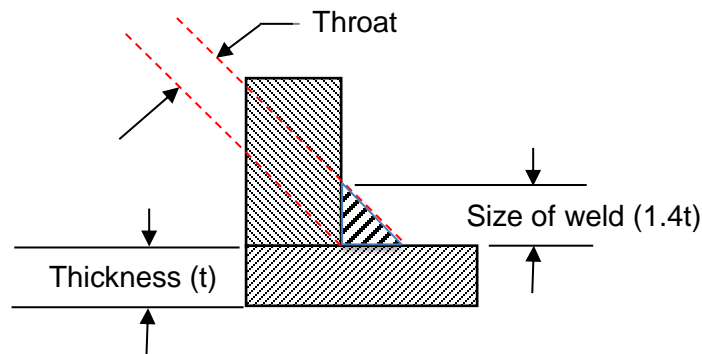


Welding of Light-weight In-Line Galvanized Tubular Steel

Galvanized tubular products can be welded using conventional arc welding processes, and that welding can be done safely. This document presents guidance on how to do that.

Welding Design

Tubular steel should be welded so that the welds are of sufficient size and length that are adequate for the intended service; accordingly, the design drawings should specify the required weld configuration and size. When tubes are butt welded together (i.e., joined end-to-end), the weld should penetrate through the full tube wall thickness and reinforcement should not exceed 3/32 inches (2.5 mm). When tubes are configured to form a tee, corner or fillet weld, the size and length required should be shown on the drawing. Generally, the throat of a fillet weld (see sketch below) should be the same as the thickness of the thinner member. Through the magic of geometry, that means that the leg length should be 1.4 times the thickness “t” of the thinner member.



Typical Fillet Weld

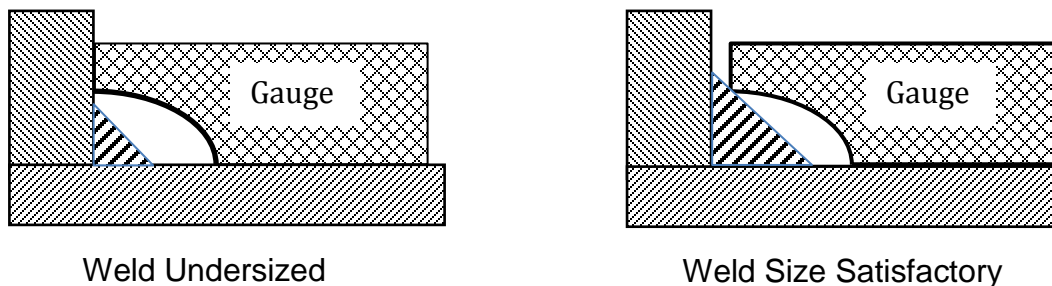
The fillet weld sizes shown below are suitable for tee, and joints at other angles where the tube end is notched to match the outside diameter of the mating tube or where the tube end is flattened so that contouring is not needed. The numbers in parentheses correspond to standard fillet gauge sizes.

Tube Wall Thickness (in.)	Minimum Fillet Weld Size	Tube Wall Thickness (in.)	Minimum Fillet Weld Size
0.049 and less	0.069 (3/32")	0.113	0.160 (3/16")
0.065	0.092 (3/32")	0.133	0.186 (3/16")
0.072	0.102 (1/8")	0.140	0.198 (7/32")
0.083	0.117 (1/8")	0.145	0.205 (7/32")
0.095	0.134 (5/32")	0.154	0.217 (7/32")
0.109	0.134 (5/32")	0.180	0.250 (1/4")

Welds significantly larger than 1.4t do not make the weld perform better, and it takes more time to make oversized welds – and this costs money. Don't over-weld.

Completed welds should be reasonably smooth and uniform and exhibit no gaps, voids, cracks, undercut, porosity or arc strikes. Weld spatter should be removed particularly if the surface being welded will be restored by painting or coating.

Fillet welds sizes should be checked using a fillet weld gauge. Simple go/no-go gauges that can be purchased from your local welding supplier, or they can be machined from heavy sheet metal for specific sizes. Fillet weld gauges should be used in the following manner:



The gauge must touch weld metal before touching the base metal. Where it is difficult to actually measure the entire weld due to the geometry of the members, measure the weld at where it can be measured, then visually check that it is the same width all around. Where the drawing specifies welding all around a joint, the weld size should meet minimum drawing requirements all around the joint.

WELDING PROCESSES

GAS METAL ARC ("MIG") WELDING

This process makes high-quality welds quickly and is by far the most widely used welding process when welding Wheatland tube.

The first choice is to weld using the spray transfer mode. Use 0.035 inch ER70S-2, ER70S-3 or ER70S-6 solid wire and a shielding gas of Argon with 8% CO₂, a welding gun rated at 400 amps 60% duty cycle and a power source rated at 300 amps, 100% duty cycle. Follow the settings shown in the table below. Travel speed and deposition rates (i.e. production rate) will be high.

When welding 18 gauge and thinner galvanized steel, it may be necessary to use the short circuiting transfer mode. The power source should be rated at 200 amps or more at 100% duty cycle, and it should have "inductance" control. Use the same wire and 98% Argon/2% CO₂ shielding gas with a welding gun rated at 300 amps.

Set the inductance to maximum and the slope control (if any) between mid-range and maximum slope. Follow the settings in the table below.

	<u>Spray Transfer</u>	<u>Short Circuiting</u>
Current Type:	DC Electrode Positive	DC Electrode Positive
Volts:	27 to 30	17 to 20
Amps:	250 to 380	100 to 190
Wire Feed Speed (ipm):	280 to 450	100 to 210
Dial Location (o'clock):	1 to 3	9 to 11
Tip position:	Recessed 1/4 inch	Extended 1/4 in
Wire Stick-out:	3/4 in	3/8 in
Gas flow rate:	25 to 30 CFH	25 to 30 CFH
Spatter indicates that:	Arc voltage too low	Arc voltage too high

The wire stickout should be held constant during welding. If the welder is using *spray transfer* and he pulls the torch *away* from the workpiece, the stickout gets longer, reducing the arc voltage; this will result in spatter and reduced penetration. If the welder is using *short circuiting transfer* and he pushes the torch *closer* to the workpiece, the stickout gets shorter and the arc voltage will increase causing spatter and reduced penetration. Welders should be aware that changing the stickout affects the arc and penetration; stickout should be held constant as much as possible.

Some of fabricators have had good success welding galvanized tube using E70C-GS metal cored wire such as Hobart's *Galvacor*; the parameters given above are a good starting point for metal cored wire, except that the current should be switched to DC Electrode Negative. This switch in polarity softens the arc which reduces penetration a little. That allows the weld pool to stay liquid longer which allows gases in the pool more time to escape, reducing porosity. The powdered metal in the core also contains arc stabilizers which help reduce spatter and keep the arc steady in the presence of vaporizing zinc.

The table above recommends starting with a shielding gas of 92% argon/8% CO₂. If the tube is 12 gauge thicker or other parts such as base plates are 1/4 inch thick or thicker, the CO₂ should be increased to as much as 18%. This increases the arc energy, ensuring penetration into thicker steel. Conversely, when welding 18 gauge or thinner, the CO₂ can be reduced to 2%. If burn-through is a problem on thin tube, switch to Argon with 2% Oxygen and reduce the voltage by 2 to 3 volts. Use of Argon/Oxygen mixtures is not recommended for tube thicknesses over 1/8 inch.

A gas that develops noticeably less zinc fume when welding galvanized tube is Praxair's *Helistar® GV*; however, since it is a helium/argon/CO₂ mixture, it is more expensive than argon-based shielding gas, but it does reduce zinc fume generation.

For assembly-line type high-productivity welding, fabricators should explore using waveform controlled power supplies. These power supplies are computer-controlled, and the software monitors the rate of change (i.e., the waveform) of the voltage and amperage at 10 KHz, adjusting the voltage and amperage instantaneously while the welder is welding, reducing spatter and optimizing penetration, making the process easier to use while making higher quality welds. These power supplies are identified as computer-controlled, synergic, pulsed, instantaneous and similar; power supply manufacturers should be tapped to get the optimum settings for the product being welded.

One of the best resources training using GMAW can be found at:

http://www.weldreality.com/eds_training_materials.htm

The book "Gas Metal Arc and Flux Cored Welding Parameters" and DVD "MIG Process Controls Made Simple" are recommended.

FLUX CORED ARC WELDING (FCAW)

Due to the rapid-freezing nature of the flux associated with gas-shielded flux cored wires, porosity is a common problem when welding galvanized steel using them. On the other hand, fabricators have found that self-shielded flux cored wire conforming to E71T-14, such as Lincoln's Innershield NR-152 and ESAB's CoreShield 10 work well in some applications; these wires are particularly convenient since a shielding gas is not needed; however, these electrodes tend to produce a lot of smoke compared to other wires, so ventilation will be even more important than with solid or metal cored wire. Follow the electrode manufacturer's recommended settings with self-shielded flux cored wire.

SHIELDED METAL ARC ("STICK") WELDING

Due to its low productivity, this process should be used where GMAW cannot be used, such as outdoors where wind would make use of a gas-shielded process impractical. Wheatland's galvanized steel tube can be welded using 3/32 inch diameter E7014 electrode with direct current and electrode positive (reverse polarity) or alternating current and the parameters recommended by the electrode manufacturer. When welding tube to thicker materials, E7018 should be used to ensure penetration into the thicker material.

GAS TUNGSTEN ARC (TIG, HeliArc) WELDING

This process also has low productivity but can make very sound welds between galvanized components. Welding of thin-gauge galvanized steel can be done using direct current and electrode negative, 3/32" diameter EWTh-2 tungsten that has been pencil-sharpened with a 1/32" flat end, ER70S-2, ER70S-3 or ER70S-6 filler metal, argon shielding gas at 20 to 30 CFH and the following parameters:

Gauge	Thickness (in.)	Amps for grooves	Amps for Fillets	Filler diameter (in.)
18 to 22	0.028 to 0.047	35 to 65	40 to 60	1/16 or 3/32
14 and 16	0.059, 0.075	45 to 75	65 to 90	3/32
12	0.105	65 to 90	95 to 105	3/32
10+	0.135	70 to 100	110 to 130	3/32 or 1.8

GTAW is the slowest and costliest of the welding processes, so it should be used only where visual appearance is critical and grinding or sanding a weld made using another process is not practical.

Restoring Galvanizing After Welding

When galvanized steel is welded, the welding arc burns the zinc off about 1/8 inch of the tube on each side of the weld, leaving it and the weld metal without the corrosion resistance provided by the galvanizing. If this weld is exposed to the elements, it will rust -- even if it is painted or powder-coated -- without doing something to bring the weld zone up to the same corrosion resistance as the unwelded material.

The most common practice is to wipe the wire brush the weld surface vigorously with a wire brush followed by wiping with a rag to remove any loose dust, then spraying the weld with a high-zinc primer sold as "cold galvanizing compound." The paint should contain 95% elemental zinc or more in the film after it has dried, and it should be applied so as to cover the weld and 1/2 inch or more of the tube with a couple of light coats. Trade names are: ZRC Cold Galvanizing Compound, ZRC Galvilite (Better color match to galvanized surfaces away from the weld), others available at <http://www.coldgalvanizing.com>. Rustoleum and other consumer "cold galvanizing" paints typically do not have enough zinc content to be effective -- read the label or the MSDS. Once the primer has dried thoroughly, it can be painted or powder coated. If the primer does not dry thoroughly, the top coat may blister.

A second option for those doing powder coating is to chemically clean the welds and apply a high zinc powder primer, follow by the finish powder. Most powder suppliers can provide specific recommendations.

A third option is for applications where maintaining the corrosion resistance of the weld area is very important, and that would be to use thermal spraying. In thermal spraying, zinc wire is melted in an oxy-fuel gas flame and blasted at high velocity against a roughened surface. The surface is typically roughened by sand blasting before applying the thermal spray, so setting up the operation is typically more costly.

More information about thermal spray can be found at the International Thermal Spray Association, a standing committee of the American Welding Society:

http://www.thermalspray.org/index.php?option=com_frontpage&Itemid=1

Thermal spray equipment can be obtained at Sulzer/Metco at the link below.

<http://www.sulzer.com/en/Products-and-Services/Coating-Equipment/Thermal-Spray>

Thermion manufactures a variety of thermal spray equipment, and also has a “mini arc spray” system available for field or shop use:

<http://www.thermioninc.com/>

A fourth option is to use micron-sized zinc powder that is blown through a nozzle at high velocity (cold spray); this technology was introduced in 2003 and does not require precleaning other than to wipe it clean. This equipment can be obtained at Centerline

http://www.supersonicspray.com/en/cold_spray?pg=SE20000

Both thermal and cold spray equipment are available at:

<http://www.thermalspraydepot.com>

SAFETY PRACTICES

When a manufacturer uses welding, he needs to be aware of safety hazards associated with welding. These include Welding Smoke and Fumes, Electrical Shock, Electromagnetic Radiation.

WELDING SMOKE AND FUMES

Welding produces smoke and fumes which come up from the weld zone in what is referred to as a plume. The smoke and fumes created by the welding arc are not especially healthy to breathe. The first thing a company that produces any welded products – **whether it is galvanized or not** -- should teach its welders to do is to keep their heads out of the fume plume. Supervisory personnel should be instructed to watch for welders whose heads are in the plume and advise them to change positions, beating them about the head and shoulders with a rubber hose as necessary (but not *while* they are welding as that can lead to bad welds. . .). Welders should set up their work so that the air flows from left to right or right to left, rather than towards or from behind the welder. This will keep the plume and its contents away from the welder's breathing zone.

When there is a ceiling height of 16 feet or more, and a space of 10,000 cubic feet per welder and the welder will not be working in a confined space, natural ventilation is considered adequate. When these criteria are not met, forced ventilation must be provided according to American National Standards Institute (ANSI) standard Z49.1¹¹. This may be done by using a mobile hood or exhaust hose which can be placed in the vicinity of welding, or by using a fixed enclosure which will provide an air flow rate of 100 feet per minute (1 to 2 MPH) in the vicinity of welding. Ventilation can also be an open grid work tables with a downdraft plenum providing at least 150 cubic feet of air per minute per square foot of open table surface. Finally, a low volume, high-velocity fume eductor may be attached to the welding gun to provide local fume removal.

The USFDA recognizes that at least 15 mg/day of zinc is essential for proper health in humans. Zinc is also a necessary micronutrient for plant and animal life. Zinc melts at 787°F, then boils at 1665°F, becoming a vapor under a welding arc and, as it mixes with oxygen in the air, changes to zinc oxide. Zinc oxide is visible as the white plume rising from the weld pool, and inhaling it quickly overloads one's body's ability to deal with it in the short term, and this results in a temporary illness known as "metal fume fever."

While inhaling the white zinc oxide which is produced when welding zinc may cause temporary symptoms of influenza, including fever and chills, no permanent or long-term effects are known to occur. To avoid zinc fume fever, it is important that the welding plume containing the zinc oxide be carried away from the welder as described above for welding materials that are not galvanized. ANSI Z49.1 requires that zinc fume removal be done by local exhaust ventilation when zinc is welded indoors.

¹¹ This Standard as well as *Welding Safety and Health Fact Sheets* are available free from the American Welding Society, Miami, Florida at: <http://www.aws.org> and search for "ANSI Z49.1:2012"

Welders should also be taught not to stand or work downwind from another welder who is welding on zinc-coated steel. In addition to local or general ventilation, personal breathing filters are recommended. Light-weight, disposable, half-face filters such as the 3M™ Welding Fume Respirator or the Dust/Fume/Mist filter (#9920) made by 3M (1-800-328-1667) are convenient for the welder, and no maintenance is required. Half-face mask cartridge filters using filter elements designed for metal fume removal are also acceptable and available from 3M. Powered air purifying systems and supplied air systems such as the 3M™ Adflo™ Powered Air Purifying Respirator (PAPR) are also available from 3M. These systems provide combined respiratory, head, eye and face protection for situations in which fume exposure cannot be avoided.

More information and recommendations on fume control equipment and PPE can be found at <http://www.sperkoengineering.com/html/welding.htm>, specifically the article “Welding Galvanized Steel – Safely” which was published in the Fabricator March, 1997, pages 30-33.

ORGANIC COATING

Wheatland’s tube is additionally protected by a clear organic top-coat. This organic top-coat will decompose during welding and generate fumes irritating to the welder if proper ventilation procedures are not followed. Removal of this coating is recommended and easily accomplished by lightly sanding with a flapper wheel or by hand with dry wet-or-dry type sandpaper for a minimum of 1 inch around where the weld will be made. Personal breathing filters are recommended to avoid inhalation of dust and related coating particulate when doing this. Wire brushing and grinding wheels are not recommended for removing the organic topcoat as they are ineffective and potentially damaging to the tube. If the tube is welded without removing the coating first, ventilation practices that are recommended above for control of zinc fumes will also remove fumes from the decomposed organic coating.

ELECTRICAL SHOCK

Welders and those who work around welding need to be aware that there is sufficient voltage in a welding circuit to cause severe injury. When using a standard arc welding machine for SMAW and GTAW, there is 80 volts of difference between the welding electrode and the work piece; when using MIG or Flux core, this difference is around 40 volts when the welder pulls the trigger. Welders are usually aware of the potential hazard, but others who work around welding are frequently unaware of this danger. This subject should be regularly addressed during safety meetings.

ELECTROMAGNETIC RADIATION

When using any arc welding process, an electrical arc is generated which emits various forms of electromagnetic radiation energy, particularly ultraviolet light which can cause blindness with excessive exposure. Welders know to wear adequate protection from radiation when they are welding.

Those who work around welding must also be protected, and this is usually done by placing either opaque or translucent ultraviolet absorbing barriers around the area where welding is being done. This radiation can also burn skin, so the welder and those who work around welding should wear protective clothing. Eye protection consisting of polycarbonate safety glasses with side shields. Polycarbonate absorbs the most harmful ultraviolet radiation, preventing eye damage. In addition, this practice will prevent "Welding Flash Burn" (sunburn of the white of the eyeball), which caused by reflection of the arc from surrounding objects, including walls and will protect eyes from occasional passing exposure to the welding arc. Welders should be encouraged to wear safety glasses under their shields when this can occur.

WELDING PROCESS GLOSSARY

Arc welding is the most widely used form of welding. In arc welding, heat is created by an electric arc between an electrode and the material to be welded. The heat melts the material to be welded and usually a filler metal or electrode which must be shielded from the atmosphere. If unwanted gases mix with the molten metal, oxides and porosity form, decreasing the metal's soundness and strength.

The common arc-welding processes and several others are listed below. Each processes is distinguished by its own means of shielding the weld pool and adding filler metal.

Gas Metal Arc Welding (GMAW), also called MIG welding, uses equipment which pushes solid or tubular wire filled with powdered metal out a gun and provides a shielding gas to protect the arc from the atmosphere. Mixtures of argon and carbon dioxide or argon and oxygen are used to shield the weld pool when welding steel, while argon is used during welding of nonferrous metals.

Flux Cored Arc Welding (FCAW) is exactly the same as GMAW, except that it uses a tubular electrode containing flux instead of powdered metal. FCAW may also be used without a shielding gas with certain electrode types.

Shielded Metal Arc Welding (SMAW) uses a length of wire that is coated with flux and is entirely controlled by hand. The flux decomposes during welding gives off gass which forms a shield around the molten weld metal. This welding process is suitable for steels and many nonferrous metals.

Gas Tungsten Arc Welding (GTAW), also known as TIG and Heli-arc welding, uses a tungsten electrode to carry the arc with the weld pool shielded by helium or argon gas. This process is a very slow welding process and can be used for welding all metals.

Submerged Arc Welding (SAW) uses a flux in the form of a coarse, granular mixture of minerals which is placed on the workpiece ahead of the welding electrode. The arc is completely covered by the flux during welding. Submerged arc welding is usually used for welding of thick materials.

Resistance Welding (RW) welds material by passing current through overlapping work pieces. The interface between the faying surfaces provides the greatest resistance to current flow, resulting in heat concentration and welding at that point. The work pieces must be clamped together, so access to both sides of the parts to be joined is necessary. This process is usually automated. Spot welding and seam welding are two types of resistance welding. Galvanized tubes can be resistance welded, but zinc builds up on the copper electrodes over a couple of hundred cycles and will cause bad welds.

Oxy-fuel Welding (OFW) is done by burning oxygen and acetylene to make a flame. Gas welding is slow compared to arc welding not recommended for welding zinc-coated products since it burns off a lot more zinc than the arc welding processes.

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