

While alloying elements add greater mechanical properties to carbon steel pipe, they also make it more difficult to weld.



Techniques for Successfully Welding Alloy Pipe

*These tips can help you
make the transition from
gas tungsten arc welding
carbon steel to GTA
welding alloy metals*

**BY NEAL BORCHERT AND
DANNY PHILLIPS**

Pipe made from highly alloyed metals requires a higher level of gas tungsten arc welding (GTAW) proficiency to meet the standards required in the power-generation, nuclear, petrochemical, food, pharmaceutical, and processing industries.

While alloying elements such as nickel, chromium, molybdenum, copper, and cobalt add greater mechanical properties to carbon steel pipe, they also make the pipe more difficult to weld. This article focuses on the techniques required from the welder's perspective, so that he or she can make the transition from GTA welding carbon steel to GTA welding alloy metals such as stainless steel, duplex stainless steel, Inconel® (Ni-Cr, Ni-Cr-Mo, and Ni-Cr-Co-Mo alloys), Monel® (Ni-Cu and Cu-Ni alloys), and pipe from related alloys. While each alloy has its own specific considerations, similarities do exist.

Slow Down, You Move Too Fast

Alloy metals have lower thermal conductivities than steel and the alloy weld pool has a lower viscosity. Because the weld pool is not as fluid, it does not "wet" as readily. The welder familiar with mild steel must physically and psychologically make adjustments. Key among them is to slow down. Slow down for stainless steel, slow down more for duplex stainless steel, and slow down even more for nickel alloys. Traveling too quickly can lead to problems like incomplete fusion.

Do not attempt to compensate for a sluggish pool by increasing weld current. Using more current than the weld procedure dictates will vaporize ("burn out") the alloying elements, leading to corro-

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sion and reduced service life. For this reason, use a low-to-moderate heat input, and visually inspect all welds for indications of excess heat input, typically a color change. This step is critical.

Keeping the “slow down” advice in mind, the following images and advice showcase the basic steps necessary to achieve good results when welding alloy metals. Be aware that in several instances the welder in the photos deliberately made mistakes. This was done to help the beginning welder learn to identify mistakes, their causes, and how to correct them.

Weld Preparation

Weld backing gas. Protect the root side of all complete penetration welds by using the proper tooling to close off the pipe and purging the atmosphere from the pipe.



Weld backing gas.

Something’s wrong. This tack weld shows numerous defects: a sluggish weld



No backing gas: outside the pipe.

pool that couldn’t be controlled, discoloration that indicates too much heat input, and a “star crack” (left) from improper gas coverage and the pool solidifying too quickly. The cause: no backing gas.

Carbide precipitation on the inside of the pipe, commonly called “sugaring” because of the appearance, indicates poor backing gas coverage.



No backing gas: inside the pipe.

Shielding gas. Argon may be used for all thicknesses, but for nickel alloys greater than 1/8 in. thick, adding helium increases penetration and allows for faster travel speeds (consult your local gas distributor for a recommendation for your application). For argon, set the flow rate at 10 to 20 ft³/h. For helium mixtures, increase flow rates by one and a half to three times to compensate for helium’s buoyancy.



Set the gas flow.

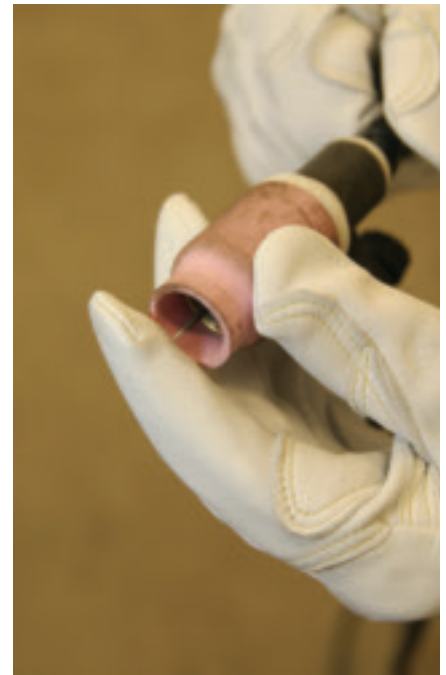
Use a gas lens. To create a smoother, more stable flow of shielding gas and su-

perior shielding gas envelope, always use a gas lens. Use the largest cup practical for the application (here, a size 12 cup is used for 6-in.-diameter, Schedule 10 duplex stainless pipe).



Always use a gas lens.

Tungsten extension. Keep the tungsten extension (stickout) as short as possible, ideally 3/16 in. or less on butt joints. This helps ensure that the welding arc stays within the shielding gas envelope. Thicker material or fillet welds may require extensions of 3/8 to 1/2 in. Use a 2% thoriated tungsten electrode for all welds.



Set tungsten extension.

Welding parameters. Set the welding machine for DC electrode negative. Arc starting methods include high frequency (HF), Lift-Arc™, or scratch start, with the first two being preferred.

Clean filler rod. Use a chemical solvent to clean the filler rod before use (safety note: remove the solvent and any



Set welding parameters.

flammable material away from the welding area before striking an arc). Ideally, wear gloves when cleaning the rod, as even oil from your fingers can lead to contamination. Generally, the filler metal should match the base metal. When welding dissimilar materials, match the filler metal to the higher-alloy base material.



Clean filler rod.

No contaminants. Prior to welding, remove all oxide film from the bevel and 2 in. back from the joint edge. Use a rotary file, hand file, or brush made from stainless steel; dedicate these tools to this application. Do not use disc grinders, as the alumina oxide in the sanding medium and gum-based adhesive can contaminate the joint. Next, use a chemical solvent to clean the joint surface. Grease, oil, paint, marking crayons, ink, lubricants, cutting fluid, and processing chemicals can contain sul-



Clean the metal's surface.

fur, phosphorus, lead, and other contaminants can lead to embrittlement. Safety note: remove the solvent and any flammable material away from the welding area before striking an arc.

Joint preparation. To obtain good fusion on alloy metals, bevel the joint to a wide angle (80 to 90 deg for a V-groove), create a narrow land, and set a wide root width. This will enable the arc to break down the bevel and ensure complete fusion.



Prepare the joint.

Mind the root opening. Pipe welders use their filler metal to set the root opening. This 1/8-in.-diameter filler rod should be just on the verge of falling through the root on this 6-in.-diameter, Schedule 10 duplex stainless pipe.



Set a wide root width.

Welding Advice

Awkward positions. Pipe welders need to be contortionists. Practice while kneeling on the remote amperage control (shown here), using your elbow, or putting the control between your thighs. For added convenience, consider using a gas tungsten arc welding torch with a remote fingertip control.

Get tight. The proper arc length when welding alloy metals is as tight as possible — on the verge of touching the metal. A tight arc produces a well-defined pool and better directional control, which is neces-



Using knee control.

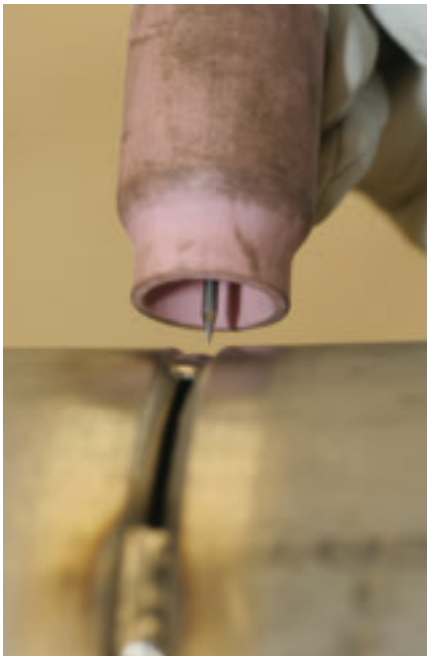
sary when dealing with a sluggish weld pool. Should the tungsten touch the weld pool, stop immediately and regrind the tungsten.



Example of proper arc length.

Too long, no control. Long arc lengths (shown here) preheat everything but the weld pool. If the heat of the arc gets to the bevel before the pool does, it can undercut the edge of the bevel. A long arc may also cause the end of the tungsten electrode to ball up prematurely.

See the arc. Welders must put their head in a position so that they can see the arc to maintain good arc length — don't guess. Generally, this involves being close to the weld. Some welders may find it helpful to use a magnifying "cheater" lens. Complicating matters, the pool on alloy metals is harder to read because, as alloying elements like chromium and nickel vaporize, they create a film or haze of plasma gas over the top of the pool.



Example of too long arc length.



Proper angle of the torch and filler metal.

Bevel breakdown. The inside of the same tack weld shows how the proper (slow) travel speed and tight arc broke down the bevel and complete fusion was obtained.



The inside of the same tack weld.

Root problem and solution. To illustrate the effects of travel speed, the welder

intentionally moved too quickly when welding on the left side of this joint, then slowed down to a proper speed. Notice how quick travel failed to break down the bevel, as indicated by a weld that is narrower than the width of the root opening.



Root problem and solution.

Angling for success. Keep the torch directed nearly straight at the joint, angling it back just enough to see the arc. Maintain a 90-deg angle (perpendicular) between the torch and filler metal. Angling the torch too much (beyond 15 deg) directs the heat away from the base metal, preheats the welding wire, and may cause it to ball up prematurely. This may lead to incomplete fusion.



Keep the torch directed nearly straight at the joint.

Slightly convex bead. This root pass shows good sidewall fusion and a slightly convex appearance. A slightly convex bead (as opposed to a flat or concave bead) prevents centerline cracking when the weld cools.

Too convex. This root bead is too convex, which can lead to fusion problems on the hot pass. Breaking down the ropey top of the bead and obtaining good fusion on both sidewalls will be extremely difficult.

Cracking up. This “star” crack or crater crack occurred because the edge of the weld pool solidified before the center. To prevent cracking, prepare the tack weld where you’ll end the weld by grinding it down. Then, follow this welding routine: about 1 in. before the end of the weld, bring the pool down to half its size. This



A slightly convex bead prevents centerline cracking when the weld cools.



A root bead that is too convex can lead to fusion problems.



This “star” or crater crack occurred because the edge of the weld pool solidified before the center.

will allow the pool to solidify or dry up from the inside out. After bringing the size of the pool down, increase travel speed to slightly faster than normal while maintaining a tight arc right up to the moment the arc is broken off. Many welders have a problem with star cracks because they increase arc length to help dry the pool up, which actually causes the pool to solidify too quickly. This causes star cracks on the root bead and causes arc marks on the surface of the pipe.

Tie-in and weld start. To start the root pass, butt the filler metal against the tack weld and fuse it in place (shown here. Note that the tack is not ground or otherwise prepared). Then, step back ¼ in. and establish the weld pool on the tack weld; next, move forward and bring the pool through to where the filler metal is tacked, and carry on. When pipe welding, note that the filler metal is not dabbed in and out of the weld pool. It remains in position and is almost “wrapped” into the weld. This technique keeps the rod inside the protective shielding gas and minimizes pool agitation, which prevents burning out the deoxidizing elements.



Starting the root pass.

Weld pass pause. When welding a weld pass freehand, move the torch from one side, always pausing at the side of the weld to allow the pool behind the arc to solidify before moving on. Also, when moving across, adjust travel speed so that about half the width of the joint is molten and the other half solid. Lastly, do not wiggle the torch as when cup walking; keep the arc pointed straight down at all times.



When welding a pass freehand, pause at the side of the weld to allow the pool behind the arc to solidify.

Stringer beads. After the first pass following the root pass, make all subsequent passes using the stringer bead technique. Alloy metals do not flow (“wet out”) readily, so the wide weave beads associated with carbon steel are difficult or impossible to make.



Make subsequent passes using the stringer bead technique.

Extended postflow. When welding alloy metals, set the gas postflow to 5 to 10 seconds longer than normal and keep the torch in position until the weld cools. Prior to using the filler rod again, trim the end to prevent contamination.

Following the steps described above will help welders make the transition from welding mild carbon steel to a variety of alloy metals. While this advice is broadly applicable, always obtain welding procedures for the specific metal on which you



Set the gas postflow to 5 to 10 s longer than normal.

are welding. Whenever possible, practice until working with alloy metals becomes second nature. Having confidence in your ability to make quality welds prepares you mentally for passing weld tests, which in turn opens up new job and career possibilities working with alloy metals. ♦

Acknowledgments

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In addition to the authors' own knowledge, this article reflects more than 100 years of pipe welding experience from Dave Stanley, journeyman welder, UA Local 598; Steve Davis, Joint Apprentice Training Committee instructor; and Gary Culvert, a 50-year Local 598 member, welding consultant, and retired college professor who is currently serving on the board of directors at Columbia Basin Community College in Pasco, Wash.

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