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Joint Efficiency Factors for Seam-Welded Factory-Made Pipeline Bends

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INTRODUCTION

Pipelines are typically constructed using bends for changes in direction. Wrought factory-made bends up to a certain size may be produced without a seam, but large components may be manufactured from plate with edges joined at one or two meridional seams. Pipeline operators attempting to verify their maximum allowable operating pressure (MAOP) are concerned with the appropriate joint efficiency factor, E, to apply to pipe containing longitudinal seams. This concern extends to wrought factory-made bends that contain one or two seams, manufactured in various eras.

CONCLUSIONS

Factory-made bends manufactured from plate where the edges are joined at one or two welded seams, from 1940 and later, should be considered to be of equivalent strength as a seamless bend or seamless pipe of matching size and material. The Joint Efficiency Factor for the seams should be taken as having a value equal to 1.00. Hence the presence of the seam does not affect the maximum allowable operating pressure of the bend or a pipeline segment containing the bend. Wrought bends made with seams prior to 1940 may or may not be seamless; seams could be fusion welded with or without inspection, or could consist of forged lap-welds. If no information about the manufacturer's inspection process of a pre-1940 wrought bend is available, and the seam is evidently of the submerged arc or other fusion-arc process, the Joint Efficiency Factor should be assumed to be 0.80. If the seam appears to be a forge-welded or lap-welded seam, the Joint Efficiency Factor should also be taken as 080. This paper does not address field bends formed cold or hot. Generally the Joint Efficiency Factors for field bends should be consistent with that of the pipe they were formed from.

DISCUSSION

Of concern is what Joint Efficiency Factor (if any) is appropriate for factory-made bends or elbows manufactured with meridional seam welds, particularly those manufactured in the 1950's and 1960's. This discussion briefly reviews the Joint Efficiency Factor concept, and then reviews product standards for factory-made bends and elbows, in order to determine what joint factor should apply given prevailing standards for the design and manufacture of these types of components.

The Joint Efficiency Factor Concept

The design pressure of a pipe used in a natural gas pipeline is calculated as $P=2SFEt/D$, where "S" is the material specified minimum yield strength, "t" is the nominal pipe wall thickness, "D" is the specified outside diameter of the pipe, "F" is the Location Class Factor, and "E" is the Joint Efficiency Factor. The Joint Efficiency Factor represents a generic level of confidence in the overall strength of a weld seam considering the method used to produce the seam, the thoroughness of inspection of the seam's quality, and testing of the seam strength. There does not appear to be any authoritative document citing specific data on which historical or present day values for joint efficiency factors are based. It is likely that pipe seam joint efficiency factors were originally developed considering the results of burst tests of pipe performed by major pipe manufacturers such as the test results reported in early product catalogs of the National Tube Company of US Steel.[1] The generic E factors specified for various seam types by the B31 Code many years later appear to reflect the results reported by National Tube.

The factor "E" was applied in the first (1935) edition of the B31 Code for Pressure Piping in setting the allowed working stress of riveted seams.[2] Effective joint efficiencies were implicit in reduced allowed working stresses for gas piping having various styles of seam compared with seamless pipe that was used in urbanized areas

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[1] National Tube Company, Book of Standards, 1913.
[2] American Standards Association, "Code for Pressure Piping", American Tentative Standard B31.1, ASME, 1935.

and industrial facilities. [3] For cross-country gas pipelines and gas pipe outside of urbanized areas, footnotes to the pressure design formula specified the use of a joint efficiency in establishing the working pressure, but the actual joint efficiency values to use were not stated.

The second (1942) edition of the Code[4] specified joint efficiency factors for radiographed fusion-welded (E=0.90), resistance-welded (E=0.85), non-radiographed fusion-welded, forge-welded and lap-welded (E=0.80), and butt-welded (E=0.60) line pipe. API 5L was a listed standard but not API 5LX, which had not yet been developed. A footnote (3) to listings for electric-fusion-welded pipe and electric-resistance-welded pipe in the "Table 6 Allowable "S" Values for Pipe in Gas and Air Piping System" stated:

> "Where pipe furnished under this classification is subjected to supplemental tests and/or heat treatments as agreed to by the supplier and the purchaser, and whereby such supplemental tests and/or heat treatments demonstrate the strength characteristics of the weld to be equal to the minimum tensile strength specified for the pipe, the "S" values equal to the corresponding seamless grades may be used."

The first (1952) edition of B31.8 as a separate, integrated standard for natural gas pipelines[5] gave joint efficiency factors for various seam types in Paragraph 807(a). Notably, stress relieved and radiographed electric fusion welded seams were assigned E=1.00, double-submerged-arc-welded seams in API 5LX pipe were assigned E=0.85, and ordinary electric fusion welded seams were assigned E=0.80. However, ahead of these specified values for E, Paragraph 807 stated:

> "The value of E shall be taken from the following list, except that it may be taken as 1.00 for electric-resistance-welded (including electric flash-welded and continuous-electric-resistance-welded) and double-submerged-arc-welded pipe if tests of representative weld-test specimens and/or cylindrical samples demonstrate the strength of the weld to be at least equal to the strength of the pipe and for double-submerged-arc-welded pipe that has been stress-relieved and radiographically inspected…".

[3] The Code specifically listed ASTM A134 pipe in this context, so this almost certainly was intended to apply to submerged-arc-welded pipe.
[4] American Standards Association, "Code for Pressure Piping", ASA Standard B31.1, ASME, 1942.
[5] American Standard Code for Pressure Piping, ASA B31.1, Section 8, "Gas Transmission and Distribution Piping Systems", 1952.

Although the type and quantity of tests required to establish E=1.00 was not stated, clearly, the intent of the Code was to allow E=1.00 for DSAW pipe having seams of sound quality as determined by testing. In that Code edition, the factor E was not used in the pressure design formula, but was used as an adjustment to the effective yield strength which in turn was used to determine the allowed working pressure.

The second (1955) edition of B31.8 omitted the inset language above but specifically listed E as equal to 1.00 for DSAW and ERW pipe manufactured in accordance with either API 5L or API 5LX.[6] The factor E was used explicitly in the calculation of the design pressure in an equation that is identical to the present-day calculation in B31.8 and in 49 CFR 192.

The foregoing information gives evidence of a long-standing intent by the authors of piping design standards to assign a Joint Efficiency Factor having a value equal to 1.00 to welded seams in pipe where:

- The seam was produced by an electric fusion (arc) method such as submerged-arc welding, and
- The seam was subjected to a stress-relieving heat treatment and was radiographically inspected, or
- Tests of representative specimens demonstrate that the seam is at least as strong as the pipe.

The Joint Efficiency Factor applicable to a factory-made bend thus depends on whether the design basis and/or manufacturing processes applied to the components meet these criteria.

Industry Standards for Factory-Made Wrought Bends

Bends have historically been formed using a wide range of techniques, probably all of which have been used in the construction of oil or natural gas pipelines at one time or another, consistent with customs that prevailed during any given era of construction and as were applicable to given pipe sizes and materials. Bends may be either produced in the field, or produced in a fabrication or manufacturing facility. Field-made

[6] "Gas Transmission and Distribution Piping Systems", Section 8 of the American Standard Code for Pressure Piping, ASA B31.1.8, 1955.

bends include cold bends, wrinkle bends, and miter bends. Factory-made bends include induction bends, forged welding elbows in short- and long-radius styles, wrought bends made from seamless pipe or tube, and wrought bends formed from plate with edges joined at one or two welded seams aligned along meridional axes. (On a pipe bend, a meridian is aligned with the longitudinal axis of an adjoining pipe, follows the arc of the bend through its full arc length, and aligns with a longitudinal axis of the adjoining pipe at the other end, all with the same angular orientation (i.e. clock position) with respect to the pipe circumference.

Factory-made bends have historically been produced in accordance with one of several product standards, or to manufacturer's standards prior to development of applicable consensus industry standards covering defined ranges of sizes and material strength grades. A summary of applicable industry wrought fittings product standards is given in Table 1 below. Some relevant standards are discussed subsequently.

Table 1. Industry Standards Applicable to Wrought Bends

By	Standard	Year	Size (inch)	Material	Comment
ASA	B16.9	1940	To NPS 12	A234	No HT required, does not discuss seams
		1951	To 24 OD	A234 A/B	No HT required, does not discuss seams
MSS	SP-48	1956	26-36 OD	A234, A420	Other materials OK, no HT required, shall be designed so E=1.0
	SP-59	1955	26-36 OD	A234, A420	Other materials OK, no HT required, shall be designed so E=1.0
	SP-63	1961	Any	WPY35-WPY52	No HT required, weld seam RT
	SP-63	1967	Any	WPY42-WPY65	HT required, weld seam RT
	SP-75	1973	To 48 OD	WPHY42-WPHY70	HT required, weld seam RT

ASME B16.9

ASME B16.9, first published in 1940, covers factory-made wrought buttwelding fittings, including bends, tees, reducers, and caps.[7] The term "buttwelding" indicates that the fittings are welded in line with and joined to the piping with weld metal deposited into a circumferential groove prepared at the end of the fitting and adjacent piece of pipe, as

[7] "Factory-Made Wrought Buttwelding Fittings", ASME B16.9-2007.

opposed to flanged in place. The term "wrought" denotes fittings made of pipe, tubing, plate, or forgings. Fittings fabricated using circumferential or intersection welds (e.g. laterals) are not covered by the standard, but longitudinal or meridional seams are allowed. The 1940 Edition covered sizes to NPS 12. The current edition covers up to NPS 48 in some styles of fitting. Materials are limited to moderate-strength grades of carbon steel and alloy steel, stainless steel (austenitic, ferritic and martensitic), and nonferrous alloy (aluminum, titanium , and nickel) generally compatible with pipe materials found in power and process facilities. The plain carbon steel materials are compatible with conventional "Grade B" line pipe (e.g. A53, A106, and API 5L) in terms of strength and welding compatibility. Materials that match high-strength grades of line pipe are not recognized by B16.9.

The basis for the pressure design of B16.9 wrought bends is a prototype proof test of a representative fitting that demonstrates that the bursting strength of the fitting will not be less than that of a pipe of the corresponding material, size, and schedule (referred to as "matching pipe").[8] If the test is not conducted to bursting, the test pressure must at least equal or exceed 105% of the computed burst pressure of the matching pipe. The proof test is intended to demonstrate that the geometric design of the fitting is not a "weak link" with respect to pressure-carrying capacity.

The stress-concentrating effects of the fitting geometry[9] are accommodated typically by providing additional thickness in appropriate parts of the fitting. The results of the prototype proof test are considered scalable to pipe having a diameter other than that of the tested prototype provided other shape-related dimensions such as wall thickness and geometry are scaled proportionately. Accordingly, a NPS 12 Schedule 160 bend made from A234 WPB carbon steel will be at least as strong as a piece of NPS 12 Schedule 160 Grade B seamless pipe, for example.

B16.9 contains no specific requirements on seams that may be incorporated into the design. However, the proof test standard applies even if the finished product contains a seam as a result of how it is manufactured. Thus any seam present in a B16.9 bend, by definition, has no effect on the allowable operating pressure of the bend.

[8] M. W. Kellogg Company, Design of Piping Systems, J. Wiley & Sons, Inc., 1956.
[9] In bends, the inside radius (intrados) experiences an increased hoop stress in accordance with the Lamé Effect, which increases as bend radius decreases. In wrought or forged tees, hoop stress concentrates in the crotch adjacent to the branch outlet.

MSS SP-63 and SP-75

SP-75, originally approved in 1970, covers wrought butt welding fittings for use in pipelines.[10] It superseded SP-44[11] and SP-59[12] published in 1955, and SP-63[13], published in 1961 and 1969 by combining the scopes of all three standards. The MSS standards were developed to address seamless and electric welded carbon and low alloy steel butt welding fittings in ranges of diameter and/or material grade not encompassed by corresponding B16 butt welding fitting standards. The intended applications for the fittings were gas and oil transmission and distribution pipelines, compressor stations, metering and regulating stations, and mains.[14]

The design basis of butt welding fittings under the various MSS specifications was the same as that of B16.9, the prototype proof test. The acceptance criterion for the proof test was the same as that of B16.9. The MSS standards gave somewhat more guidance than does B16.9 to the selection of the test prototype and range of test applicability. The selected prototype had to be representative of production. Scalability was limited to sizes from one-half to two times the size of the tested fitting, and a t/D ratio between one-half and three times that of the tested fitting. Testing of a nonreducing fitting qualified reducing fittings of the same pattern, and testing of a bend or elbow qualified a bend or elbow of a larger radius of curvature of the same pipe size.[15] The burst performance of a given geometric design was considered proportional to the tensile properties of the material.

Tubular products used to form the fittings were required to be either seamless or fusion welded with filler metal added. Preference was expressed for the submerged arc process for welds made by machine. Submerged arc welds were required to be completed with at least one weld pass on the inside (except where accessibility made this impossible in which case the root pass could be made by other means provided it could be inspected visually). All butt welds were required to have full penetration. All welders and welding procedures were required to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code, or API 1104. Longitudinal

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[10] "Specification for High Test Wrought Butt Welding Fittings", Standard Practice SP-75, Manufacturers Standardization Society (MSS) of the Valve and Fittings Industry, Inc., 1973.
[11] "Steel Butt Welding Fittings", Standard Practice SP-48, 1956.
[12] "Steel Butt Welding Short Radius Elbows and Returns", Standard Practice SP-59, 1955.
[13] "High Strength Wrought Welding Fittings" Standard Practice SP-63, 1961.
[14] Requirements described herein applied generally within all of the MSS standards. They are described in the past tense but may also be found in the present MSS product standard.
[15] In both cases, this is because a lower stress concentration would be present in the alternative pattern.

seam welds were required to be inspected to the standards of Section VIII of the ASME Boiler and Pressure Vessel Code. These requirements assured that the meridional seam was sound. Tensile tests of production fittings were required once per production lot or heat. Fittings containing welds were tensile tested and bend tested across the weld when requested by the customer.

Manufacturer Practices and Products

Prior to the development of MSS standards for pipeline fittings, and prior to the inclusion of large fitting sizes in the ASME B16 fitting standards, manufacturers implemented their own standards. Examples reviewed for this study included those from Tube Turns, Ladish, Taylor Forge, and Crane, all major fittings manufacturers in the 1950's.

Tube Turns

Tube Turns of Louisville KY manufactured a full complement of piping fittings for the pipeline and process industries. Through 1952, Tube Turns appears to have manufactured pipe bends only from seamless tubular stock.[16] The maximum bend diameter was 30 inches. Carbon steel material grades were limited to A234. By 1954, Tube Turns had increased the available sizes of bends to include 34-, 36-, and 42-inch OD in Standard and Extra Strong 90-degree and 45-degree short- and long-radius patterns.[17] Starting in 1954 and later, the commercial literature included the following notes with respect to piping bends:

- "Unless otherwise indicated on quotation, 30-inch and smaller furnished seamless. Non-seamless elbows are marked to indicate that they are fabricated from rolled cylinders with one longitudinal seam weld. Welds are 100% radiographed per Par. UW-51 of Section VIII of the ASME Boiler and Pressure Vessel Code and stress relieved."

- "Pipe Line Welding Fittings, conforming to MSS Standard Practice SP-63, High Strength Wrought Welding Fittings, are available in sizes 6-inches and larger with physical properties to match pipe with 42,000, 46,000, 48,000, 50,000, and 52,000 psi minimum yield strengths."

[16] Chemetron Corp., Tube Turns Catalog 211, 1952.
[17] Chemetron Corp., Tube Turns Catalog 311, 1954, 1958, and 1962.

Figure 1 is an excerpt from Catalog 311 for standard wrought carbon steel bends. The notes cited above are highlighted at the bottom of the figure. These notes do not appear in the earlier Catalog 211.

The first note indicates that Tube Turns performed full volumetric nondestructive examination of welded seams in order to fully justify a Joint Efficiency Factor of 1.00. The second note indicates that Tube Turns had adopted the MSS requirements for seam and material quality, and used materials matching line pipe grades available at that time. The 1952 catalog lists no material grades for bends matching line pipe materials other than Grade A and Grade B, and those were listed as seamless, so the transition to seamed bends and high strength materials occurred sometime between 1952 and 1954.

The following note appeared in 1952 and 1954 and later catalogs:

- "Pressure-Temperature Ratings are identical with those of seamless pipe of the same size, thickness or schedule, and material grade."

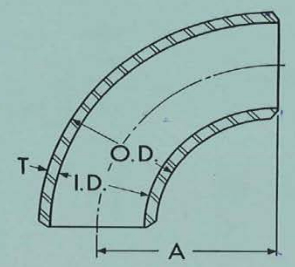
While this seems obvious for bends made from seamless tubing, this note applied to all bend products including those manufactured with seams as described in the 1954 and later catalogs.

TUBE-TURN
Welding Fittings

90° ELBOWS

Standard Weight†

Long Radius



Part No. 1

ASA B16.9▲ ASTM A234*

NOMINAL PIPE SIZE	OUTSIDE DIAMETER O. D.	INSIDE DIAMETER I. D.	WALL THICKNESS T	CENTER TO FACE A	†PIPE SCHEDULE NUMBERS	APPROXIMATE WEIGHT IN POUNDS	LIST PRICE
½	.840	.622	.109	1½	40	.16	
¾	1.050	.824	.113	1⅛	40	.16	
1	1.315	1.049	.133	1½	40	.35	
1¼	1.660	1.380	.140	1⅞	40	.6	
1½	1.900	1.610	.145	2¼	40	.8	
2	2.375	2.067	.154	3	40	1.5	PRICES ON APPLICATION
2½	2.875	2.469	.203	3¾	40	3.0	
3	3.500	3.068	.216	4½	40	4.5	
3½	4.000	3.548	.226	5¼	40	7	
4	4.500	4.026	.237	6	40	9	
5	5.563	5.047	.258	7½	40	15	
6	6.625	6.065	.280	9	40	24	
8	8.625	7.981	.322	12	40	50	
10	10.750	10.020	.365	15	40	83	
12	12.750	12.000	.375	18	ST(1)	123	
14	14.000	13.250	.375	21	30	164	
16	16.000	15.250	.375	24	30	210	
18	18.000	17.250	.375	27	ST(1)	273	
20	20.000	19.250	.375	30	20	343	
22	22.000	21.250	.375	33	ST(1)	385	
24	24.000	23.250	.375	36	20	516	
26	26.000	25.250	.375	39	ST(1)	602	
30	30.000	29.250	.375	45	ST(1)	775	
34	34.000	33.250	.375	51	ST(1)	926	
36	36.000	35.250	.375	54	ST(1)	1040	
42	42.000	41.250	.375	63	ST(1)	1420	

All dimensions are in inches.

* Grade B fittings are available from stock.

Unless otherwise indicated on quotation, 30" and smaller are furnished seamless. Non-seamless elbows are marked to indicate that they are fabricated from rolled cylinders with one longitudinal seam weld. Welds are 100% radiographed per Par. UW-51 of Section VIII of the ASME Boiler and Pressure Vessel Code and stress relieved.

† All thicknesses agree with those for Standard Wall Pipe (see ASA B36.10). Pipe Schedule Numbers are in accordance with ASA B36.10.

Pipe Line Welding Fittings, conforming to MSS Standard Practice SP-63, High Strength Wrought Welding Fittings, are available in sizes 6" and larger with physical properties to match pipe with 42,000, 46,000, 48,000, 50,000, and 52,000 psi minimum yield strengths.

Odd degree elbows also available.

(1) ST designates Standard Weight (standard wall).

Pressure-Temperature Ratings are identical with those of seamless pipe of the same size, thickness or schedule, and material grade.

For Dimensional Tolerances see page 93.
For bevel detail see page 94.
▲ For information on this Standard see page 94.

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Figure 1. Standard Long-Radius Elbows from Tube Turns Catalog 311

Ladish

The Ladish Company manufactured a full complement of piping fittings that substantially overlapped those manufactured by Tube Turns. Ladish commercial literature[18] indicates that as of the mid-1950s, piping bends were manufactured from seamless pipe or tube stock only. Informal communication with a former engineering manager who retired from Ladish revealed that Ladish did in fact have half-shell dies for manufacturing bends from plate stock almost from the beginning but they were used more often for stainless steel rather than carbon steel bends. The half-shell ells would have had two seams. Most of their carbon steel and low-alloy steel bend products were mandrel formed (i.e. seamless) unless it was a special product. However, all half-shell ells would have had the seams 100% radiographed in order to consider the completed bend product equivalent to seamless pipe.

Taylor Forge

Taylor Forge manufactured pipe, fittings, and vessels of riveted, forged hammer-welded, electric fusion welded (i.e. submerged-arc welded), and seamless construction in diameters from 16 inches to 96 inches. Taylor Forge's primary market for large diameter pipe and fittings at that time was water pipelines and penstocks, and for steam piping, however pipe and fittings were produced for the gas pipeline industry. The Taylor 1930 product catalog[19] shows large diameter shallow angle bends identified for 600-psig gas pipelines, reproduced in Figure 2. Considering that they must have been produced in the late 1920's, they were probably of forged hammer-welded construction. However Catalog 31 does depict "a new line" of seamless fittings in what appear to be standard patterns with ends beveled "for acetylene or electric welding of pipe." The sizes and materials are not described in Catalog 31.

[18] Ladish Company, Catalog 55, 1954.
[19] Taylor Forge & Pipe Works Company, Catalog 31, 1930.

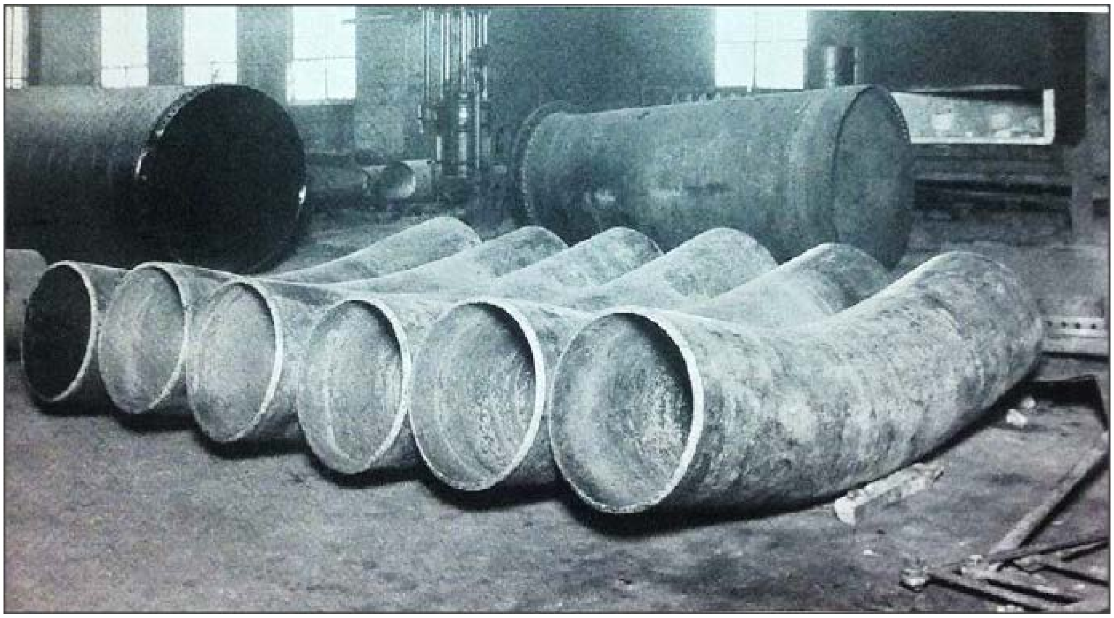


Figure 2. Large Diameter Bends for 600 psig Gas Pipeline (from Taylor Forge Catalog 31)

In 1940,[20] Taylor Forge listed seamless welding fittings (e.g. "WeldELLS") in sizes up to 24 inches in conventional schedules and meeting the requirements of ASTM A106 Grades A and B seamless pipe. Light-wall fittings were available in a limited selection. Reducers in sizes from 26-inch through 30-inch carried the footnote

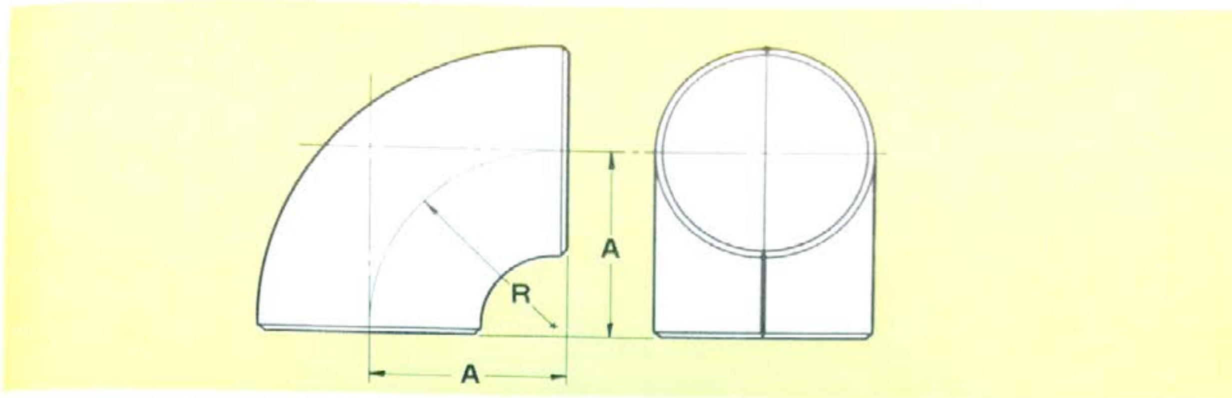
- "These sizes will be made from either Lap Welded or Electric Welded pipe at our option, unless ordered otherwise."

Page 71 of Catalog 401, reproduced here in Figure 3, shows large-diameter "WeldELLS" of two-piece fusion-welded construction in 24-inch, 30-inch, and 36-inch construction with available wall thickness from 1/4-inch to 3/4-inch. A footnote states:

- "When specified by the purchaser, welds will be X-rayed and made to comply with Paragraph U-68 of the 1939 ASME Code."

This note is highlighted in Figure 3.

[20] Taylor Forge & Pipe Works, Catalog 401, 1940.



Large Diameter WeldELLS

Two Piece Construction

Fusion Welded

*Size Inches	†Center to End †A	Radius †R	Thickness T
24	34	30	¼ to ¾
30	28	24	¼ to ¾
30	34	30	¼ to ¾
36	24	24	¼ to ¾

*Elbows can be furnished to either nominal inside or outside diameter.
†Center to face dimension can be varied from a dimension equal to the radius to maximum center to end indicated in the table.

Thickness must be specified by the purchaser.
When specified by the purchaser, welds will be X-rayed and made to comply with Paragraph U-68 of 1939 ASME Code.

Figure 3. Two-Piece Welded Wrought Bend from Taylor Forge Catalog 401

The Paragraph U-68 reference is to a paragraph in the ASME Boiler and Pressure Vessel Code establishing joint efficiency factors for seams subject to the full hoop stress depending on the extent of inspection by radiography. A photograph in a Taylor Forge pipe catalog of the same year, reproduced in Figure 4, shows a 30-inch OD bend with two fusion-welded seams.[21] The caption notes that the seams were radiographed. The appearance of this photo in a 1940 catalog implies that it was manufactured sometime in the late 1930’s.

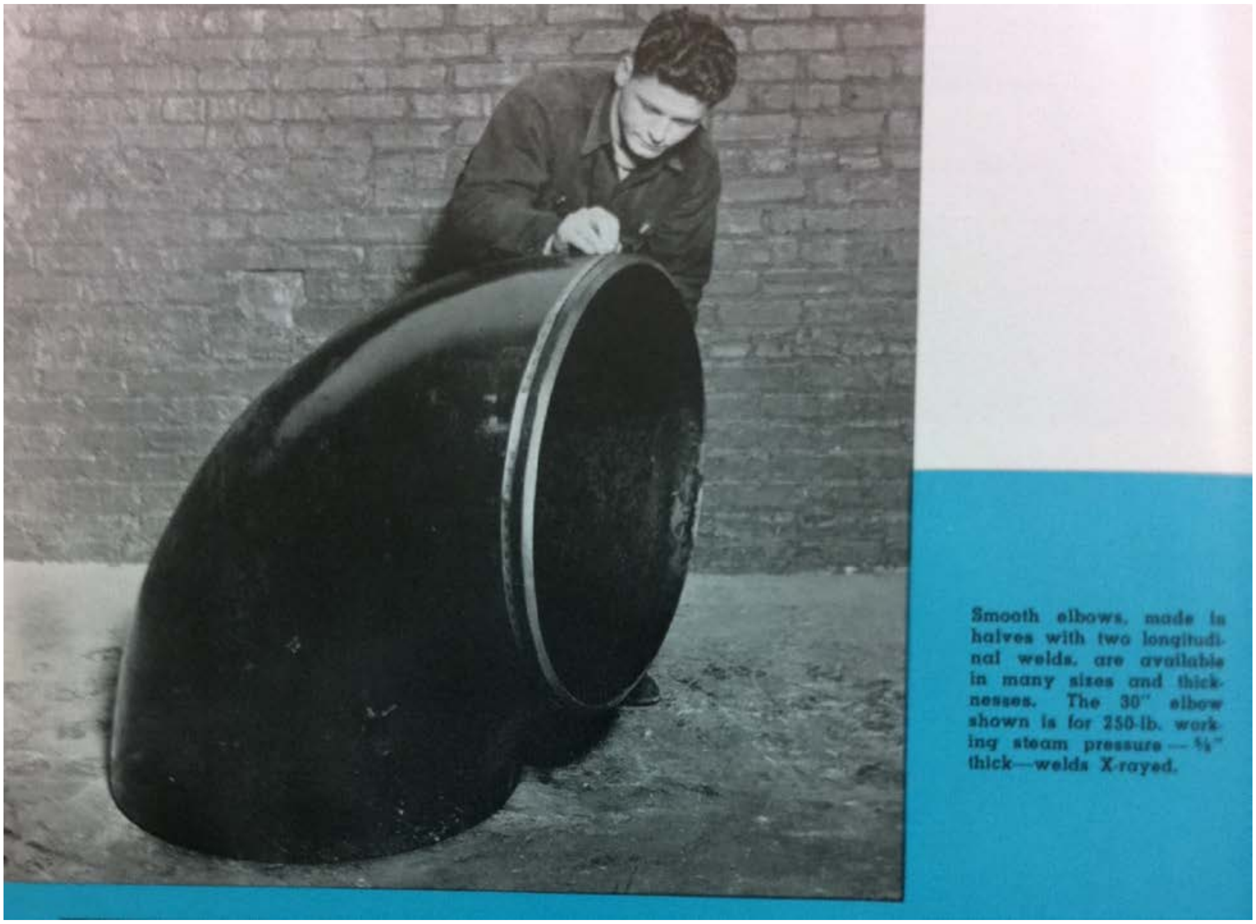


Figure 4. Two-Piece 30-inch OD Elbow, from Taylor Forge Catalog 404

A similar statement regarding radiography of long seams as the one given in Catalog 401 also appears in the 1948 Catalog 484, but an additional note appears indicating that the material is ASTM A234, Grade B.[22] Catalog 484 also shows a railcar load of 30-inch 180-degree bends that will be cut up in the field into small-angle bends, reproduced here inFigure 5. These are what are referred to as segmentable bends today.

[21] Taylor Forge & Pipe Works, Catalog 404, 1940.
[22] Taylor Forge & Pipe Works, Catalog 484, 1948.

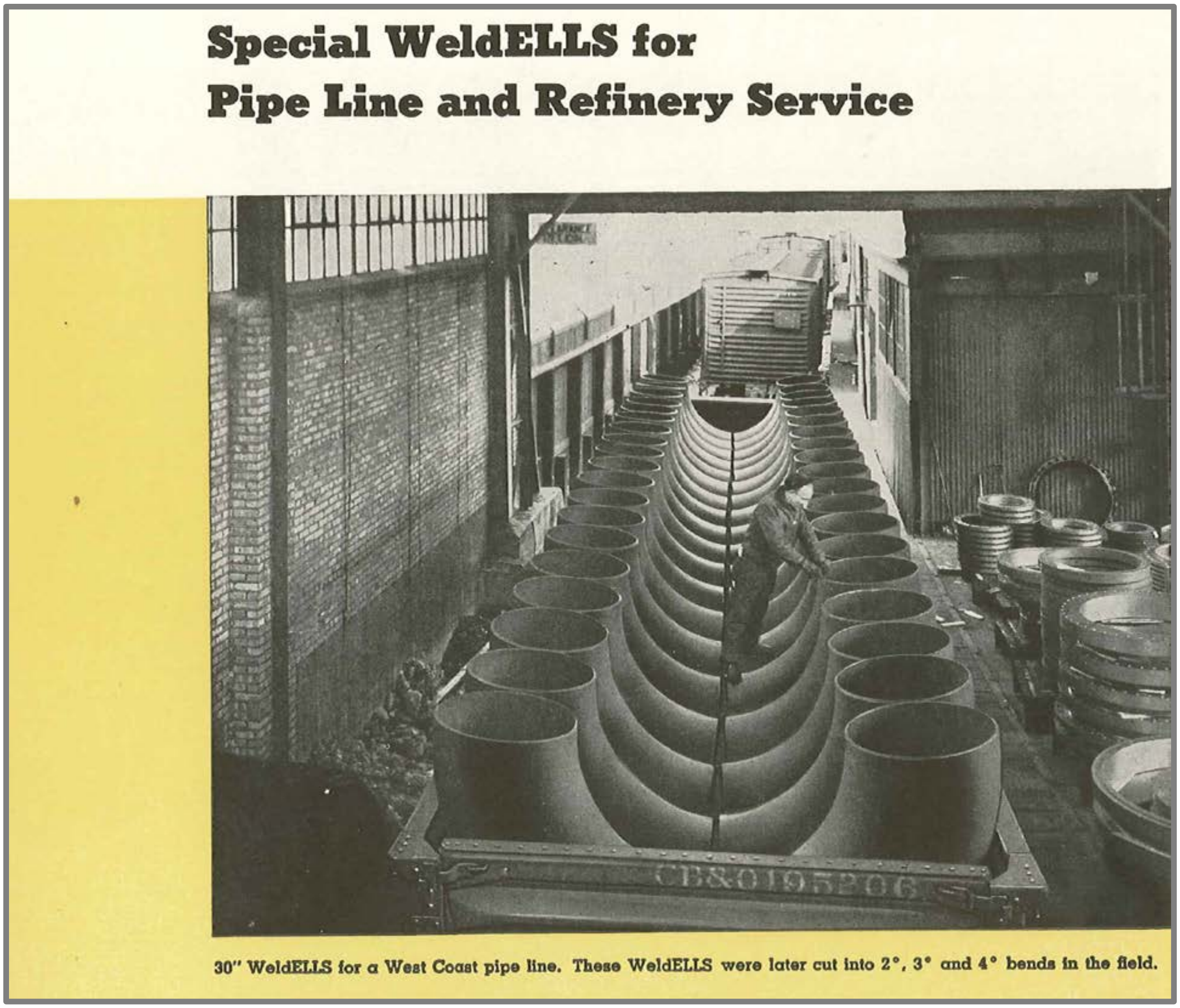


Figure 5. Segmentable 30-inch OD Bends for Gas Pipelines, Taylor Forge Catalog 484

Crane Company

Crane Company manufactured a range of piping fittings, flanges, and valves. A review of product literature[23,24] indicates that through the 1930's and into the 1940's, Crane only offered seamless style fittings.

Other Manufacturers

Other companies manufactured factory bends in the 1930's through 1960's, including Grinnell, Bonney Forge, and probably others not identified. No company-specific standards from those manufacturers for the time period of interest were available for

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[23] Crane Company, Catalog 31, 1931.
[24] Crane Company, Catalog 39, 1939.

review. Incidental references along with a review of a more modern Grinnell catalog imply that Grinnell may have manufactured only seamless carbon steel fittings through NPS 16 during the period of interest. With any manufacturer, it is likely that practices would have been followed so as to enable their products to be sold without a derating for any seam present, because to do otherwise would have put them at a competitive disadvantage.

Summary

Industry standards for factory-made bends, as well as industry practices typified by company standards, required that the geometric design of factory-made bends be proven to equal or exceed the strength of matching seamless pipe through a prototype burst test. Such requirements date to 1940 and primarily covered forged, seamless, Grade A and B carbon steel fittings through NPS 24. By the mid-1950's standards were developed to cover larger sizes (26-inch OD and up) and higher strength grades (42-ksi SMYS and up). They further required that where seams were present, the seams must be subjected to strength testing on a sampling basis and each seam must be radiographed to demonstrate equivalence to a seamless component.

The standards reflected what was already widely practiced by manufacturers. Some manufacturers were producing bends and other fittings in sizes larger than 24-inch OD with seams, and radiographing the seams, by around 1940, although seamless fittings were the rule for 24-inch OD and smaller.

Some manufacturers were producing large diameter pipeline bends prior to 1940, mainly by bending pipe or tubular product which might incorporate a seam according to the prevalent methods of making seamed cylinders, e.g. forged lap-welded or hammer-welded seams, or early submerged-arc welded seams. The production of pipe with such seams preceded the Joint Efficiency Factor concept. The seams in the bends would have been of the same quality as the seams in straight pipe of similar construction.

A summary of the wrought product descriptions from commercial literature that was reviewed for this study is given in Table 2.

Table 2. Vintage Manufacturer Product Descriptions

Mfr.	Catalog	Year	Size (in.)	Material	Comment
Tube Turns	211	1952	To 30 OD	A234 A/B	Seamless Standard, XS, XXS
			To 24 OD	A234 A/B	Lightweight gage, seamless to NPS 10, ERW NPS 12-24
	311	1954	To 24 OD	A234 A/B	Lightweight, Sch 10, does not discuss seams
			To 42 OD	A234 A/B, WPY42-WPY52, MSS SP63	Seamless through 24 OD, 30-42 OD from rolled cylinder, seam weld RT
			To 24 OD	A234 A/B, WPY42-WPY52, MSS SP63	Tees, 20 OD and larger with one seam, weld RT
Crane	31	1931	To 24 OD	Grade A	Seamless, sizes larger than NPS 12 made to order
	39	1939	To 24 OD	Grade A standard, Grade B to order	Seamless, sizes larger than NPS 12 made to order
Taylor Forge	31	1931	All	A78 Grade A/B	Seamless under 16 OD, hammer welded seams and flanged larger sizes
	401, 423	1940, 1942	To 24 OD	A234 A/B	Seamless
			24-36 OD	Carbon steel	Two-piece fusion welded, RT by request
			To 30 OD	Carbon steel	Reducers 26 OD and larger either lap welded or fusion welded
	484	1948	To 24 OD	A234 A/B	Seamless Standard, XS, XXS
			To 24 OD	A234 A/B	Light wall, Schedule 10, may have seam, does not discuss RT
			To 24 OD	A234 A/B	Tees, 24 OD with one seam, weld RT
			22-38 OD	A234 Grade B	Two-piece fusion welded, RT by request
Grinnell	n/a	1940	To 16 OD	A234 A/B	Seamless
Ladish	55	1955	To 36 OD	A234 A/B	Seamless Standard, XS, XXS, anecdotal report of welded seams with RT
			To 36 OD	A234 A/B	Tees, 22 OD with one seam, weld SR and RT
			To 36 OD	A234 A/B	Reducers 26 OD and larger either lap welded or fusion welded

In Table 2 above, all entries refer to wrought bends or elbows unless stated otherwise. Wrought tees and reducers are listed where the product catalog mentions longitudinal seams (with or without radiographic inspection), which is taken as evidence that the manufacturer produced fittings with seams.

Based on a review of standards and manufacturing practices, Table 3 below summarizes the most probable construction for in-line fittings, particularly bends or elbows.

Table 3. Fittings Construction by Era

Size, NPS	Pre-1930	1930-1939	1940-1949	1950 and later
Through 12	Seamless or forge welded	Seamless	Seamless	Seamless
>12 through 16	Forge welded	Seamless or forge welded	Seamless	Seamless
>16 through 24	Forge welded	Seamless or forge welded	Seamless	Seamless
Larger than 24	Not common	Forge welded or fusion welded	Fusion welded, possibly radiographed	Fusion welded, radiographed

"Forge welded" as used above refers to either lap-welded or hammer-welded. "Fusion welded" refers to electric arc welding either by submerged-arc or shielded metal-arc process. The Joint Efficiency Factor in seamless and radiographed fusion welds should be taken as equal to 1. From 1950 and later, such welds in wrought fittings were highly likely to have been radiographed. Between 1940 and 1950 they would have been radiographed if they were so ordered, and possibly so in any case. Prior to 1940, the seams were either forge welded or were fusion welded, but either way were probably not radiographed.