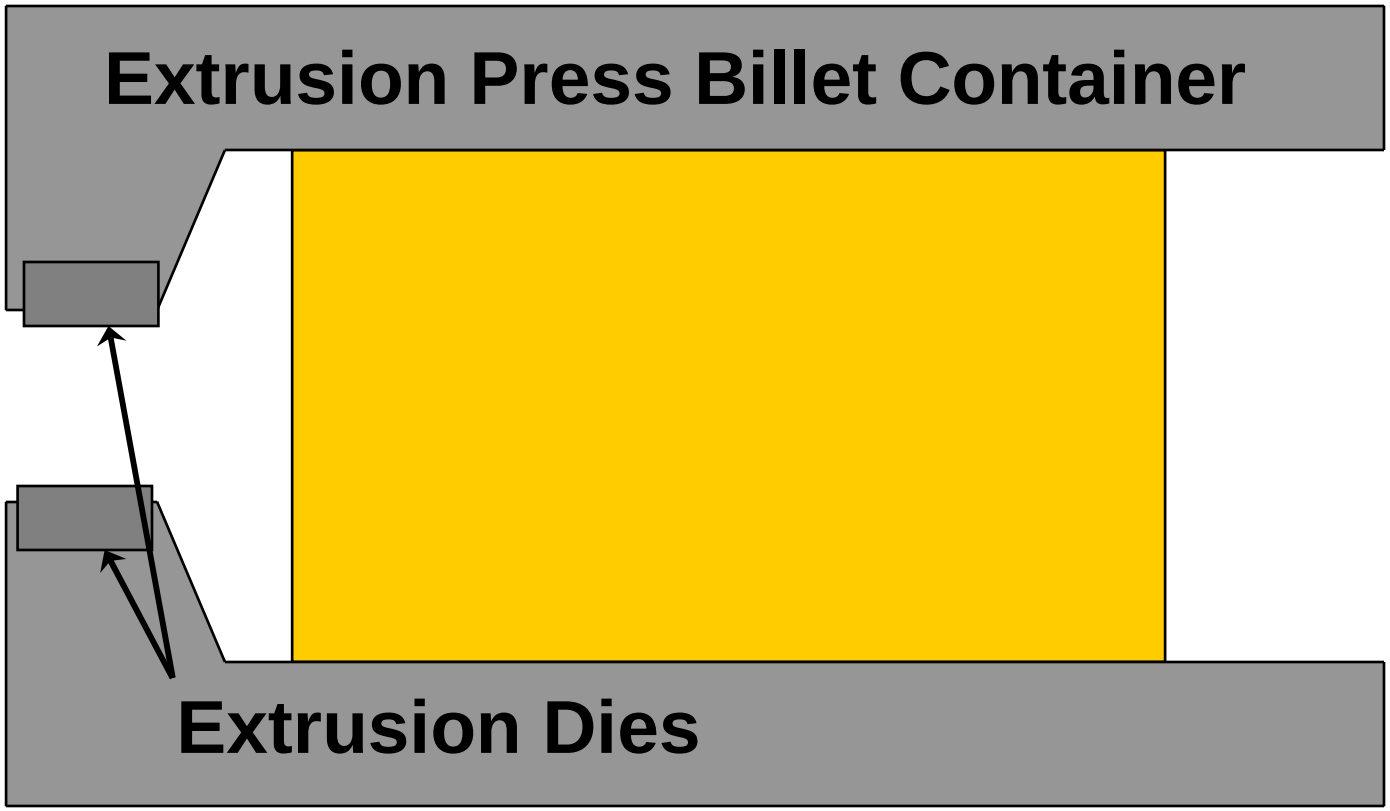
THE QUALITY ADVANTAGES OF FINEWELD® TUBE'S "WELDED" TUBE

The manufacturing process utilized by Olin Fineweld® Tube for the production of tubing is technically described as a high frequency, induced current "forge-weld" process. This process is significantly different from the process used by manufacturers of "seamless" tube in a number of important product-quality areas. A critical review of these differences highlights the quality advantages of Olin Fineweld® Tube's welded tube versus competitive seamless tube.

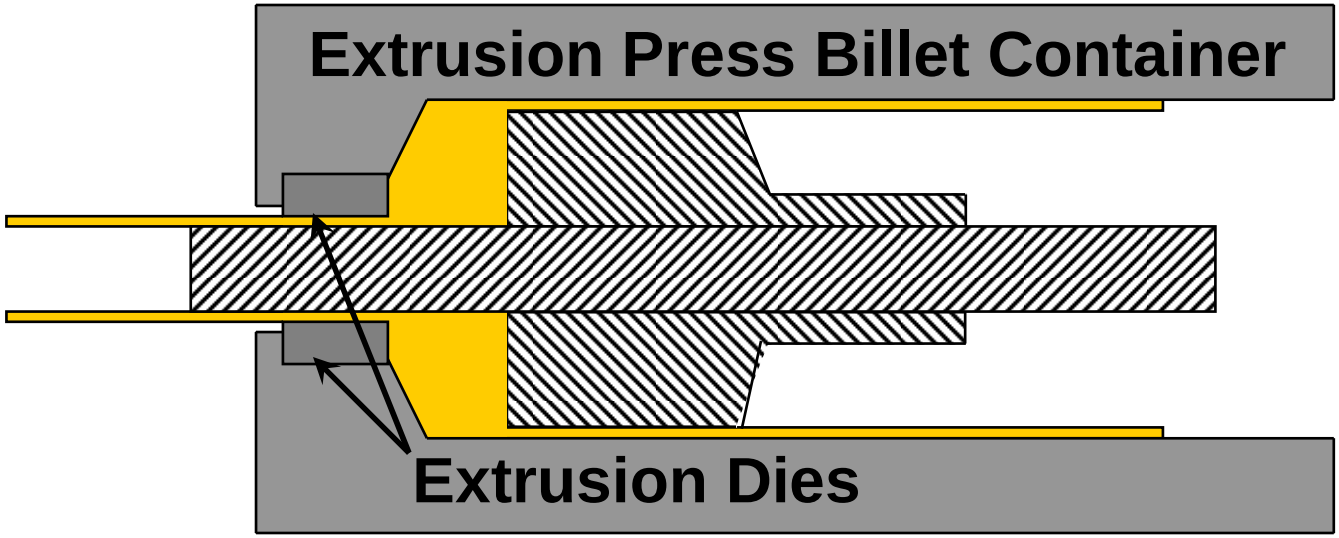
CONVENTIONAL EXTRUSION PROCESS

A 10” diameter x 17” long cylindrical billet weighing ~ 450 pounds is preheated and fed to an extrusion press consisting of a billet container and extrusion dies.



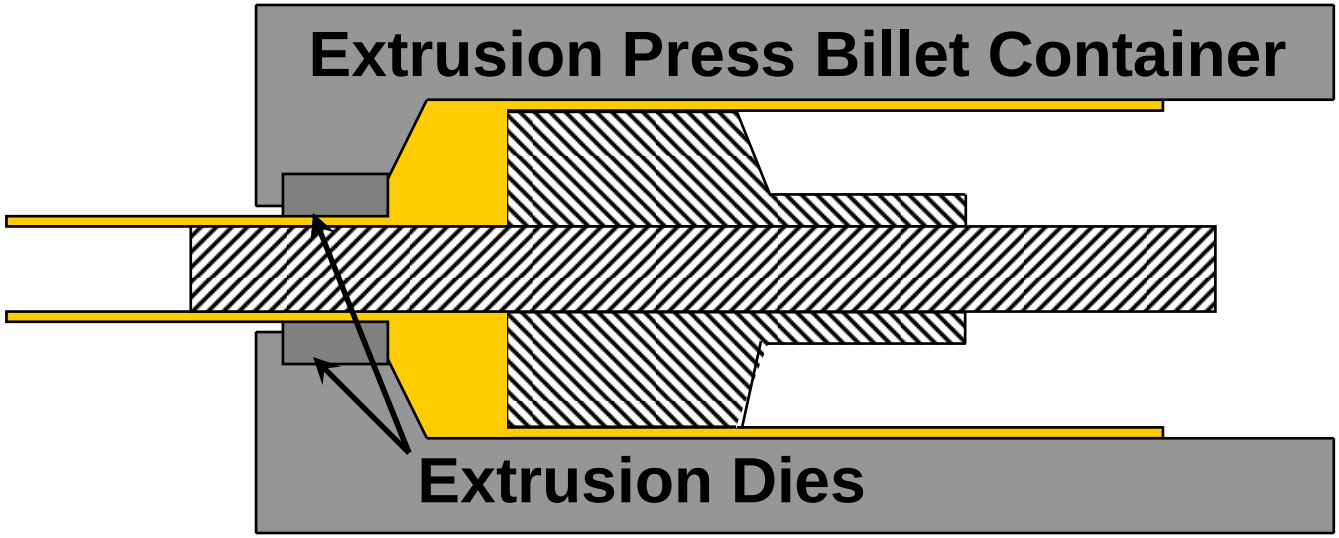
CONVENTIONAL EXTRUSION PROCESS

- **The ID of the extrusion die determines the OD of the extruded tube.**
- **The OD of the piercing ram determines the ID of the tube.**
- **The gap between the piercing ram and the extrusion die defines the tube wall thickness.**



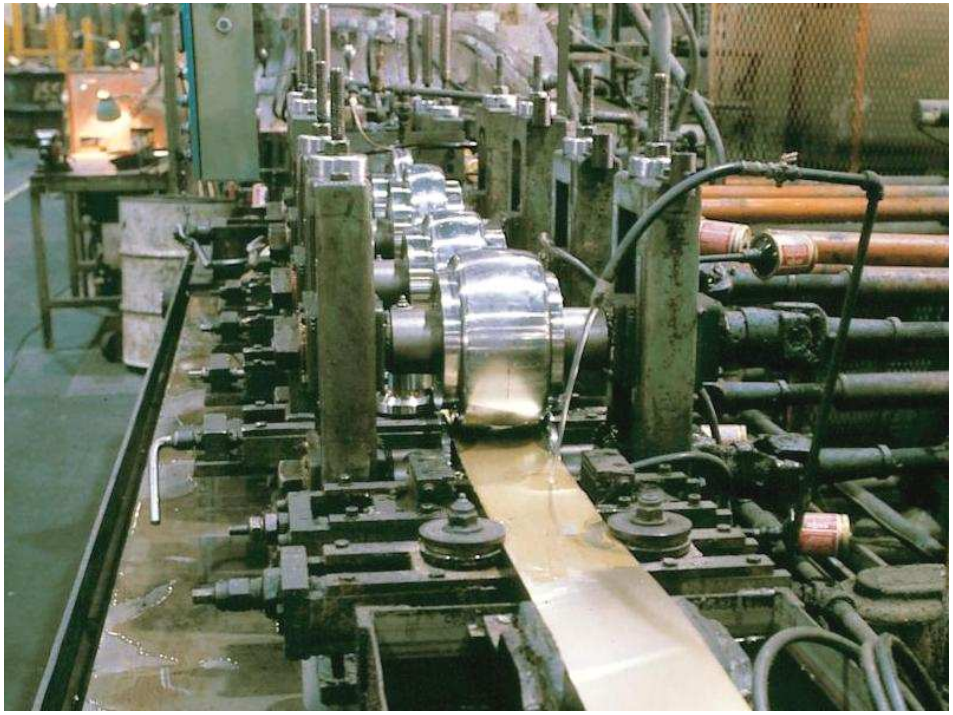
CONVENTIONAL EXTRUSION PROCESS

- **If the Piercing Ram is not perfectly centered within the Extrusion Dies, the heavy wall extruded tube will exhibit significant wall thickness variation, or eccentricity.**
- **During extrusion, metal flows from all areas of the billet, including metal adjacent to the billet container; thus, "Good" surface quality is difficult to achieve.**



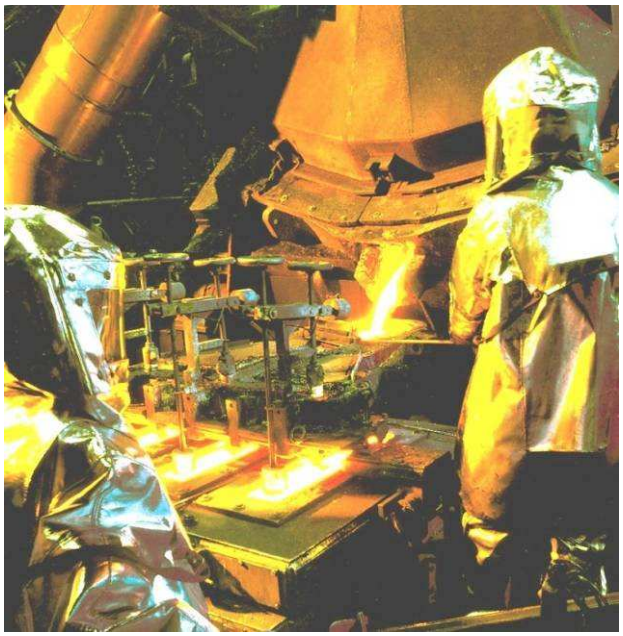
HIGH FREQUENCY WELDED TUBE PROCESS

THE FINEWELD TUBE PROCESS



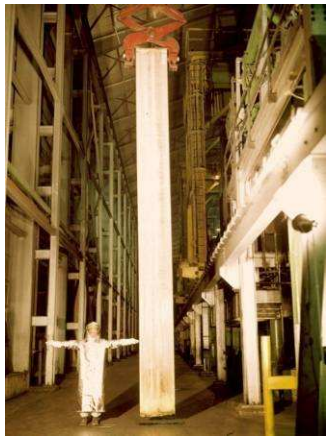
Flat-rolled strip produced by Olin Brass, our parent company, is roll-formed into a tubular shape and then welded by means of a high frequency, induced current “forge-weld” process.

CASTING & HOT ROLLING



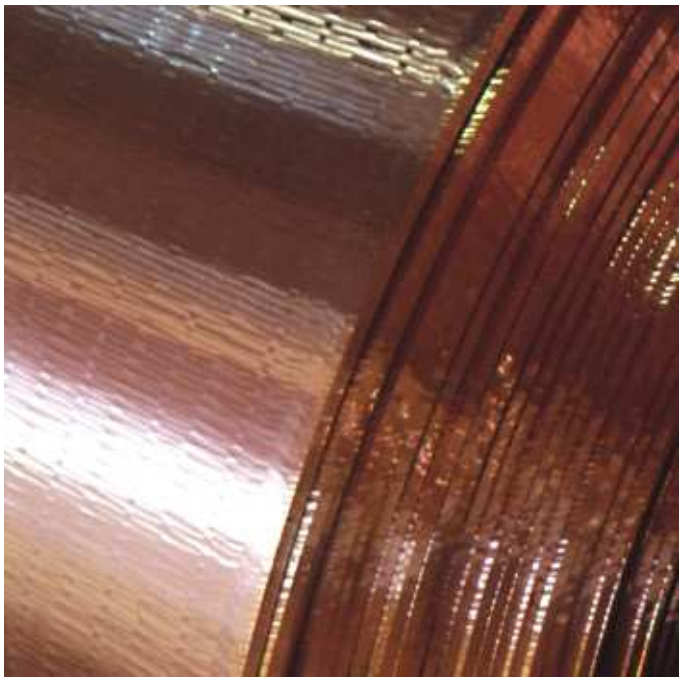
"Direct Chill" semi-continuous casting in results in exceptionally good homogeneity of the cast bars such that *laminations and inclusions are essentially non-existent* in the strip, and therefore in the welded tube that is made from the strip.

Cast bars weighing 15,000 pounds, versus 450 pound billets with the seamless process, provides for *greater chemical uniformity from one tube to another*.



After casting, the bars are hot-rolled to a thickness of about 0.500", and take on the form of a coil, versus an ingot.

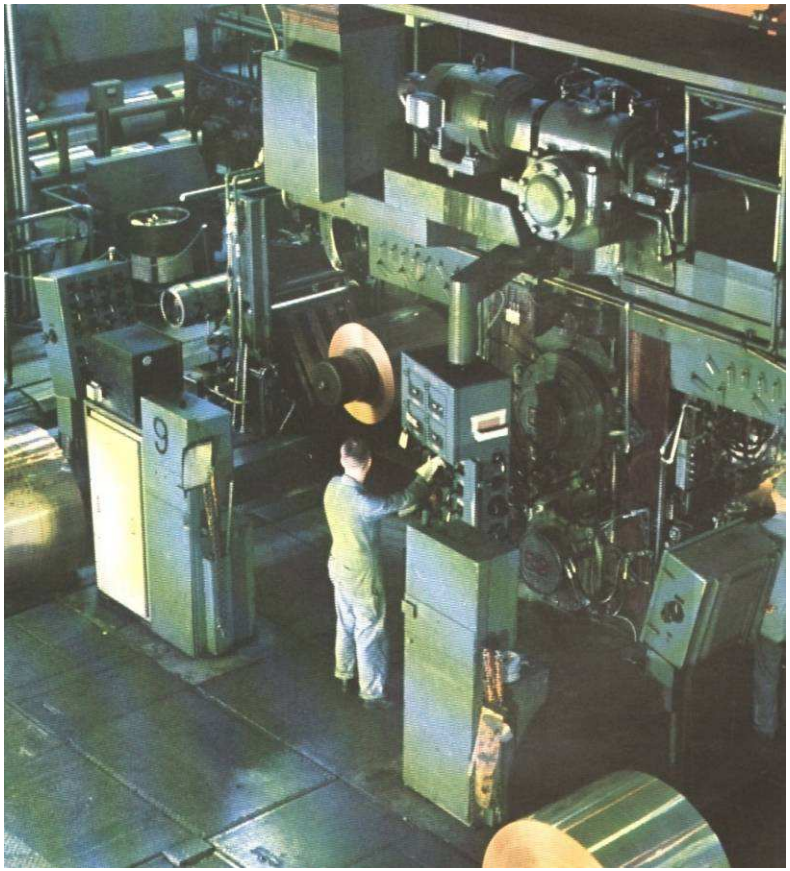
COIL MILLING



All castings have surface defects and are contaminated with carbonaceous mold lubricant residues. At Olin Brass, the top, bottom, and edges of the hot-rolled coil are mechanically milled to provide for the positive removal of surface discontinuities, surface oxides, and other contaminants inherent with castings. Since either the top or bottom surface of the milled coil will ultimately become the ID of a tube, *the possibility of a casting defect being present on the ID (or OD) of a welded tube is essentially non-existent*.

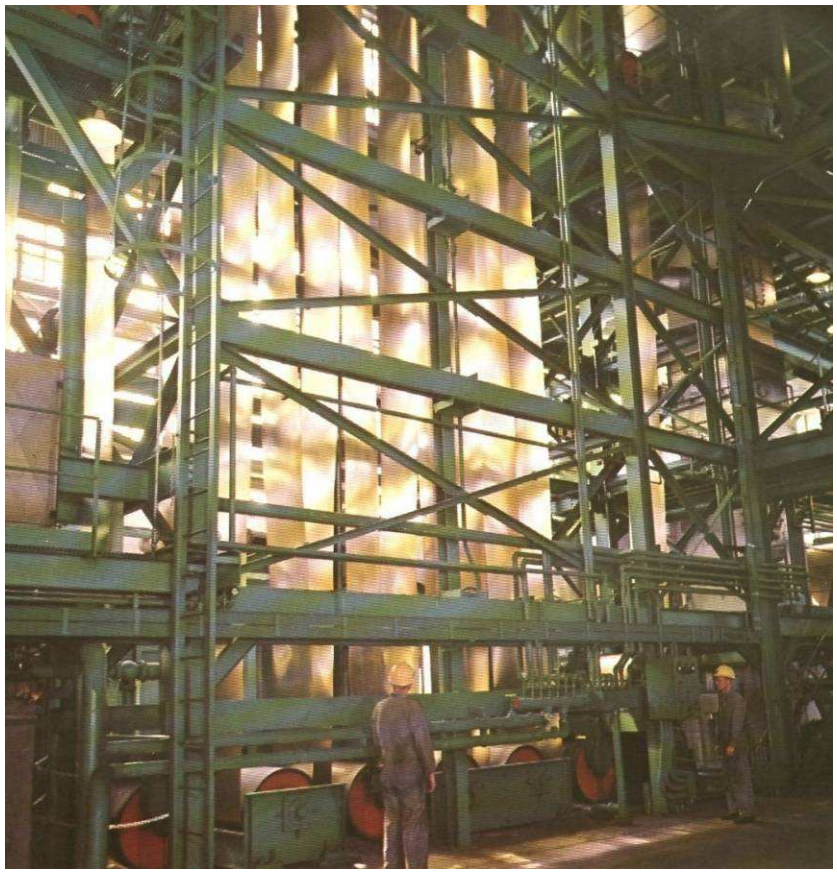
The seamless process does incorporate a provision for the removal of deleterious surface defects and residues, but does not include a milling operation; the potential for surface defects is therefore much greater with seamless tube. This is important since *surface defects of any magnitude represent potential sites for localized corrosion or pitting*.

COLD ROLLING



The next steps in the process are to alternately cold-roll and anneal the coils of strip until the desired final thickness is achieved. Both surfaces of the strip are visible during these operations so any surface defects that might be present can be detected and eliminated; thus further assuring the *superior surface quality* of welded tube versus seamless tube. The use of cold-rolled strip also results in a *much more uniform wall thickness* as compared to the seamless tube process (a strip thickness tolerance of ± 0.001" is standard). Uniformity of wall thickness is highly desirable for the rolling of the tubes into tubesheets, and also if the tubing is subsequently fabricated, expanded, or bent.

STRAND ANNEALING



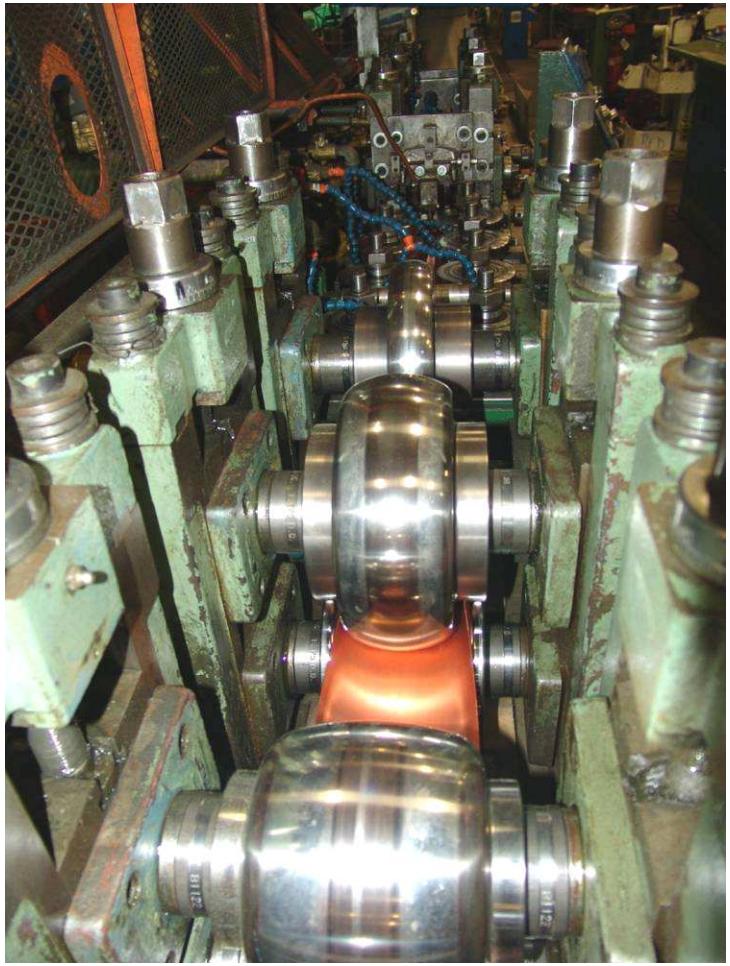
Continuous strand annealing, versus batch annealing, is utilized and results in a *more uniform temper* from one tube to another; this is beneficial for the rolling of tubes into tubesheets. The Strand Annealing furnaces include a water quench at the exit end of the furnaces. 90/10 copper-nickel includes 1.0-1.8% iron, and *the resistance of 90/10 copper-nickel to erosion-corrosion and stress corrosion is optimized* when the iron is present in solid solution; our high temperature strand anneal followed by a water quench puts the iron in solid solution. Most seamless tube mills do not water quench after annealing.

Strip processing is completed with the material being slit to a specified width and the slit coils of strip metal are transferred to the tube mill.

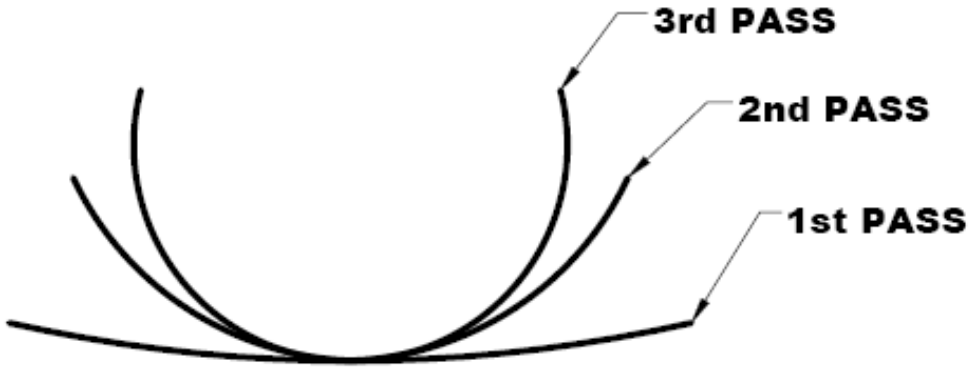
COIL PAYOFF

The tube manufacturing process starts with 2000-4000 foot long coils received from the Brass Mill.

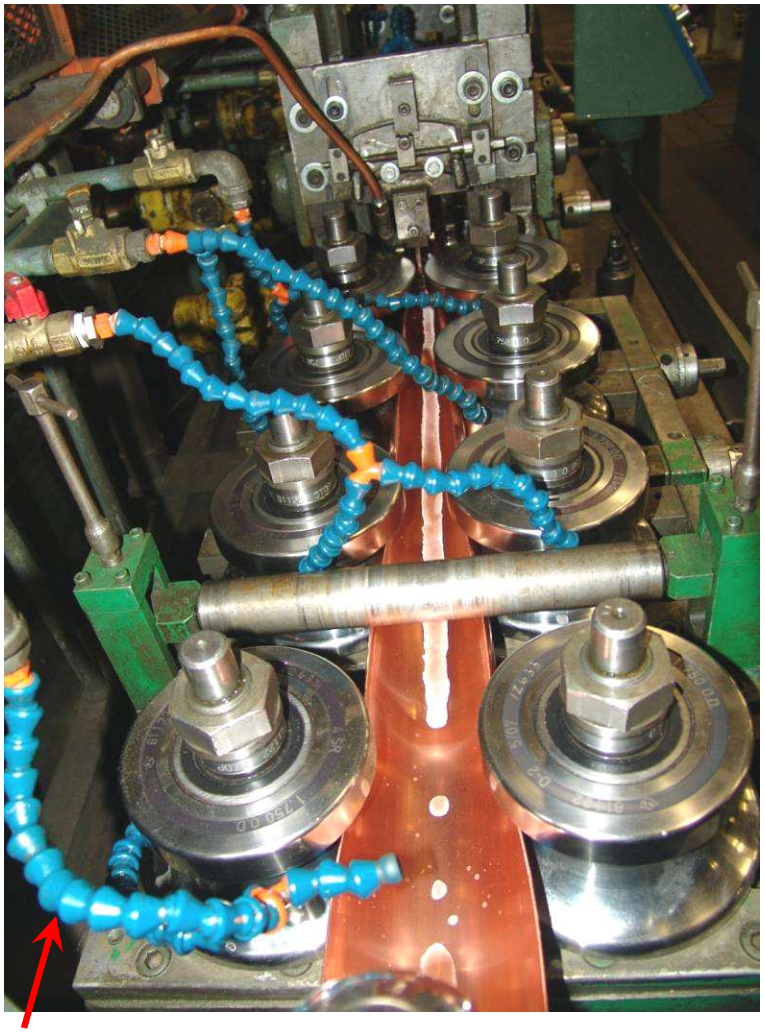
BREAKDOWN ROLLING



Roll Forming starts with a series of 3-4 Breakdown Rolls where a tubular shape is first introduced.



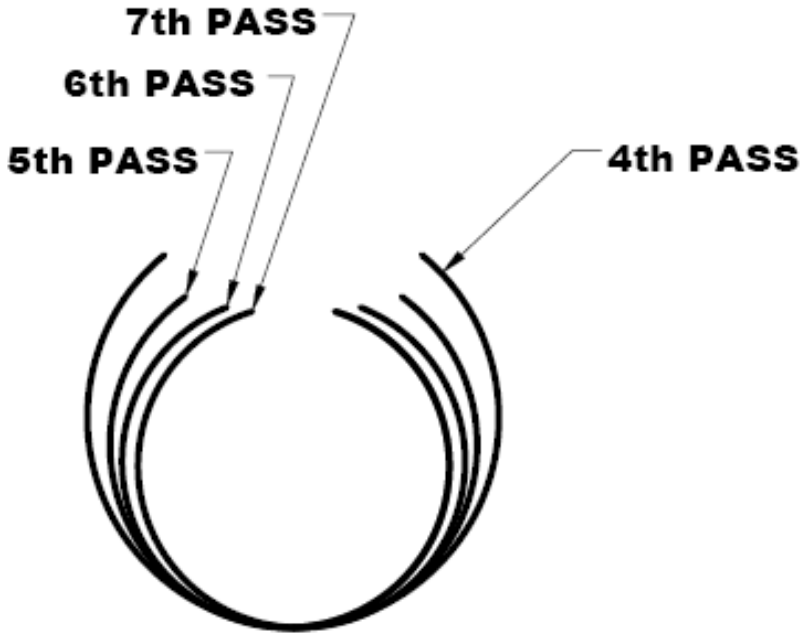
SIDE ROLLING



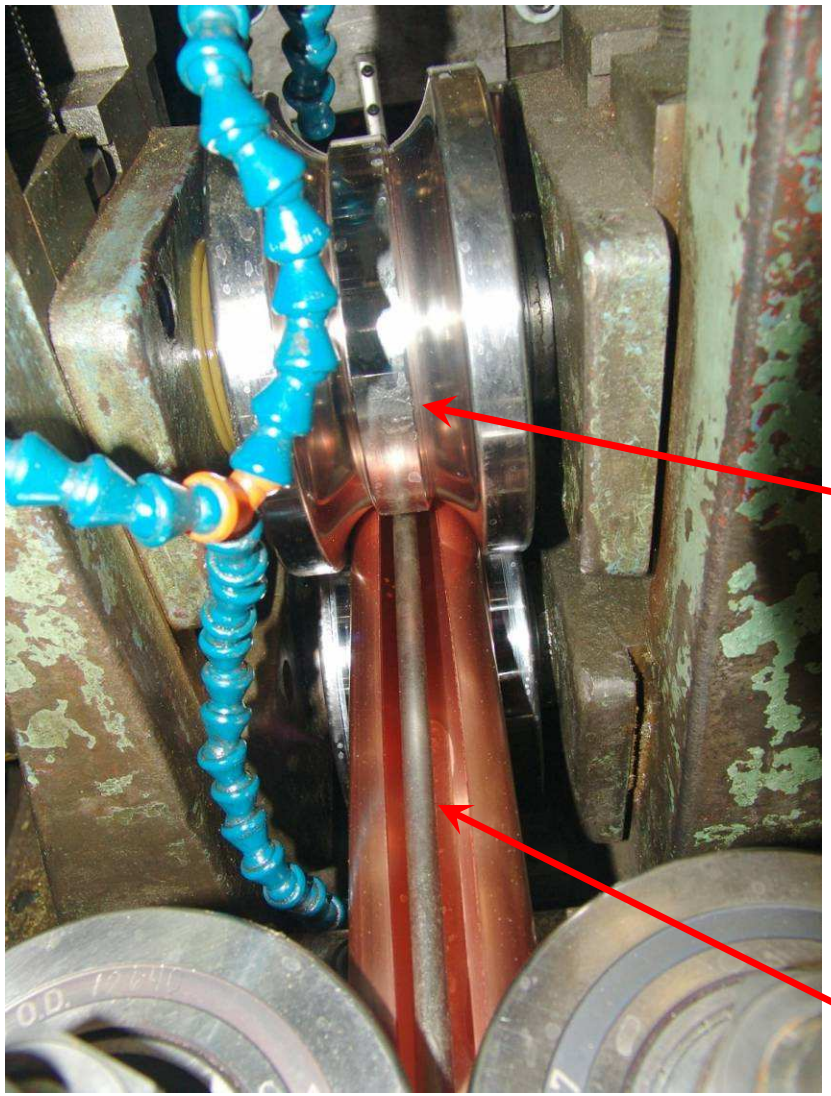
Cooling Water

(No Hydrocarbon Lubricants; thus no Carbonaceous Surface Residues)

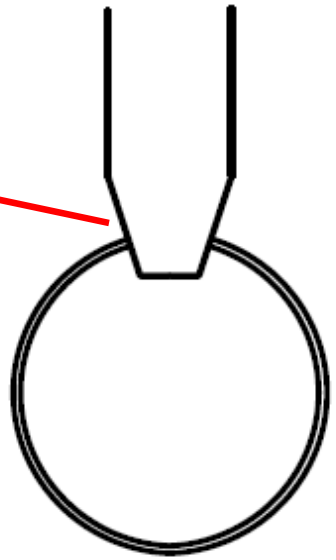
Roll Forming continues with a series of 3-4 side rolls.



FIN ROLLS

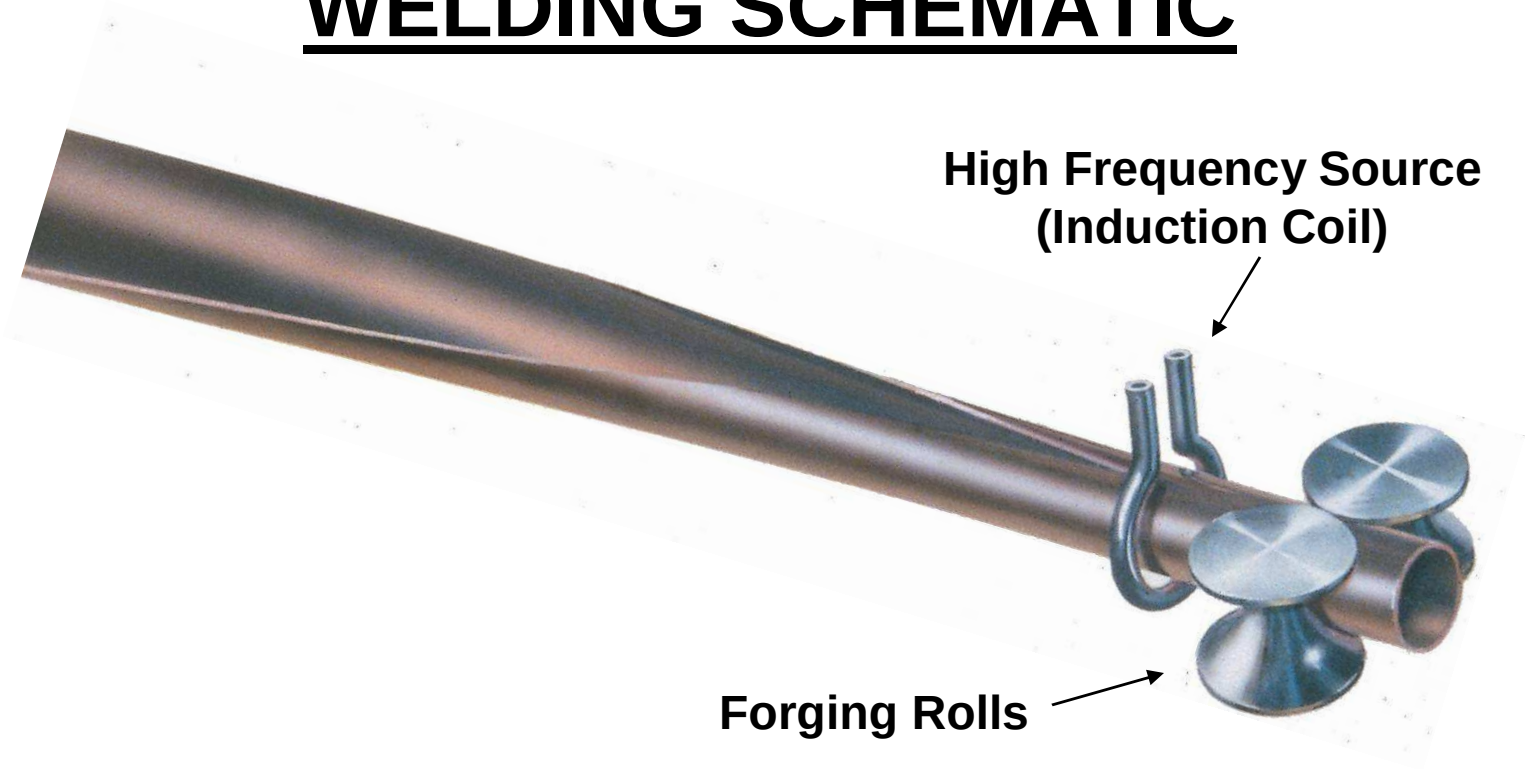


To insure that the strip edges are perfectly parallel in the welding section, the strip edges are planished in a series of fin rolls.



Impeder Mounting Rod

WELDING SCHEMATIC

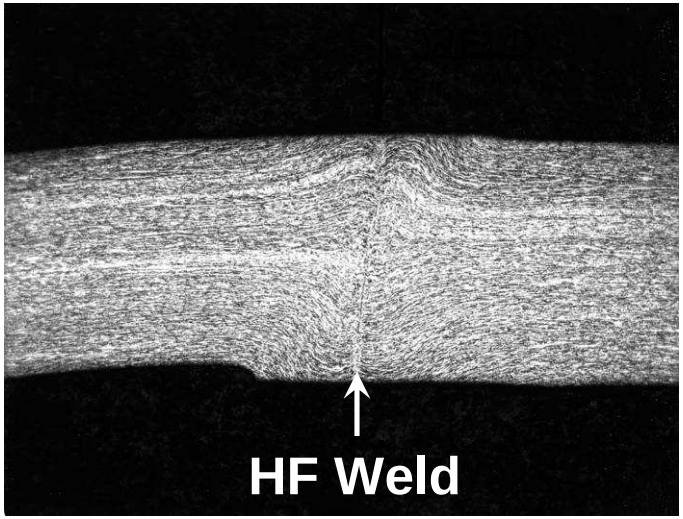


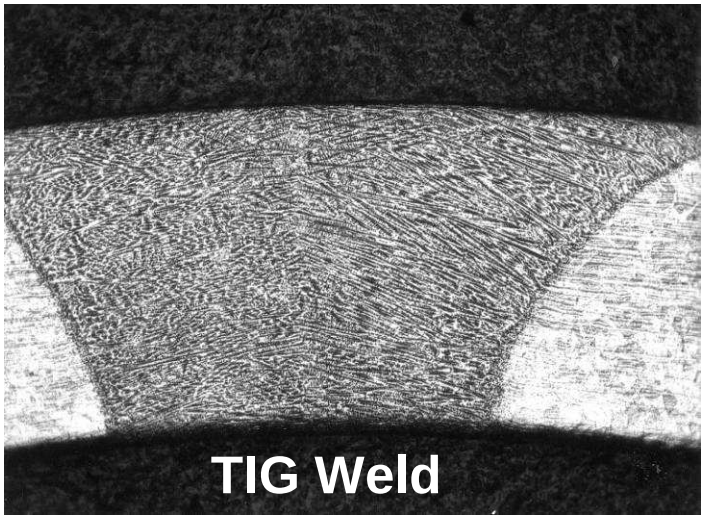
High frequency induced current (450 kilohertz) is concentrated at the edges of the strip metal by means of an impeder; the strip edges reach a plastic (almost molten) state. Concurrently, a heavy forging or squeezing pressure is applied to the tube to force the two strip edges together. This forging pressure expels the plastic metal, metal oxides, and impurities outward and inward in the form of a weld flash. No filler metals are used

WELD STRUCTURE

A photomicrograph of a typical "forge-weld" is shown on the left. Note the narrow homogeneous structure of the weld. The width of the weld is uniform from top to bottom indicating that the heat input was uniform. Flow lines pass parallel to and away from the weld indicating the high forging pressure which formed the metallurgical bond. Since a high frequency induction weld is a wrought structure similar to the parent material, it's strength, ductility, and corrosion resisting characteristics are similar to the parent material. *This permits the use of "as-welded" tube for most alloys in corrosive environments.*

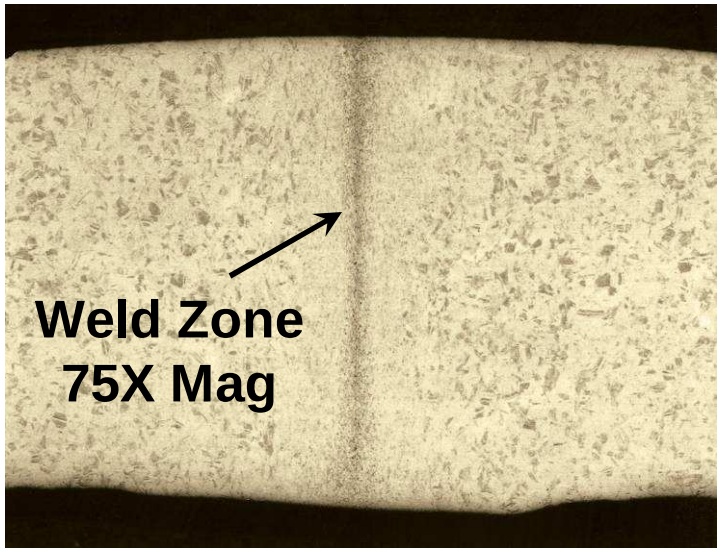
A photomicrograph of a typical TIG weld is shown on the right. Note the cast structure associated with this process. This weld would need to be cold worked and annealed for use in a corrosive environment.





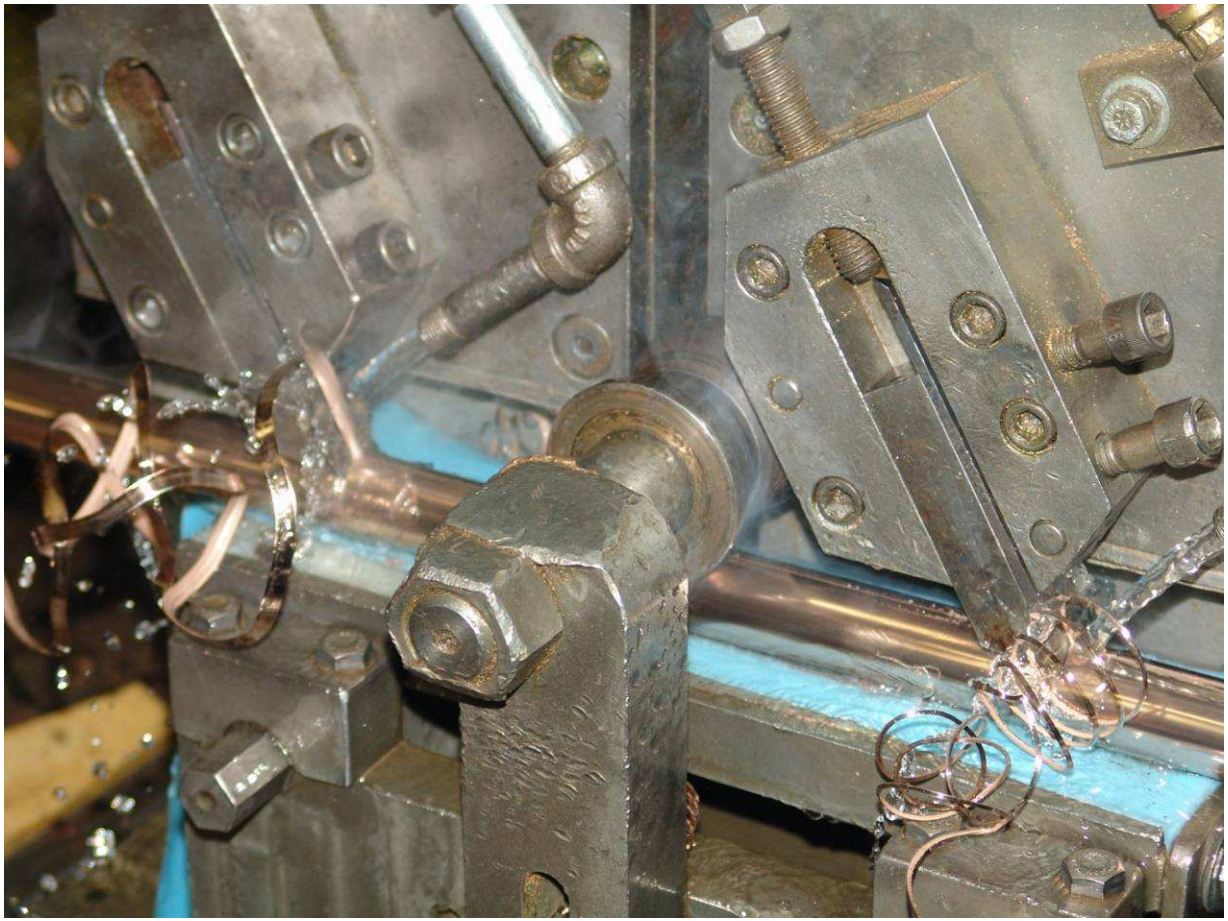
WELD STRUCTURE

The photograph shown on the left is another example of the weld produced by Fineweld Tube's "forge-welding" process. The photograph on the right is a photo of the same weld shown on the left, but after annealing. Note that the "forge-weld" area is indiscernible from the rest of the tube after annealing.



Admiralty Brass Alloy C443

OD SCARFING



OD flash is removed downstream of the welding section

ID SCARFING

ID flash is removed by a scarfing tool attached to the impeder

SIZING ROLLS

Sizing Rolls insure that diameter and ring gage specs are met.

STRAIGHTENING ROLLS

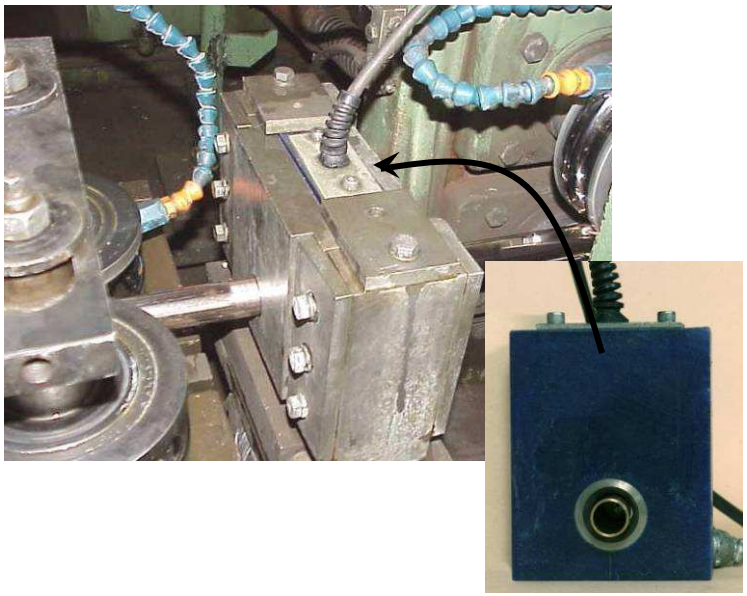
Turkshead Rolls insure straightness.

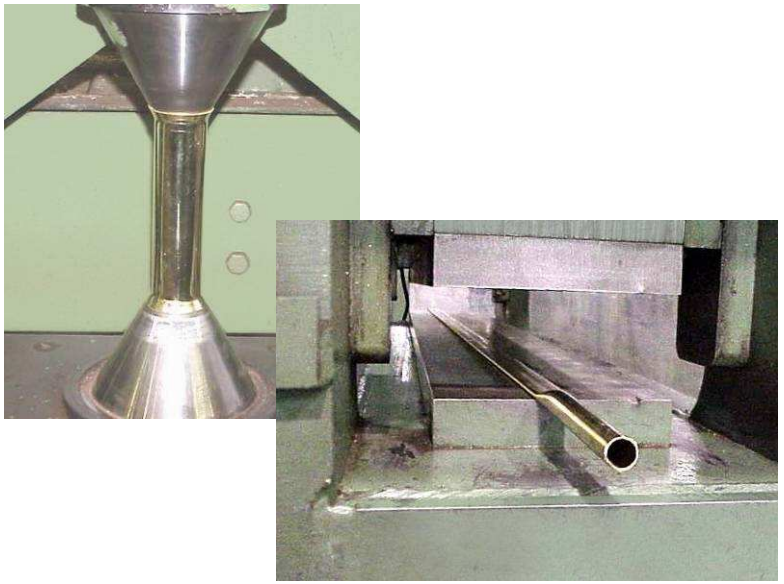
RE-CUT LINE & PACKING

Subsequent to welding, tubes are precision re-cut, deburred, and packed.

QUALITY ASSURANCE & TESTING

Fineweld Tube is ISO 9001:2008 certified. Tubes are 100% "in-line" eddy current tested. *In-line eddy current testing avoids "end effects"* which are associated with off-line eddy current testing utilized for seamless tube. Destructive testing includes expansion testing, flattening, and reverse flatten testing. Dimensional checks are conducted for diameter, wall thickness, length, straightness, and RIF. Hydrostatic and pneumatic testing are performed when specified.





COMPARISON OF ASTM B-111 & ASTM B-543

Eddy current testing	**100% testing required in both specs**
Expansion testing	**Requirements identical; Olin testing exceeds ASTM by 600%**
Flattening testing	**Required in both specifications; Olin testing exceeds ASTM by 600%**
Reverse flatten testing	**Not required in for B-111; Olin testing exceeds ASTM by 100%**
Diameter tolerance	**Requirements identical; Olin testing exceeds ASTM by 250%**
Wall thickness tolerance	**Requirements identical; Olin testing exceeds ASTM by 250%**
Length tolerance	**Requirements identical; Olin testing exceeds ASTM by 200%**
Squareness of cut	**Requirements identical; Olin testing exceeds ASTM by 200%**
Straightness	**Not required in either specification – Olin applies the requirements of ASTM B-587**
Residual Internal Flash	**Applies only to ASTM B-543 …. +0.006”/ -0.000” – Olin testing exceeds ASTM by 250%**

COMPARISON OF ASTM B-135 & ASTM B-587

Eddy current testing	**100% testing required in both specs**
Expansion testing	**Requirements identical; Olin testing exceeds ASTM by 600%**
Flattening testing	**Required in both specifications; Olin testing exceeds ASTM by 600%**
Reverse flattening testing	**Not required in B-135; Olin testing exceeds ASTM by 100%**
Diameter tolerance	**Requirements identical; Olin testing exceeds ASTM by 250%**
Wall thickness tolerance	**Requirements identical; Olin testing exceeds ASTM by 250%**
Length tolerance	**Requirements identical; Olin testing exceeds ASTM by 200%**
Squareness of cut	**Requirements identical; Olin testing exceeds ASTM by 200%**
Straightness	**Requirements identical**
RIF (Residual Internal Flash)	**Applies only to ASTM B-587 - +0.006”/ -0.000” – Olin testing exceeds ASTM by 250%**

WELD INTEGRITY FOR DEMANDING APPLICATIONS

Shown below are several applications in which Fineweld Tube's welded tubing is used. These applications demonstrate the superior weld integrity of the product.

Integral Fin Tube

Twisted Tube

U-Bent Hairpin Tube

SUMMARY

- Specification requirements for welded tube are equal to or greater than seamless tube.
- Performance in demanding applications is equal to or greater than seamless tube.
- More uniform temper and chemistry from one tube to another.
- Superior concentricity and wall thickness uniformity.
- Eddy current “end effects” are avoided.
- Superior surface quality and cleanliness on both the OD and ID.
- No carbonaceous surface residues.