

CLOSE RADIUS PIPE BENDING AND FORMING

PIPE FORMING GUIDE

Specification No. ES7 | March 1, 1996

1.0 SCOPE

This specification covers machine 1½D and 3D pipe bends (made at ambient temperatures). Substituting pipe bends for butt welded elbows will provide piping with higher integrity, faster fabrication, and lower cost.

2.0 BEND RADIUS

2.1 General

Pipe bends are classified according to the centerline radius (CLR) of the bend as a ratio to the nominal pipe diameter. For example, 4" N.P.S. pipe which is bent on a 6" CLR is classified as a 1½D Bend (1½ times the nominal pipe diameter). When bent on a 12" CLR, the bend is classified as 3D.

2.2 1½D Bends

Most cold bends are made on a 1½D radius. The major reason for choosing 1½D is that it is interchangeable with long radius butt weld elbows (a 4" Long Radius 90° Elbow is 6" center-to-face). As a result, drawings do not need to be changed to permit bending. When modifying an existing formed system, a standard weld fitting can be used or vice versa.

2.3 3D Bends

As an alternative to 1½D bending, when flow restriction may be a concern, 3D bend radii may be utilized. Studies have also indicated potential energy savings using larger bend radii. 3D Bending may require special design consideration.

3.0 SIZE LIMITS

Cold machine formed close radius bends are currently available as follows;
½ - 6" N.P.S. Sch 5- Sch 80

Cold close radius bending of Schedule 5 pipe is only possible with carefully selected pipe and tooling.

4.0 MATERIALS

4.1 Carbon Steels

Carbon steel pipe is suitable for machine cold bending without heat treatment to bend radius limits indicated in the following table.

	A-587 ERW	A-53 Grade B Seamless	A-53 Grade B ERW	A-106 Grade B Seamless
Cold Bending	1½D	3D – 6D	3D – 6D	3D – 6D
Heat Treatment	Normalized	Hot Finished	Hot Finished	Hot Finished
Tensile Strength, Min. PSI	48,000	60,000	60,000	60,000
Yield Point, Min. PSI	30,000	35,000	35,000	35,000
Elong. In 2", Min. %	40	30	30	30
Carbon % Max.	0.15	.3	.3	0.3
Manganese %	0.27 – 0.63	1.20 Max.	1.20 Max.	0.27-1.06
Sulphur % Max.	0.058	0.06	0.06	0.058
Phosphorous % Max.	0.048	0.05	0.05	0.048
Aluminum % Min.	0.02	Not Specified	Not Specified	0.10 Min. Silicon
Grain Size	Fine Grain	Not Controlled	Not Controlled	Not Controlled
ASME B31.3 – 93 Allowable Stress Values KIPS / Sq. In. -20° F to 400° F	13.60	20.00	17.00	20.00

4.2 Alloys

ALLOY	SPECIFICATION
Stainless Steel	A-312, Types 304, 304L, 316, 316L, 309, 310, 317, 321, 347
Nickel Alloys	Nickel 200, Alloy 400 (Monel®) Alloys 600, 601, 625, 690 (Inconel®) Alloys 800, 825 (Incoloy®) Alloys C-276, B-2 (Hastelloy®)
Aluminum	3003, 5083, 6061-T4, 6061-T6, 6063-T6
Titanium	Grade 1, Grade 2
Zirconium	702 Grade

MACHINE COLD BENDING 1½D AND 3D

5.0 BEND SPECIFICATIONS

5.1 Bends

A pipe bend made to this specification and verified for pressure design is accordance with ASME B31.3 shall be suitable for the same service as the pipe from which it is made.

5.2 Out of Roundness

Flattening of a bend, is measured by the difference between the maximum and minimum outside diameter at any cross section. For 1½D bends, out of roundness shall not exceed 5 percent of the nominal outside diameter for internal pressure and 3 percent for external pressure. For 3D bends, out of roundness shall not exceed 3 percent. (See FIG. 1)

5.3 Dimensional Tolerances

Degree of bend is to be held to plus or minus 1 degree. Overall spool length will be held to plus or minus 1/8 inch. All centerline-to-centerline or centerline-to-end face dimensions will be plus or minus 1/8 inch. (See FIG. 2)

5.4 Wall Thinning

Wall thinning of 1½D and 3D bends, as measured by the difference between the actual thickness of the pipe "A" and the minimum thickness "B" on the outside bend shall not exceed 18 percent of the actual thickness for 1½D bends and 12 percent for 3D bends. (See FIG. 3) Maximum allowable working pressure should be calculated using the following formula:

$$\text{For } 1\frac{1}{2}\text{D Bending } P = \frac{2SE [.82t - c]}{D} \quad \text{For 3D Bending } P = \frac{2SE [.88t - c]}{D}$$

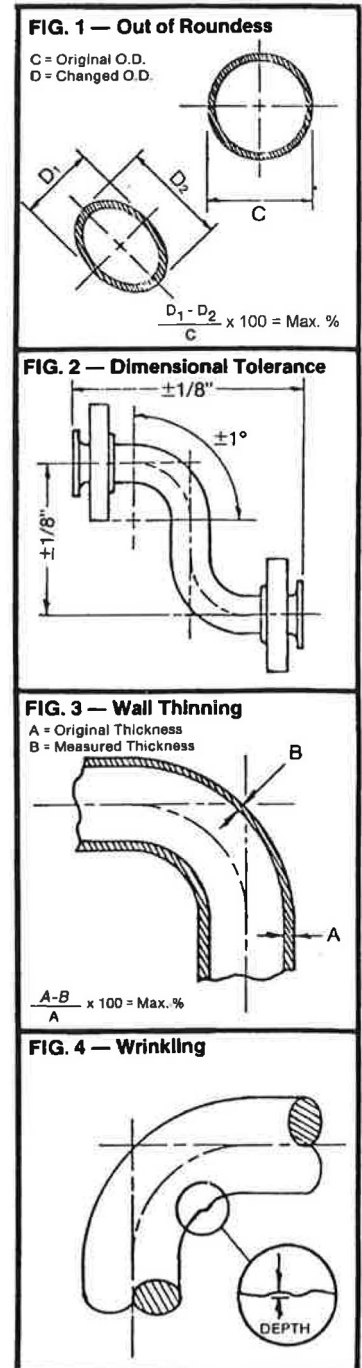
P – Maximum Allowable Working Pressure

SE – Allowable Stress

t – Actual Pipe Wall Before Bending

c – Corrosion Allowance

D – Outside Diameter of the Pipe



5.5 Wrinkling

Light wall stainless coupled with pipe wall variation near the outer limits of mill specifications may occasionally wrinkle. (See FIG. 4) In these cases, peak to valley depth will be limited to:

TABLE 1: CLOSE RADIUS BENDING TABLES

Pipe Size	Max. Depth
1/2" – 2"	1/32"
3"	3/64"
4"	1/16"
6"	3/32"

Piping designers should refer to the Close Radius Bending Tables as a guide to maximizing the use of bending in their piping layout. These minimum dimensional values are established to allow adequate clamping during bending. Closer center-to-center or center-to-face dimensions are obtained by cutting pipe and/or adding welds as required. Minimum forming dimensions for degree of bend other than those shown are available upon request.

1-1/2 DIAMETER BENDING TABLE

Pipe Size	Radius R	90 Degree Bends			45 Degree Bends			G
		A	B	C	D	E	F	
1/2"	1 1/2"	5 1/2"	7"	7"	4 5/8"	6"	5 1/4"	6 1/8"
3/4"	1 1/2"	5 1/2"	7"	7"	4 5/8"	6"	5 1/4"	6 1/8"
1"*	1 1/2"	5 1/2"	7"	7"	4 5/8"	6"	5 1/4"	6 1/8"
1 1/2"*	2 1/4"	8"	8"	10 1/4"	6 11/16"	6"	7 5/8"	8 15/16"
2"	3"	11"	8"	14"	9 1/4"	6 1/2"	10 1/2"	12 1/4"
2 1/2"	3 3/4"	13 3/4"	10"	17 1/2"	11 9/16"	7 3/4"	13 1/8"	15 15/16"
3"	4 1/2"	13 1/2"	12"	18"	10 7/8"	9"	12 3/4"	15 3/8"
4"	6"	16 1/4"	14"	22 1/4"	12 3/4"	9 3/4"	15 1/4"	18 3/4"

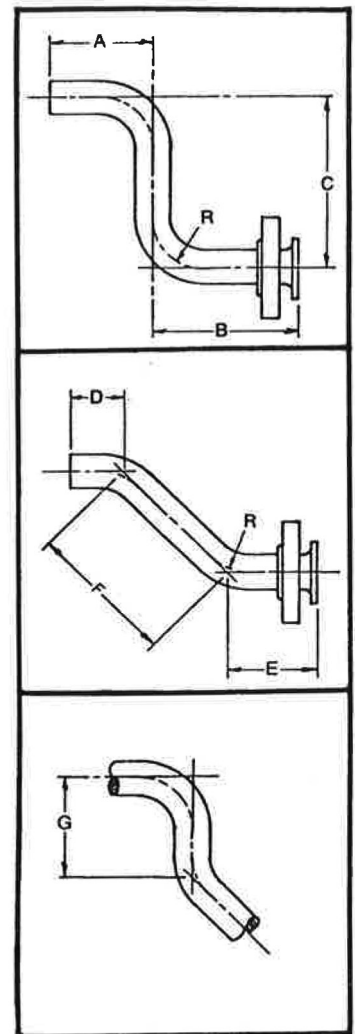
A or D – Plain or Beveled End

B or E – Flanged End

C, F, G – Center-to-Center

Minimum Center-to-Center, and Center-to-Face Dimensions to allow forming. Some Center-to-Center bends may require a weld due to the plane of bend and/or the distance from the centerline of the bender mandrel to the shop floor.

*12" Center-to-Center is required for 1/2", 3/4" 1" N.P.S. and 13 1/2" Center-to-Center is required for 1 1/2" N.P.S., if the plane of bend is below the horizontal plane (due to bender limitations). 1 1/2" D pipe bends in 2 1/2" N.P.S. are not available in Carbon Steel.



3 DIAMETER BENDING TABLE

Pipe Size	Radius R	90 Degree Bends			45 Degree Bends			G
		A	B	C	D	E	F	
1/2"*	1 1/2"	5 1/2"	7"	7"	4 5/8"	6"	5 1/4"	6 1/8"
3/4"*	2 1/4"							
1"*	3"	7"	6 7/8"	10"	5 1/4"	6"	6 1/2"	6 1/4"
1 1/2"*	4 1/2"	10 1/4"	9 3/16"	14 3/4"	7 5/8"	6 1/2"	9 1/2"	12 1/8"
2"	6"	14"	10 15/16"	20"	10 1/2"	7 7/16"	13"	16 1/2"
2 1/2"	7 1/2"							
3"	9"	18"	16"	27"	12 3/4"	10 11/16"	16 1/2"	21 3/4"
4"	12"	22 1/2"	19"	34 1/4"	15 1/4"	12"	20 1/4"	27 1/4"
6"	18"	31 1/2"	34"	51 1/2"	21"	23 1/2"	30 1/2"	41"

A or D - Plain or Beveled End

B or E - Flanged End

C, F, G - Center-to-Center

Minimum Center-to-Center, and Center-to-Face Dimensions to allow forming.
Some Center-to-Center bends may require a weld due to the plane of bend and/or the distance from the centerline of the bender mandrel to the shop floor.

*12" Center-to-Center is required for 1/2", 3/4" 1" N.P.S. and 13 1/2" Center-to-Center is required for 1 1/2" N.P.S., if the plane of bend is below the horizontal plane (due to bender limitations). Closer dimensions for 6" N.P.S. bends are available depending on pipe material. Minimum forming dimensions for 3/4" and 2 1/2" N.P.S. are available upon request.