**90 William Avenue**
**Staten Island, New York 10308**




## How to Join or Renew your Membership in NJBA:

**NJBA Dues are $20 per year.**
**NJBA Business Dues are $40 per year**
**Please make your check out to: "NJBA"**
**Please mail checks to:**
**NJBA, P.O. Box 224, Farmingdale, NJ 07727-9998**

Please include payment with the information listed below.
"I want to join NJBA, and I am enclosing my check for $20 ($40 for a business) to cover annual membership dues and newsletter subscription. "I understand and acknowledge that NJBA dues are credited from June to June, that I will receive for my first years dues the current volume, and that dues will be payable again in June."
The following information will be listed in a roster available to other members.

Name _____ Home Phone_____
Address _____ Day Phone _____
City _____
State _____ Zip _____
E-Mail _____ Skill Level (optional)_____
Comments _____