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TUBE BENDING STANDARD AND MANUFACTURING TOLERANCES

1. Scope

This specification covers cold bending of carbon steel tube materials via rotary arm bending equipment, utilizing a hydraulic boost system when required. Materials other than carbon steel may require further consideration due to their chemical and physical characteristics. Customer requirements, when less stringent, will normally apply and supersede this specification.

2. Manufacturing

2.1
All bends will be produced within the tolerances shown in Figures 1-4. In addition, all bends will conform to the requirements of ASME code standards and ANSI B31.1.

2.2
Water soluble lubricants may be used on the internal and external tube surfaces as required for bending.

2.3
Replacement bends will be supplied where breaking or an otherwise unacceptable bend occurs except when prohibited by customer requirements.

3. Quality Control

3.1
Materials of quality suitable for bending to a specified radius may be supplied by either the customer or Tulsa Fin Tube, Inc.

3.2
Bends will be produced with a minimum of deformations including wrinkles, kinks, waves or humps. Tolerances for these types of deformations, when they do occur, will be in accordance with the tolerances outlined in Figure 4.

3.3
For bends of 180° or less the bend degree tolerance is ± 1°

3.4
Tube wall thin-out will normally be checked at the beginning of each shift by either destructive means using spoilage materials or non-destructive means on the production bends via ultrasonic thickness gauge. More frequent checks may be made depending on the type of bending and / or customer requirements. Customer must specify maximum thin-out otherwise the standards outlined in Figure 1 will apply.

3.5
Ovality or flattening of individual bends will be a maximum of 10% calculated as follows. At any cross section, Max Ø - Min Ø ÷ specified Ø x 100. All flattening will be kept to an absolute minimum taking into consideration all other specific bend requirements. See Figure 2.

3.6
The diameter at any bent end, as measured not more than 0.25” from the end, will not vary more than ± 0.03125” from the specified tube diameter.

4. Duplex Bending Practice

The Duplex bending equipment at TFT allows for the bends on both ends of the tube to take place at the same time. There are two synchronized machines of the rotary arm type that are operated from a central control panel. The machines are mounted on leveled tracks and are capable of bending tubes from approx. 4’ up to approx. 70’ in length and up to 90° of bend on each end. The tooling used on this machine will accommodate bending over the fin on 2” tubes with up to 1” high fins in some cases and also bend over the bare portion of the finned tube without damage to the fins. It is common to clamp on the finned area of a tube and bend over the bare portion. The fins are generally capable of enduring the pressure of clamping without damage as the forces involved are directed vertically over the fin and toward the center of the tube. As a result the forces are spread evenly over an area of 6” of finned tube. It is preferable, but not absolutely required, to have a small amount of bare tube between the end of the fins and the tangent of the bend, even if it’s only 0.500”. In addition to the tube / fin configuration mentioned above the equipment is capable of bending much larger diameters and various configurations of tube diameter, fin heights, thicknesses and fins per inch with the correct tooling. At this time we have tooling for radii of 3” up to 12” for various diameters and fin heights. Please inquire for specific capabilities.

APPENDIX

Minimum wall thickness after bending	**See section 3.4 and Figure 1**
Ovality (out of roundness)	**See section 3.5 and Figure 2**
Bent end diameter after bending	**See section 3.6**
Center to center dimension	**See Figure 3**
Back to face dimension	**See Figure 3**
Alignment of ends	**See Figure 3**
Off-angle	**See Figure 3**
Off-plane	**See Figure 3**
Deformation tolerances	**See section 3.2 and Figure 4**
Duplex bending	**See section 4**

Figure 1

MAXIMUM ACCEPTABLE TUBE WALL THIN-OUT

Ø of Bend (Ratio of Bend CLR / Tube Ø)	Acceptable Thin-Out (unless noted)
1"	33.3%
1.5"	25.0%
2"	20.0%
2.5"	16.7%
3"	14.3%
3.5"	12.5%
4"	11.1%
4.5"	10.0%
5"	9.1%
5.5"	8.3%
6"	7.7%

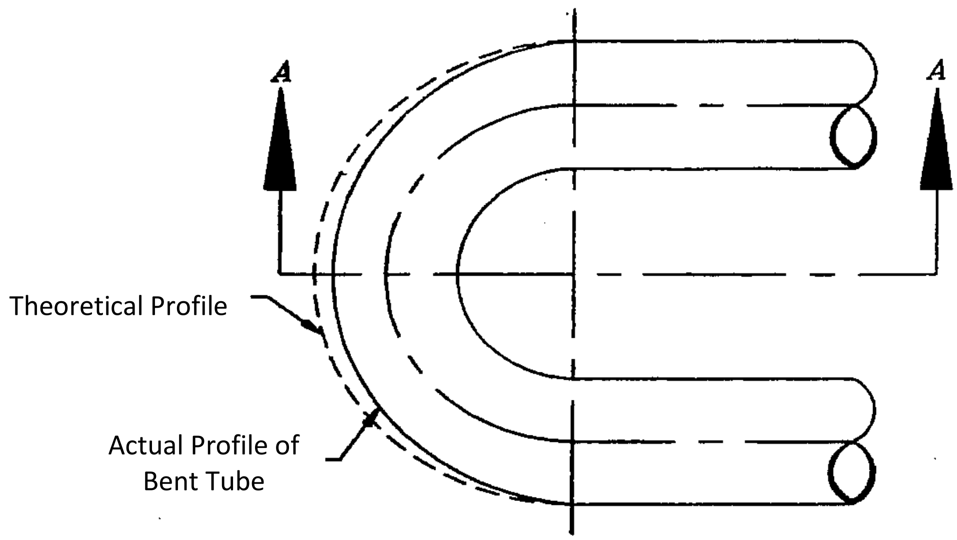
For diameter of bend not listed in the above table, either of the following two formulas may be used to calculate the maximum acceptable tube wall thin-out when a specification is not otherwise noted on the drawing.

$$\text{Method \#1 Thin-out (\%)} = \left[\frac{\text{(Bend Outside Radius)} - \text{(Bend Centerline Radius)}}{\text{(Bend Outside Radius)}} \right] \times 100$$

$$\text{Method \#2 Thin-out (\%)} = \left[\frac{1 - (2 \times \text{Bend Centerline Radius}}{(2 \times \text{Bend Centerline Radius}) + (\text{Tube Outside Diameter})} \right] \times 100$$

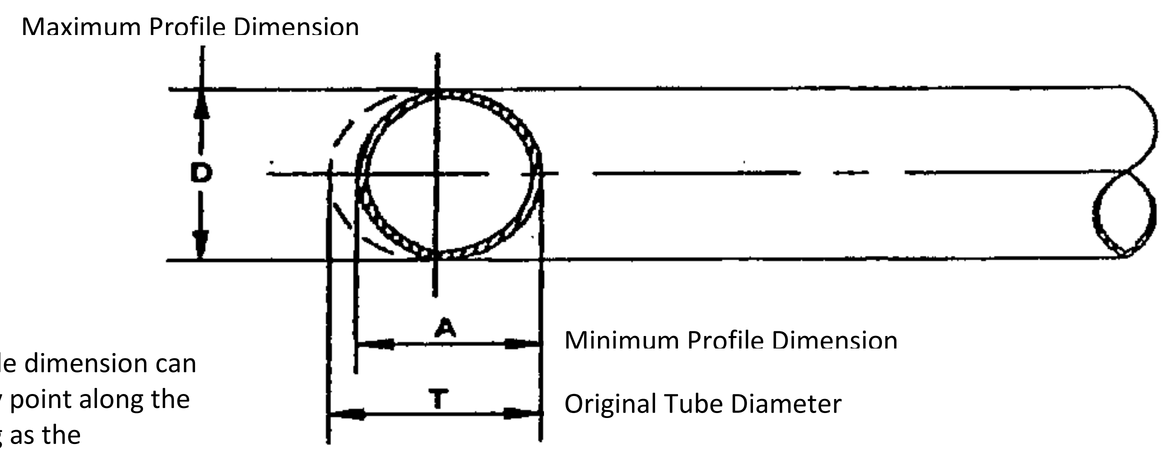
Figure 2

OVALITY TOLERANCE



$$\% \text{ Ovality} = \frac{D - A}{T} \times 100$$

$$\frac{\text{Max. Profile } \varnothing - \text{Min. Profile } \varnothing}{\text{Original Tube } \varnothing} \times 100 \leq 10\%$$



The minimum profile dimension can be measured at any point along the bend profile as long as the measurement reflects the smallest profile reading.

Figure 3

MANUFACTURING TOLERANCES

(B) Center-To-Center	± 0.125"
(E) Back-To-Back	± 0.250"
(N) Alignment of Ends	± 0.125"
(D) Off-Angle	± 0.03125"
(S) Off-Plane for Dim. (E) < 15"	± 0.0625"
(S) Off-Plane for Dim. (E) > 15"	± 0.125"

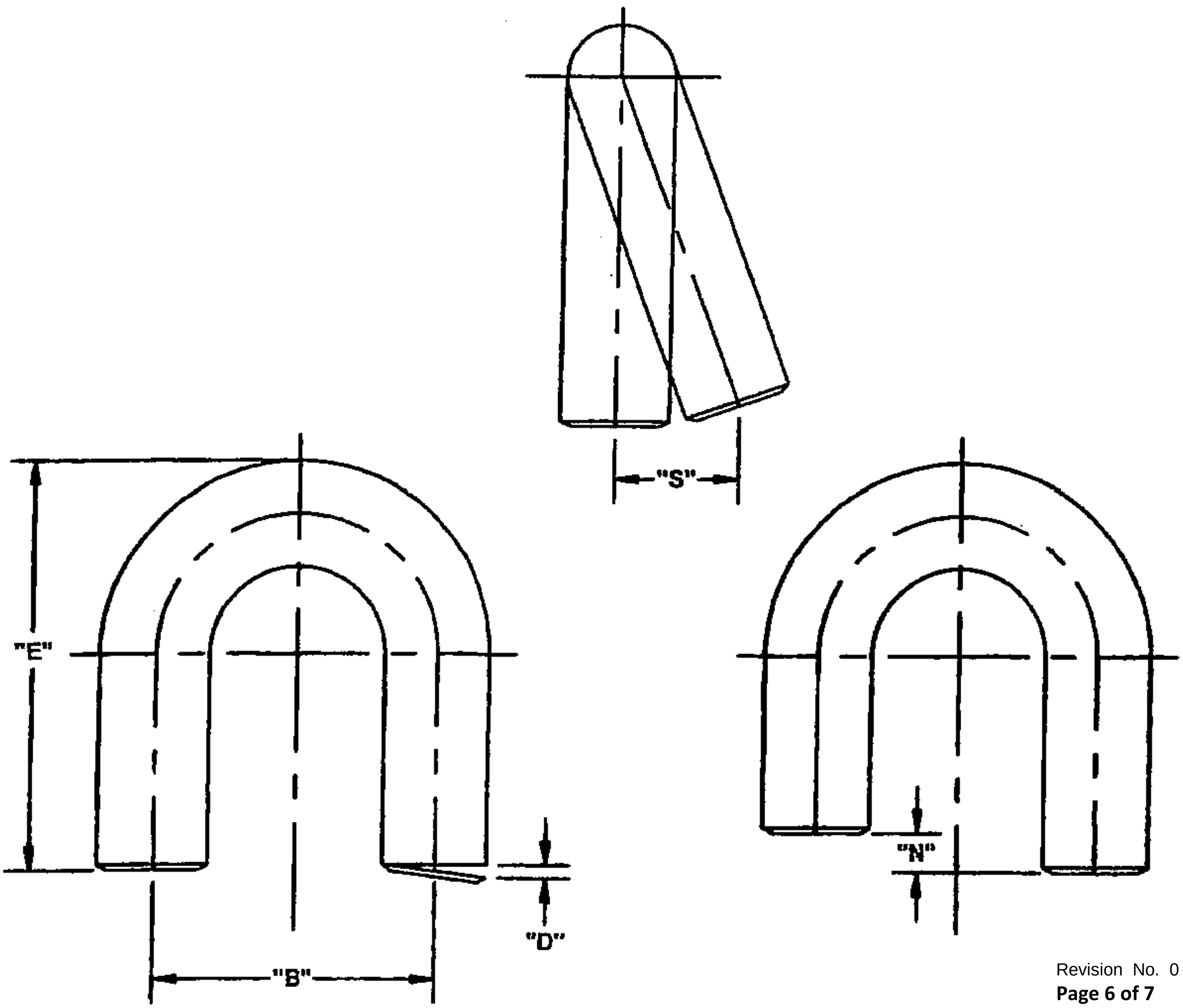
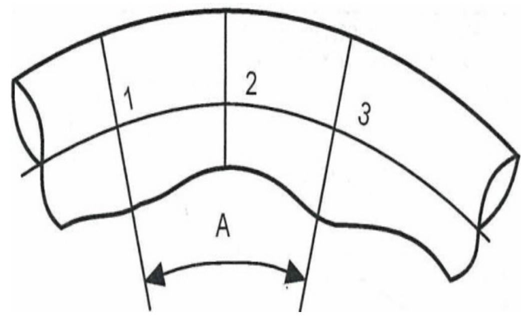


Figure 4

WRINKLE TOLERANCE



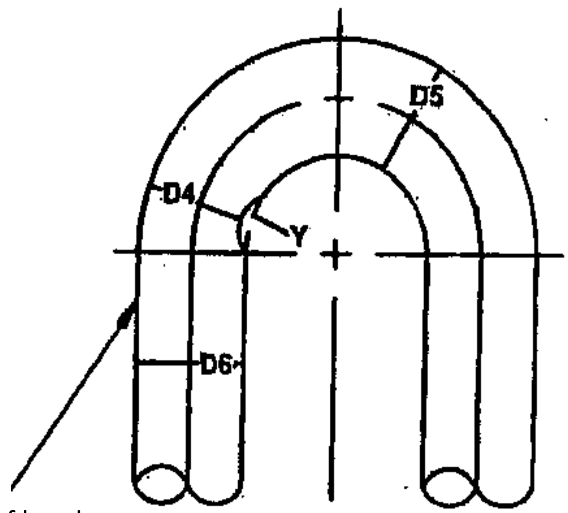
1. Average Depth – Crest to Valley

$$\frac{1+3}{2} - 2 \le 3\% \text{ of Nominal Ø}$$

2. Ratio of Distance Between Crest and Average Depth

$$\frac{A}{\text{Average Depth}} \ge 12$$

KINK TOLERANCE



Clamp end of bend

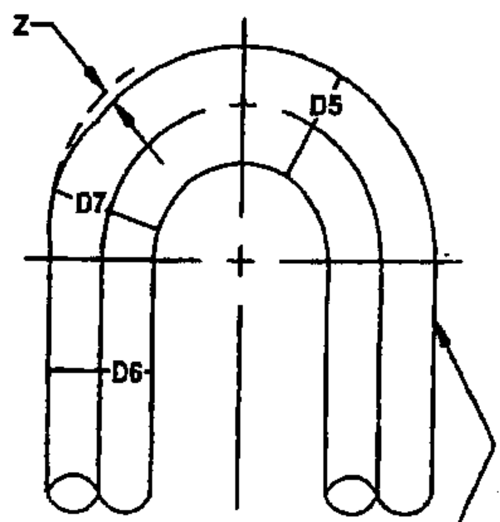
1. Maximum Depth of Kink

$$1 - \left[\frac{D6 - D4}{D5}\right] \le 15\% \text{ of nominal Ø}$$

D6-D4 = Y (Depth of Kink)

2. A kink results from clamp die slippage and must not be confused with wrinkles or a collapsed tube.

HUMP TOLERANCE



Clamp end of bend

1. Maximum Height of Hump

$$1 - \left[\frac{D7 - D4}{D5}\right] \le 10\% \text{ of nominal Ø}$$

D7-D6 = Z (Height of Hump)

2. A hump results from an internal mandrel that has extended too far and this problem should be corrected, if possible.