Steel Tube Institute
OF NORTH AMERICA

Handbook of Welded Carbon Steel Mechanical Tubing

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WELDED CARBON STEEL MECHANICAL TUBING

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FOREWORD

It has become evident, with the growth in the knowledge of mechanics, that the tubular shape possesses distinct advantages over other shapes. Pound for pound welded steel tubing is stronger in many applications than other steel sections. It is pleasing to the eye, can be readily fabricated, and is widely available. This Handbook has been prepared for engineers, designers, and manufacturers who have used tubing, and also for those who contemplate its use. Readily accessible data are included to aid them in the selection of the proper tube for their application. Obviously it is not possible to cover all contingencies, and further information is available from any member of the Steel Tube Institute.

The data in this book apply to Electric Resistance Welded (ERW) carbon and alloy mechanical steel tubing, whether used in the as-welded condition or after further processing. Unlike pipe, mechanical tubing is not intended for the transmission of fluids, except in fluid power applications, and is produced to exact rather than nominal OD or wall dimensions, and to exacting tolerances.

Mechanical steel tubing is distinguished from steel pressure tubing by its use or application. Pressure tubing is used to contain or convey fluids under pressure and generally at other than ambient temperatures. Mechanical tubing is used in a multitude of applications not involving fluids. These include applications where strength, appearance, machinability and fabricability, resistance to torsion, and maximum strength to weight ratio are required.

It is hoped that readers will come to recognize why welded mechanical steel tubing enjoys universal acceptance, and will become aware of some of its many applications. The data will cover mechanical tubing only. Literature on carbon steel pressure tubing and structural tubing is also available from the Steel Tube Institute office or from its individual member companies.

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SECTION I — General Characteristics

Welded steel tubing has many advantages over other materials. Engineers and designers specify welded steel tubing for a progessively widening variety of applications. It may be used straight, where its strength to weight advantage is the prime requirement, or in parts requiring bending, flattening, flaring or many other types of fabrication.

Savings result from its use because the workability of welded tubing means less scrap loss and better adaptability to applications where more expensive and less reliable materials had been used. Welded tubing normally is lower in cost than seamless tubing, generally has a better surface finish, is available in lighter wall to diameter ratios, and can be manufactured from precoated steel. Its superior uniformity and concentricity allow the designer the choice of a lighter wall and thus less allowance for stock removal when the tube is to be machined.

Welded tubing is produced from flat rolled steel supplied to the tube mill in coils. The excellent surface quality on both sides of this flat rolled material results in uniform, smooth surfaces free from defects inside and out, and a uniform wall thickness.

Tubing may be cold drawn for applications requiring even better surface finish, closer tolerances, and improved tensile properties. When tubing is cold drawn over a mandrel, it is often referred to as DOM (drawn over mandrel) tubing, but when nothing is used inside the tube (drawn without mandrel), the product is referred to as sink drawn tubing.

SECTION II — Manufacturing Process

1. Raw Material

The raw material used in the production of welded tubing is flat rolled steel received from the steel mill in coils. The coiled steel is produced by the open-hearth, basic oxygen or electric furnace process. The coiled steel is killed or semi-killed (see glossary) depending on application or specifications. The tube mill specifies steel-making practice, thickness, width, edge condition, chemical analysis and in the case of cold rolled, surface finish and temper, to insure the production of tubing which meets all quality standards required. All coils are properly tagged by the producing mill, permitting identity to be maintained through all tube mill processing.

Coils may be either hot rolled (HR) or cold rolled (CR). Hot rolled steel is either without the scale removed (black) or in the pickled and oiled condition. The scale may be removed by pickling or particle blasting prior to tube manufacture. Hot rolled steel usually possesses higher tensile and yield strength properties than does cold rolled steel, which is normally annealed to facilitate forming. Cold rolled steel may be ordered with various surface finishes, closer tolerances and better control of temper and hardness, but is generally limited to the lighter gauges. Tubing made from cold rolled may be plated in the as-received condition or with surface preparation, depending on the type and quality of plating surface required. Both hot rolled and cold rolled steel are well suited for painting and, with proper procedures, a very smooth, attractive surface finish can be produced.

2. Tubing Mill Equipment

Welded steel tubing is formed, welded, sized, and cut to length in a continuous process. The flat steel is passed through consecutive matching rolls with contoured grooves which gradually form the cold steel into a tubular shape whose butted edges are welded by one of the electric resistance methods described in the next section. To facilitate uninterrupted production and consistent quality, many mills end weld coils together at the mill. This end welded section is removed at the cutoff and scrapped.

Tubing is generally welded slightly oversize with emphasis at the point of welding on weld quality rather than size. The tubing, after being welded, enters the sizing section, which consists of sets of rolls in pairs with accurate semi-circular grooves. The sizing section reduces the tube to final dimensions. The fine finish on the sizing rolls can actually improve the surface finish of the steel.

Tubing then enters the cut-off section, the forward speed of which is synchronized with the tube so that the cut-off operation is performed with accuracy at mill operating speed. Rotary head, saw, or punch cutting are generally used.

3. The Welding Process

The electric resistance method is the most common welding procedure for carbon and many alloy steels. As the name implies, heat for welding the butted edges together is generated by resistance to the flow of an electric current. The heat is confined to a narrow band along the edges, with the highest temperature at the extreme edges. The balance of the tube remains cold. Low frequency alternating current (AC), direct current (DC), and ultra high frequency alternating current are the three electric resistance welding methods being used.

In low frequency AC welding, the low voltage and high amperage current is conducted to the strip edges by a pair of rotating copper alloy discs which are insulated from each other. These are called the electrodes. Frequencies generally range from 60 to 360 Hz (cycles per second). A set of special rolls directly under the electrodes squeezes the butted edges together while they are at welding heat to produce the weld. It is important to note that no filler metal is added in the welding operation keeping the metal composition of the weld line the same as the balance of the tube.

Mills utilizing DC welding equipment have the same configuration as that described above.

A modification of the electric resistance welding process is the use of ultra high frequency (HF) electrical current with frequencies in the range of 300,000 to 500,000 Hz. Current flow along the strip edges is induced by shoes which make sliding contact with the tubing surface ahead of the butted edges, or by an encircling induction coil. At welding heat, side pressure rolls complete the weld as in low frequency welding.

4. The Weld Flash

The ERW process extrudes a small amount of metal (weld flash) on both the inside and outside of the tubing. This weld flash is removed from the outside diameter (OD) of the tube immediately after welding with a cutting or planing tool contoured to the diameter of the tube being produced. The inside diameter (ID) flash may be left in or controlled in height depending on customer requirements and application. The flash can be controlled by rolling, or by cutting with a tool contoured to the tube ID.

5. Cold Drawn and Cold Worked Tubing

Welded tubing may be further processed by cold drawing to meet specific end use requirements. The user may want OD and/or ID tolerance limits closer than can be supplied with off-the-welder tubing, a better OD or ID surface, or higher tensile properties. Cold drawing makes these possible. The drawing operation increases the yield and tensile strengths with a corresponding decrease in ductility. The drawn tube may be thermally treated to produce specific mechanical properties if desired.

The starting stock for cold drawn tubing is electric resistance welded mechanical steel tubing, either produced in-plant or purchased. Specifications require a thoroughly tested tube, and extra precautions are taken with ID weld flash removal. The flash must be cut accurately to prevent any lapping in the subsequent drawing operation. A wide variety of carbon and alloy steels up to about 0.45% carbon is drawn. If no grade is specified, Grades MT 1010 to MT 1020 may be furnished.

Preparatory to drawing the ERW tube hollow or shell is fully annealed, pickled for cleanliness, pointed, and coated with a lubricant. The pointed end of this tube is placed between jaws attached to a chain or hydraulic pulling device, which pull it through a hardened steel or carbide die with an orifice of the required dimension. If the ID tolerance and/or surface finish are important or higher tensiles are required, the tube hollow or shell is simultaneously pulled over a plug mandrel or hardened steel bar.

In drawing very small diameters, extensive use may be made of the mandrel bar drawing process. In this case a solid hardened alloy rod is inserted in the tube, and both tube and bar are drawn simultaneously through the die. The size of the bar thus controls the ID of the drawn tube. After each such draw, the tube is cross rolled to permit withdrawal of the mandrel bar.

Sink drawing (drawing without mandrel) is employed when outside diameter tolerances are the only consideration. In the smaller sizes sink drawing is often used as a final operation to bring the tube to size where final tube size is too small to use a plug or bar.

6. Thermal Treatments

When so specified carbon steel tubing whether as-welded or cold drawn is heated in temperature controlled annealing or normalizing furnaces. Stress relief annealing removes stresses induced in the cold working operation, while normalizing results in complete recrystallization of weld and base metal. This operation is usually done in an atmosphere controlled furnace. After the tubes are heated in the furnace and held at the proper temperature for the required time, they are cooled in the same atmosphere. Temperatures may range from 850 to 1750 degrees F depending on whether stress relieving, sub-critical annealing, or full normalizing is ordered.

7. Straightening

Although tubes are straight within mechanical tube tolerances as they come off the welder, special applications may demand further straightening operations. Cold drawn tubing is always straightened to specification tolerances.

8. Secondary Cutting and End Finishing

Tubes are often cut at the welder in multiples of the ordered length. For many applications final length tolerances are usually closer than can be held by cutting on the mill. In these cases secondary cutting is performed. Secondary cutting can be performed with a metal saw, single or double action shear, or a rotary lathe or disc cut-off. These operations give different end conditions which must be evaluated by the user. Punch cutting is also used, particularly where many short lengths are required and the wall thickness is comparatively light. A slow moving cold saw may be used followed by a facing operation to remove burrs and obtain a completely square end. When required, tube ends may be chamfered or brushed to remove OD or ID burr.

9. Inspection and Testing

Weld quality is checked at the welder by means of destructive and/or nondestructive tests.

Tubing ordered to a designated specification or application may be given any one or several of the following tests on the finished product:

a. Destructive Tests

1) Flattening Test. A force is applied to the tubing surface at right angles to its axis. The weld is positioned at 90 degrees or 0 degrees to the applied force. The tube is flattened to a specified amount as a check for OD or ID weld integrity.

2) Crush Test. A force is applied axially to a short length of tubing resulting in a fold which stretches outside fibers completely around the tube. This test could disclose seams or laps and also is another check for weld integrity.

3) Flare and Flange Test. A short length of tubing is expanded over a cone of predetermined included angle. A flange is produced when the tubing is flared over the cone and then placed on a flat surface under increased load. This test stresses the tubing including the weld to the extent desired.

b. Nondestructive Tests

1) Nondestructive Electric Test. The welded tubing industry has been a leader in initiating and developing new techniques for nondestructive testing. These have proven to be more sensitive to the detection of defects not generally located by pressure testing. The wide acceptance of welded tubing for many critical service applications has been due to the rapidly increasing use of these methods for testing. Some of the nondestructive techniques employed by the industry are the following:

Eddy Current (Electromagnetic). Consult ASTM E 309.
Ultrasonic. Consult ASTM E 213 and E 273.
Flux Leakage. Consult ASTM E 570.

2) Hydrostatic Test. This is an internal pressure test where the tube is filled with liquid at a specified pressure. The pressure is maintained for a specified length of time.