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LOKRING® TECHNOLOGY LLC

A Guideline for Designing ASME B31 Pressure Piping Using Lokring™ Fittings with Elastic Strain Preload® (ESP®) Technology

For Lokring Product Lines:

- Stainless Steel (SS40)
- Microalloyed Steel (MAS-3000)
- 4130 Alloy Steel (LTCS-333)

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TABLES

Note: The following methodology is presented for the Lokring Elastic Strain Preload (ESP®) Series SS40 stainless steel, Series MAS-3000 microalloyed steel and Series LTCS-333 4130 alloy steel fittings (e.g., couplings, tees, elbows, reducers, and flanges). For other Lokring fittings made from different materials, the method will remain the same but some specific material dependent values such as temperature limits, pipe materials to be used with the fitting, pressure capabilities, or installed span tables will vary.

By publication of the following rules, Lokring does not assume any liability for the safe design of ASME B31 *Code for Pressure Piping* (B31) systems. Responsibility for such is the sole responsibility of the user. The user is cautioned that the B31 system design, including the evaluation of unusual loads (other than pressure, weight, and thermal expansion), should be performed by, or under the supervision of, someone experienced in the design of the applicable B31 application.

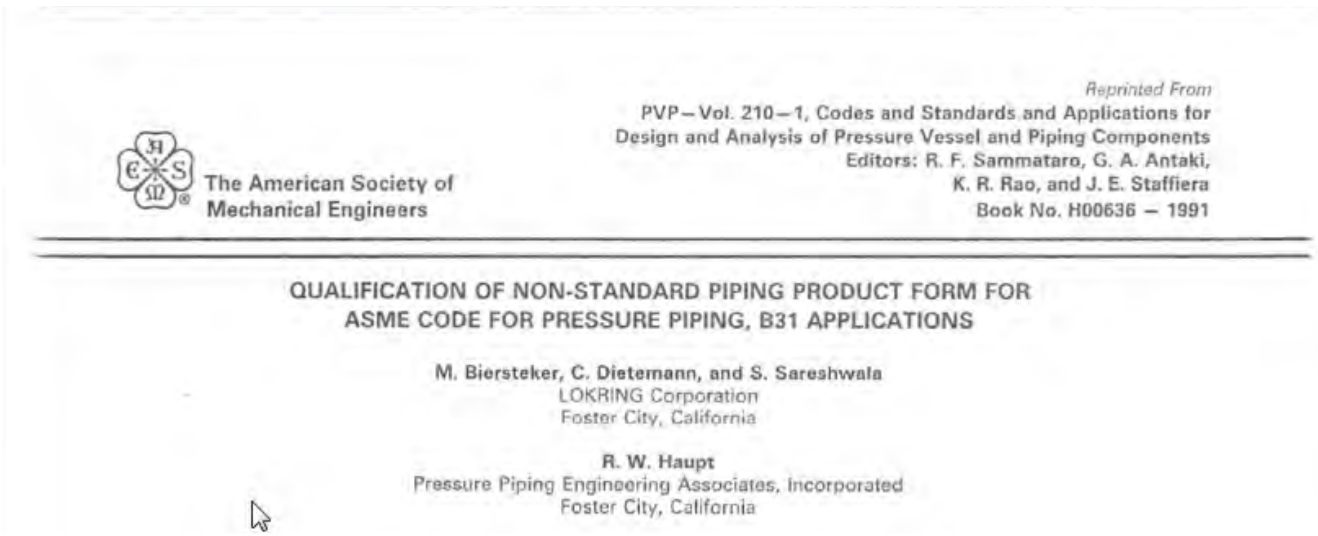
Contact Us

If you have any questions regarding this document or need assistance with your application, please contact your authorized Lokring representative.

The Qualification of Lokring Fittings

Additional information regarding the qualification of the Lokring fitting to ASME B31 and other piping applications is available upon request. The following reference may also be of help:

> M. Biersteker, C. Dietemann, S. Sareshwala, and R. Haupt, "QUALIFICATION OF NON-STANDARD PIPING PRODUCT FORM FOR ASME CODE FOR PRESSURE PIPING, B31 APPLICATIONS" ASME PVP – Vol. 210, Codes and Standards and Applications for Design and Analysis of Pressure Vessel and Piping Components, Book No. H00636 – 1991



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QUALIFICATION OF NON-STANDARD PIPING PRODUCT FORM FOR ASME CODE FOR PRESSURE PIPING, B31 APPLICATIONS

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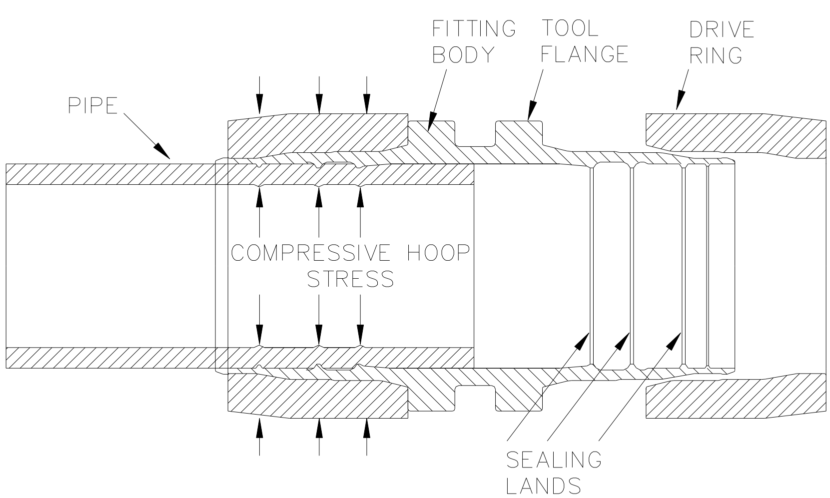
1.0 Introduction

ASME B31 *Code for Pressure Piping* (B31) provides simplified requirements for the safe design of various pressure piping system applications. The Sections of the B31 *Code for Pressure Piping* include the requirements for the following: *Power Piping* (B31.1), *Process Piping* (B31.3), *Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids* (B31.4), *Refrigeration Piping and Heat Transfer Components* (B31.5), *Gas Transportation and Distribution Piping Systems* (B31.8), and *Building Services Piping* (B31.9). The B31 simplified requirements were developed with and retain a focus on high-pressure, high-temperature piping which is typically welded or flanged. ASME B31 simplified rules are not developed as thoroughly regarding the design, manufacture, and installation of safe piping systems using non-welded, proprietary fittings (nonstandard components), such as the Lokring™ fitting with Elastic Strain Preload® (ESP®) technology. However, there are B31 rules developed for pressure design and the development of stress multipliers (stress intensification factors) for nonstandard components that will allow the organization using Lokring fittings to develop a B31-compliant design.

Lokring fittings use a patented, Elastic Strain Preload (ESP) technology to permanently join small diameter pipe (NPS 1/4 to NPS 4) and tube (1/4 to 2 1/2 inch OD) without threading or welding. Following insertion of the pipe end into the fitting, hydraulic tooling is used to advance each drive ring axially over the fitting body, radially compressing (swaging) the fitting body on to the outside diameter (OD) of the pipe. As the pipe is compressed, first elastically and then plastically, by the swaging action during installation, circumferential sealing lands machined in the bore of the fitting body grip and seal on the pipe OD, forming a gas-tight, metal-to-metal seal without O-rings or other elastomeric seals. Figure 1.0 below shows the sealing lands on the coupling fitting body inside surface indenting the pipe OD.

Figure 1.0: Installed and Sectioned Fitting/Pipe



Lokring SS40 stainless steel straight couplings (Figure 1.0) are designed with a "thru-bore" feature that permits the coupling to be installed by sliding the fitting onto the pipe past the pipe cut and drawing the fitting back over the cut, centering the fitting on the cut before swaging. This design attribute facilitates the repair of existing piping.

The Lokring MAS-3000 microalloyed steel LTCS-333 4130 alloy steel fittings (sizes up to 3 inch NPS) have a center stop, which contributes to the positioning of the fitting body on the pipe during assembly. For further details on product features, refer to product catalogues and Lokring website at www.lokring.com

The rules that follow are provided to assist the Lokring user in the construction of safe piping systems that meet the requirements of ASME B31 *Code for Pressure Piping* for above ground applications and, in particular, the requirements of ASME B31.1 *Power Piping (except for Boiler External Piping)*, ASME B31.3 *Process Piping (for Normal Service piping)*, B31.5 Refrigeration Piping and Heat Transfer Components, and B31.9 *Building Services Piping*. These rules are not applicable to buried piping, which are the principal concerns of B31.4 *Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids* and B31.8 *Gas Transmission and Distribution Piping Systems*. However, the rules below may be applied for the above ground portions of B31.4 and B31.8 piping with the understanding that supplementary requirements specific to the application may be necessary to consider to ensure safe piping systems. Further, the rules are not limited to B31 applications and could be used and adapted as necessary for other piping system applications.

Safe Selection Guide

When selecting Lokring fittings for use in any application, total system design must be considered to ensure safe, trouble free performance. Material compatibility, system pressure and temperature ratings, adequate corrosion control or allowances, control of fluid velocities, fluid chemical treatment, proper installation, operation, maintenance, and overall system safety are the responsibility of the system designer, owner, and operator.

2.0 General

In the designing of B31 piping, after selection of materials, then the design for pressure, weight, and thermal expansion effects is performed. Pressure and weight loads produce sustained stresses; thermal expansion loads; usually evaluated from ambient to operating temperatures, produce displacement stresses. The B31 rules for pressure and weight design guard against pipe rupture or collapse; the B31 rules for thermal expansion design guard against fatigue failure. On occasion, other load producing stresses may need to be evaluated, but experience has shown that evaluating pressure, weight, and thermal expansion effects may be sufficient for the application, particularly for small piping, the sizes that are typically joined by Lokring fittings.

Evaluating pressure, weight, and thermal expansion effects is usually done in three steps:

1. Pressure design—done by either a calculation or testing
2. Thermal expansion design—typically done by a calculation, often referred to as performing a flexibility analysis
3. Weight design—done by either a calculation or use of span tables

For a variety of operating considerations, the design pressures and temperatures and the normal operating pressures and temperatures of the majority of piping systems are not the same. Thus, the sustained (pressure plus weight) and thermal expansion (flexibility) analyses may not be performed with the same pressures and temperatures that would be used for the pressure design. The determination of the wall thickness (the pressure design) is always performed with the design pressure and temperature, but the sustained (pressure plus weight) analysis and the thermal expansion (flexibility) analysis may be performed using the normal operating pressures and temperatures rather than the design pressure and temperature.

In these recommended design rules and guidelines, both U.S. Customary and SI (metric) units are given. The work to develop the rules and guidelines was performed using U.S. Customary units and then transformed to SI (metric) units. The multipliers used are:

For pressures and stresses, multiply pound per square inch (psi) by 0.006895 to get megapascal (MPa).
For lengths, multiply inch (in.) by 25.4 to get millimeter (mm).
For lengths, multiply foot (ft) by 0.3048 to get meter (m).
For forces, multiply pound (lb) by 0.4536 to get kilogram (kg).

3.0 Materials

3.1 The Lokring Stainless Steel (SS40) Product Line

The Lokring stainless steel Series SS40 fitting is manufactured using ASTM A276 and A479 TP316 stainless steel material made from barstock and mechanical tubing conforming to Lokring material specifications. SS40 fittings are designed for use with the materials listed in Table 3.1, except as noted:

Table 3.1: Lokring Series SS40 Fittings are Designed for Use with the Following Pipe Materials

• ASTM A-312 TP 304 ①	• ASTM A-53 Grades A and B Seamless ③④
• ASTM A-312 TP 304L ①	• ASTM A-53 Grades A and B Welded ②③④
• ASTM A-312 TP 316 ①	• ASTM A-106 Grades A, B, and C ③④
• ASTM A-312 TP 316L ①	• ASTM A-587 Welded ②③④

① Lokring Series SS40 is limited in high-temperature services to 800 °F (426 °C) and low-temperature services to the low-temperature limits of the applicable B31 Code. In B31.3 services, Lokring Series SS40 may be used in services to −425 °F (−254 °C) when joining ASTM A-312 Grades TP 304L, TP304, TP316L, and TP 316 pipe. However, if special fittings having welds are used, services are limited to −150 °F (−101 °C).
② Special installation provisions apply for ERW pipe. See Lokring Installation Guide LP-105 for further instructions on pipe selection and preparation for proper installation.
③ On ASTM A53 Grade A, A106 Grade A, or A 587 pipe, multiply the listed pressure-temperature ratings by 0.80.
④ Lokring Series SS40 is limited in high-temperature services to 650 °F (343 °C) maximum when joining carbon steel pipe.

3.2 The Lokring Microalloyed Steel (MAS-3000) Product Line

The Lokring microalloyed steel Series MAS-3000 fitting is manufactured using 15V24 microalloyed steel bar or drawn-over-mandrel, stress relieved, microalloyed steel mechanical tubing. Bar stock material conforms to ASTM A675 and the chemical and mechanical properties conform to Lokring material specifications. Mechanical tube stock material conforms to ASTM A513/DIN 2393 Grade ST 52.3 with chemical and mechanical properties conforming to Lokring material specifications. MAS-3000 fittings are designed for use with the materials listed in Table 3.2, except as noted:

Table 3.2: Series MAS-3000 Fittings are Designed for Use with the Following Pipe Materials

• ASTM A-53 Grades A and B Seamless ①③	• ASTM A-106 Grades A, B, and C ①③
• ASTM A-53 Grades A and B Welded ①②③	• ASTM A-587 Welded ①②③

① Lokring Series MAS-3000 is limited in high-temperature services to 650 °F (343 °C) and in low-temperature services to −20 °F (−29 °C).
② Special installation provisions apply for ERW pipe. See Lokring Installation Guide LP-105 for further instructions on pipe selection and preparation for proper installation.
③ On ASTM A53 Grade A, A106 Grade A, or A 587 pipe, multiply the listed pressure-temperature ratings by 0.80.

3.3 The Lokring 4130 Alloy Steel (LTCS-333) Product Line-

The Lokring 4130 Alloy Steel Series, LTCS-333, fitting is manufactured using low alloy normalized, quenched and tempered microalloyed steel bar, mechanical tubing, and forgings. The material conforms to one or more of the following specifications:

- ASTM A519 Grade 4130
- E4130 HR Norm Q&T Bar according to API 6A PSL3
- API 5CT Grade L80 Type 1 (or) API 5L X80
- ASTM A322 Grade 4130 (UNS G41300)

LTCS-333 fittings may be used to join the materials listed in Table 3.3 without adjustment of the Lokring capacities, except as noted:

Table 3.3: Lokring Series LTCS-333 Fittings are Designed for Use with the Following Pipe Materials

• ASTM A-53 Grades A and B Seamless ①③	• ASTM A-587 Welded ①②③
• ASTM A-53 Grades A and B Welded ①②③	• ASTM A-333 Grades 1 and 6 ①③
• ASTM A-106 Grades A, B, and C ①③	• API 5L Grade B ①

① Lokring Series LTCS-333 is limited in high-temperature services to 800 °F (426 °C) and in low-temperature services to −50 °F (−46 °C).
② Special installation provisions apply for ERW pipe. See Lokring Installation Guide LP-105 for further instructions on pipe selection and preparation for proper installation.
③ On ASTM A53 Grade A, A106 Grade A, A 587, or A333 Grade 1, multiply the listed pressure-temperature ratings by 0.80.

The Lokring Series SS40, MAS-3000, and LTCS-333 fittings are also designed to join materials similar to the materials shown. The Lokring user is responsible for determining whether the materials used, other than those listed, are appropriate. Further, if the material is unlisted in the applicable B31 code, the Lokring user is responsible for determining the material capabilities in accordance with the applicable B31 code. If you have questions about the use of Lokring products, please contact your Lokring representative or go to www.lokring.com for assistance.

3.4 Material Traceability

Lokring fittings have unique “LOK” or production-work-order numbers that are stamped onto each machined component as part of the manufacturing process. These part-marking identifications allow for the traceability of a manufactured part back to the material test reports (documenting the physical and chemical properties of the material) as well as to the manufacturing process. All butt-welding fittings and flanges are received with a unique heat number marked on the fitting. The material test reports are on file at the Lokring headquarters facility.

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4.0 Pressure Design

4.1 Pressure Design of Piping

To meet B31 Section code pressure requirements the design wall thickness, t_m, for the given size piping must be determined. Eq. 4.2 is the equation used by both B31.1 and B31.3 (although the nomenclature differs). In addition, after determining the design wall thickness, t_m, the wall thickness must be increased by an amount sufficient to provide for the manufacturing tolerance allowed in the applicable pipe specification (normally 12.5 %).

$$t_m = \frac{PD}{2(SE + 0.4P)} + A \qquad \text{(Eq. 4.1)}$$

where:

t_m	=	Required B31 Section code pressure design wall thickness, inch (mm)
P	=	Design pressure, psi (MPa)
D	=	Outside diameter of matching pipe, inch (mm)
S	=	Allowable stress from the appropriate B31 Section code at the Design Temperature, psi (MPa)
E	=	Piping weld joint efficiency factor from the appropriate B31 Section code
A	=	Additional thickness to provide for corrosion or erosion or for mechanical strength of the pipe, inch (mm)

Note: The B31 Section code-pressure-design equation includes an equation transition factor, y, which is equal to 0.4, within the permitted operating limits of the Lokring fitting as explicitly shown in the denominator of Eq. 4.1. In addition, the code pressure design equation has a piping weld joint strength reduction factor, W, that is equal to 1.0 within the permitted operating limits of the Lokring fitting but is not included in Eq. 4.1.

4.2 Pressure Design of Lokring Fittings

The maximum design pressures given in this section are for the Lokring fittings, and not for the pipe joined by the fitting. The Lokring user must determine whether the fittings are acceptable according to B31 rules. The pipe itself must be designed in accordance with the pressure design rules of the appropriate B31 Section code (see Section 4.1). Further, the maximum design pressures listed for the Lokring fittings exclude consideration of any effects of corrosion or erosion. The Lokring user is responsible for determining if corrosion or erosion effects are such that they may affect pressure design.

4.2.1 Lokring Stainless Steel, SS40, Design Pressure Ratings

The Lokring stainless steel Series SS40 maximum design pressures for the listed fitting sizes and temperatures are given in Table 4.2.1-1: SS40-10, for use of the Lokring fitting with schedule 10 or 10S pipe; Table 4.2.1-2: SS40-40, for use of the Lokring fitting with schedule 40 or 40S pipe; and Table 4.2.1-3: SS40-80, for use of the Lokring fitting with schedule 80 or 80S pipe. These pressures were developed in accordance with the applicable B31 code requirements for nonstandard components and, in particular, the proof test methodology as is soon to be published in *B31H, Standard Method to Establish Maximum Allowable Pressure for Piping Components by Testing*.

Table 4.2.1-1: Stainless Steel Pipe, Schedule 10 or 10S, SS40-10

		B31.X Maximum Design Pressure, psi (MPa) on Schedule 10 or 10S Pipe ①②					
Fitting Size NPS (DN)	Pipe Schedule	Min. Temp. to 300 °F (148 °C)	400 °F (204 °C)	500 °F (260 °C)	600 °F (315 °C)	700 °F (371 °C)	800 °F (426 °C)
1/4 (8)	10 or 10S	5320 (36.6)	5140 (35.4)	4600 (31.7)	3910 (26.9)	3180 (21.9)	2530 (17.4)
3/8 (10)	10 or 10S	4170 (28.7)	4020 (27.7)	3600 (24.8)	3060 (21.0)	2490 (17.1)	1980 (13.6)
1/2 (15)	10 or 10S	4290 (29.5)	4140 (28.5)	3700 (25.5)	3140 (21.6)	2560 (17.6)	2040 (14.0)
3/4 (20)	10 or 10S	3370 (23.2)	3250 (22.4)	2910 (20.0)	2470 (17.0)	2010 (13.8)	1600 (11.0)
1 (25)	10 or 10S	3550 (24.4)	3420 (23.5)	3060 (21.0)	2600 (17.9)	2120 (14.6)	1680 (11.5)
1-1/4 (32)	10 or 10S	2520 (17.3)	2430 (16.7)	2180 (15.0)	1850 (12.7)	1510 (10.4)	1200 (8.2)
1-1/2 (40)	10 or 10S	2400 (16.5)	2310 (15.9)	2070 (14.2)	1760 (12.1)	1430 (9.8)	1140 (7.8)
2 (50)	10 or 10S	1900 (13.1)	1830 (12.6)	1640 (11.3)	1390 (9.5)	1130 (7.7)	900 (6.2)
3 (80)	10 or 10S	1400 (9.6)	1350 (9.3)	1210 (8.3)	1030 (7.1)	840 (5.7)	660 (4.5)

① Design pressure may be interpolated between temperature values.

② Lokring Series SS-3300 or "-XR" fitting products that are subjected to 100 % radiographic examination can be specified for B31.3 applications at temperatures equal to or greater than 750 °F (400 °C).

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4.2.1 Lokring Stainless Steel, SS40, Design Pressure Ratings (cont.)

Table 4.2.1-2: Stainless Steel Pipe, Schedule 40, SS40-40

		B31.X Maximum Design Pressure, psi (MPa) on Schedule 40 Pipe ①②					
Fitting Size NPS (DN)	Pipe Schedule	Min. Temp. to 300 °F (148 °C)	400 °F (204 °C)	500 °F (260 °C)	600 °F (315 °C)	700 °F (371 °C)	800 °F (426 °C)
1/4 (8)	40 or 40S	7490 (51.6)	7230 (49.8)	6470 (44.6)	5500 (37.9)	4480 (30.8)	3560 (24.5)
3/8 (10)	40 or 40S	5690 (39.2)	5490 (37.8)	4910 (33.8)	4170 (28.7)	3400 (23.4)	2700 (18.6)
1/2 (15)	40 or 40S	5370 (37.0)	5180 (35.7)	4640 (31.9)	3940 (27.1)	3210 (22.1)	2550 (17.5)
3/4 (20)	40 or 40S	4700 (32.4)	4540 (31.3)	4060 (27.9)	3450 (23.7)	2810 (19.3)	2230 (15.3)
1 (25)	40 or 40S	3660 (25.2)	3530 (24.3)	3160 (21.7)	2690 (18.5)	2190 (15.0)	1740 (11.9)
1-1/4 (32)	40 or 40S	2870 (19.7)	2770 (19.0)	2480 (17.0)	2100 (14.4)	1710 (11.7)	1360 (9.3)
1-1/2 (40)	40 or 40S	3040 (20.9)	2930 (20.2)	2620 (18.0)	2230 (15.3)	1810 (12.4)	1440 (9.9)
2 (50)	40 or 40S	2160 (14.8)	2090 (14.4)	1870 (12.8)	1590 (10.9)	1290 (8.8)	1030 (7.1)
3 (80)	40 or 40S	2590 (17.8)	2500 (17.2)	2240 (15.4)	1900 (13.1)	1550 (10.6)	1230 (8.4)

① Design pressure may be interpolated between temperature values.

② Lokring Series SS-3300 or "-XR" fitting products that are subjected to 100 % radiographic examination can be specified for B31.3 applications at temperatures equal to or greater than 750 °F (400 °C).

Table 4.2.1-3: Stainless Steel Pipe, Schedule 80, SS40-80

		B31.X Maximum Design Pressure, psi (MPa) on Schedule 80 Pipe ①②					
Fitting Size NPS (DN)	Pipe Schedule	Min. Temp. to 300 °F (148 °C)	400 °F (204 °C)	500 °F (260 °C)	600 °F (315 °C)	700 °F (371 °C)	800 °F (426 °C)
1/4 (8)	80 or 80S	7930 (54.6)	7650 (52.7)	6850 (47.2)	5820 (40.1)	4740 (32.6)	3770 (25.9)
3/8 (10)	80 or 80S	6100 (42.0)	5880 (40.5)	5260 (36.2)	4470 (30.8)	3640 (25.0)	2900 (19.9)
1/2 (15)	80 or 80S	5690 (39.2)	5490 (37.8)	4920 (33.9)	4180 (28.8)	3400 (23.4)	2700 (18.6)
3/4 (20)	80 or 80S	5450 (37.5)	5260 (36.2)	4700 (32.4)	4000 (27.5)	3260 (22.4)	2590 (17.8)
1 (25)	80 or 80S	4050 (27.9)	3910 (26.9)	3500 (24.1)	2970 (20.4)	2420 (16.6)	1920 (13.2)
1-1/4 (32)	80 or 80S	2750 (18.9)	2660 (18.3)	2380 (16.4)	2020 (13.9)	1640 (11.3)	1310 (9.0)
1-1/2 (40)	80 or 80S	2700 (18.6)	2600 (17.9)	2330 (16.0)	1980 (13.6)	1610 (11.1)	1280 (8.8)
2 (50)	80 or 80S	2160 (14.8)	2090 (14.4)	1870 (12.8)	1590 (10.9)	1290 (8.8)	1030 (7.1)
3 (80)	80 or 80S	2540 (17.5)	2450 (16.8)	2190 (15.0)	1860 (12.8)	1520 (10.4)	1200 (8.2)

① Design pressure may be interpolated between temperature values.

② Lokring Series SS-3300 or "-XR" fitting products that are subjected to 100 % radiographic examination can be specified for B31.3 applications at temperatures equal to or greater than 750 °F (400 °C).

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4.2.2 Lokring Microalloyed Steel, MAS-3000, Design Pressure Ratings

The Lokring microalloyed steel Series MAS-3000 maximum design pressures for the listed fitting sizes and temperatures are given in Table 4.2.2-1: MAS-3000-40, for use of the Lokring fitting with schedule 40 pipe; Table 4.2.2-2: MAS-3000-80, for use of the Lokring fitting with schedule 80 pipe; and Table 4.2.2-3: MAS-3000-160, for use of the Lokring fitting with schedule 160 pipe. These pressures were determined in accordance with the applicable B31 code requirements for nonstandard components and, in particular, the proof test methodology as is soon to be published in *B31H, Standard Method to Establish Maximum Allowable Pressure for Piping Components by Testing*.

Table 4.2.2-1: Carbon Steel Pipe, Schedule 40, MAS-3000-40

		B31.X Maximum Design Pressure, psi (MPa) ①							
Fitting Size NPS (DN)	Pipe Schedule	Min. Temp. to 400 °F (204 °C)		500 °F (260 °C)		600 °F (315 °C)		650 °F (343 °C)	
1/4 (8)	40	6280	(43.2)	5940	(40.9)	5140	(35.4)	3860	(26.6)
3/8 (10)	40	5020	(34.6)	4740	(32.6)	4100	(28.2)	3080	(21.2)
1/2 (15)	40	4480	(30.8)	4240	(29.2)	3660	(25.2)	2750	(18.9)
3/4 (20)	40	3600	(24.8)	3400	(23.4)	2940	(20.2)	2210	(15.2)
1 (25)	40	3060	(21.0)	2890	(19.9)	2500	(17.2)	1870	(12.8)
1-1/4 (32)	40	3300	(22.7)	3120	(21.5)	2690	(18.5)	2020	(13.9)
1-1/2 (40)	40	2680	(18.4)	2540	(17.5)	2190	(15.0)	1650	(11.3)
2 (50)	40	2620	(18.0)	2470	(17.0)	2140	(14.7)	1600	(11.0)
2-1/2 (65)	40	2290	(15.7)	2160	(14.8)	1870	(12.8)	1400	(9.6)
3 (80)	40	3150	(21.7)	2980	(20.5)	2570	(17.7)	1930	(13.3)
4 (100)	40	1680	(11.5)	1580	(10.8)	1370	(9.4)	1030	(7.1)

①Design pressure may be interpolated between temperature values.

4.2.2 Lokring Microalloyed Steel, MAS-3000, Design Pressure Ratings (cont.)

Table 4.2.2-2: Carbon Steel Pipe, Schedule 80, MAS-3000-80

		B31.X Maximum Design Pressure, psi (MPa) ①							
Fitting Size NPS (DN)	Pipe Schedule	Min. Temp. to 400 °F (204 °C)		500 °F (260 °C)		600 °F (315 °C)		650 °F (343 °C)	
1/4 (8)	80	8520	(58.7)	8050	(55.5)	6960	(47.9)	5230	(36.0)
3/8 (10)	80	6510	(44.8)	6150	(42.4)	5320	(36.6)	4000	(27.5)
1/2 (15)	80	6620	(45.6)	6250	(43.0)	5410	(37.3)	4060	(27.9)
3/4 (20)	80	4550	(31.3)	4300	(29.6)	3720	(25.6)	2790	(19.2)
1 (25)	80	4590	(31.6)	4330	(29.8)	3750	(25.8)	2810	(19.3)
1-1/4 (32)	80	3950	(27.2)	3730	(25.7)	3230	(22.2)	2420	(16.6)
1-1/2 (40)	80	3160	(21.7)	2990	(20.6)	2580	(17.7)	1940	(13.3)
2 (50)	80	2710	(18.6)	2560	(17.6)	2210	(15.2)	1660	(11.4)
2-1/2 (65)	80	2540	(17.5)	2400	(16.5)	2080	(14.3)	1560	(10.7)
3 (80)	80	2630	(18.1)	2480	(17.0)	2150	(14.8)	1610	(11.1)
4 (100)	80	2240	(15.4)	2110	(14.5)	1830	(12.6)	1370	(9.4)

①Design pressure may be interpolated between temperature values.

Table 4.2.2-3: Carbon Steel Pipe, Schedule 160, MAS-3000-160

		B31.X Maximum Design Pressure, psi (MPa) ①							
Fitting Size NPS (DN)	Pipe Schedule	Min. Temp. to 400 °F (204 °C)		500 °F (260 °C)		600 °F (315 °C)		650 °F (343 °C)	
1/2 (15)	160	6370	(43.9)	6020	(41.5)	5210	(35.9)	3910	(26.9)
3/4 (20)	160	4650	(32.0)	4400	(30.3)	3800	(26.2)	2850	(19.6)
1 (25)	160	3730	(25.7)	3530	(24.3)	3050	(21.0)	2290	(15.7)

①Design pressure may be interpolated between temperature values.

4.2.3 Lokring 4130 Alloy Steel, LTCS-333, Design Pressure Ratings

The Lokring Series LTCS-333 maximum design pressures for the listed fitting sizes and temperatures are given in Table 4.2.3-1: LTCS-333-40, for use of the Lokring fitting with schedule 40 pipe; Table 4.2.3-2: LTCS-333-80, for use of the Lokring fitting with schedule 80 pipe; Table 4.2.3-3: LTCS-333-160, for use of the Lokring fitting with schedule 160 pipe and Table 4.2.3-4: LTCS-333-XXS, for use of the Lokring fitting with schedule XXS pipe. These pressures were determined in accordance with the applicable B31 code requirements for nonstandard components and, in particular, the proof test methodology as is soon to be published in *B31H, Standard Method to Establish Maximum Allowable Pressure for Piping Components by Testing*.

Table 4.2.3-1: 4130 Alloy Steel, Schedule 40, LTCS-333-40

		B31.X Maximum Design Pressure, psi (MPa) ①							
Fitting Size NPS (DN)	Pipe Schedule	Min. Temp. to 150 °F(65 °C)		200 to 650 °F (93 to 343 °C)		700 °F (371 °C)		800 °F (426 °C)	
1/2 (15)	40	4900	(33.7)	4802	(33.1)	4753	(32.7)	4263	(29.3)
3/4 (20)	40	4050	(27.9)	3969	(27.3)	3929	(27.0)	3524	(24.2)
1 (25)	40	3790	(26.1)	3714	(25.6)	3676	(25.3)	3297	(22.7)
1 1/2 (40)	40	2770	(19.0)	2715	(18.7)	2687	(18.5)	2410	(16.6)
2 (50)	40	2090	(14.4)	2048	(14.1)	2027	(13.8)	1818	(12.5)
3 (80)	40	2010	(13.8)	1970	(13.5)	1950	(13.4)	1749	(12.0)
4 (100)	40	1900	(13.1)	1862	(12.8)	1843	(12.7)	1653	(11.3)

①Pressures may be interpolated between temperature values.

Table 4.2.3-2: 4130 Alloy Steel, Schedule 80, LTCS-333-80

		B31.X Maximum Design Pressure, psi (MPa) ①							
Fitting Size NPS (DN)	Pipe Schedule	Min. Temp. to 150 °F (65 °C)		200 to 650 °F (93 to 343 °C)		700 °F (371 °C)		800 °F (426 °C)	
1/2 (15)	80	6780	(46.7)	6644	(45.8)	6577	(45.3)	5899	(40.6)
3/4 (20)	80	4810	(33.1)	4714	(32.5)	4666	(32.1)	4185	(28.8)
1 (25)	80	5440	(37.5)	5331	(36.7)	5277	(36.3)	4733	(32.6)
1 1/2 (40)	80	3560	(24.5)	3489	(24.0)	3453	(23.8)	3097	(21.3)
2 (50)	80	3240	(22.3)	3175	(21.8)	3143	(21.6)	2819	(19.4)
3 (80)	80	2960	(20.4)	2901	(20.0)	2871	(19.7)	2575	(17.7)
4 (100)	80	2170	(14.9)	2127	(14.6)	2105	(14.5)	1888	(13.0)

①Pressures may be interpolated between temperature values.

4.2.3 Lokring 4130 Alloy Steel, LTCS-333, Design Pressure Ratings (cont.)

Table 4.2.3-3: 4130 Alloy Steel Fitting, Schedule 160, LTCS-333-160

		B31.X Maximum Design Pressure, psi (MPa) ①							
Fitting Size NPS (DN)	Pipe Schedule	Min. Temp. to 150 °F (65 °C)		200 to 650 °F (93 to 343 °C)		700 °F (371 °C)		800 °F (426 °C)	
1/2 (15)	160	7280	(50.1)	7134	(49.1)	7062	(48.6)	6334	(43.6)
3/4 (20)	160	6070	(41.8)	5949	(41.0)	5888	(40.5)	5281	(36.4)
1 (25)	160	4300	(29.6)	4214	(29.0)	4171	(28.7)	3741	(25.7)
1 1/2 (40)	160	4350	(29.9)	4263	(29.3)	4220	(29.0)	3785	(26.0)
2 (50)	160	4180	(28.8)	4096	(28.2)	4055	(27.9)	3637	(25.0)

①Pressures may be interpolated between temperature values.

Table 4.2.3-4: 4130 Alloy Steel Fitting, Schedule XXS, LTCS-333-XXS

		B31.X Maximum Design Pressure, psi (MPa) ①							
Fitting Size NPS (DN)	Pipe Schedule	Min. Temp. to 150 °F (65 °C)		200 to 650 °F (93 to 343 °C)		700 °F (371 °C)		800 °F (426 °C)	
1/2 (15)	XXS	7280	(50.1)	7134	(49.1)	7062	(48.6)	6334	(43.6)
3/4 (20)	XXS	6070	(41.8)	5949	(41.0)	5888	(40.5)	5281	(36.4)

①Pressures may be interpolated between temperature values.

4.3 Operating Temperature Limitations

Lokring fittings are capable of maintaining joint integrity through a range of system temperatures. Tables listed in Section 4.2 for Lokring product lines are to be used to de-rate pressure based upon the applicable system design temperature. The temperature of an ASME B31 system shall be limited when using Lokring fittings as follows.

- SS40 product line:

  Lokring Series SS40 straight couplings are limited for low-temperature services to −425 °F (−254 °C) when joining ASTM A-312 Grades TP 304L, TP304, TP316L, and TP 316 pipe. However, if special fittings that are manufactured with welds are used, then services are limited to −150 °F (−101 °C). B31.3 allows for services to −425 °F (−254 °C) when joining ASTM A312 Grades TP 304L and TP 316L (only when pipe material is solution heat-treated).

  Lokring Series SS40 products are limited for high-temperature services to 800 °F (426 °C).

  If the piping system design is for an ASME B31.1 application using stainless steel fittings at temperatures greater than or equal to 750 °F (400 °C), Lokring offers the product lines designated as “SS-3300” or SS40 with the suffix “-XR” that do undergo 100 % Radiographic examination.

- MAS-3000 product line:

  Lokring Series MAS-3000 products are limited for low-temperature services to −20 °F (−29 °C) and limited for high-temperature services to 650 °F (343 °C).

- LTCS-333 product line:

  Lokring Series LTCS-333 products are limited for low-temperature services to −50 °F (−46 °C) and limited for high-temperature services to 800 °F (426 °C).

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5.0 Thermal Expansion (Flexibility) Design

5.1 General

The flexibility of small piping, the sizes that are typically joined by Lokring fittings, is usually not a great concern because small pipe has been shown by experience to be more robust than larger pipe. One reason may be that supports are typically far enough apart that they do not significantly restrain the pipe from deflecting due to thermal expansion. Observing several easy guidelines on the following pages for piping systems operating with modest temperature increases (and decreases) will be sufficient to ensure that thermal expansion stress-ranges do not exceed allowable stress-ranges in the respective B31 books.

5.2 Simplified Thermal Expansion (Flexibility) Design for “Cold” Piping

If piping operates at ambient temperatures and low pressures, it may be assumed to have adequate flexibility regardless of the piping layout.

Even piping with modest operating temperatures above ambient may be evaluated simply to ensure the piping has sufficient flexibility. Historically, piping operating at temperatures less than 300 °F (150 °C) has been considered “cold.” The piping layouts with in-plane and out-plane offsets (L and Z bends and expansion loops and variations) shown in Figure 5.2 at temperatures up to 300 °F (150 °C) may be assumed to provide sufficient flexibility if the L_2 leg or, in an expansion loop, the average of the L_2 legs meets the following criteria.

(a) U.S. Customary Units

$$L_2 \geq f\,(D\,L_1)^{0.5} \qquad \text{(Eq. 5.2a)}$$

(b) SI Units

$$L_2 \geq (f/9)\,(D\,L_1)^{0.5} \qquad \text{(Eq. 5.2b)}$$

where D equals the outside diameter of matching pipe, inch (mm), and L_1, L_2, L_3, L_4, and L_5, ft (m), and f are shown in the simple piping layout shown in Figure 5.2.

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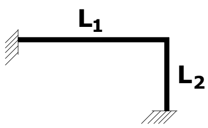
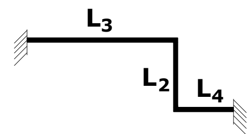
5.2 Simplified Thermal Expansion (Flexibility) Design for "Cold" Piping (cont.)

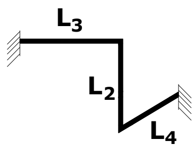
Figure 5.2: Simple Piping Layouts for Flexibility (Thermal Expansion) Design



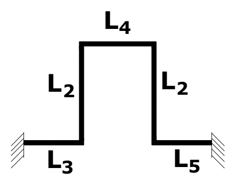
L-bend
$f = 0.55, L_1 = L_1$



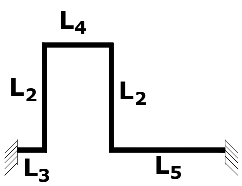
Z-bend
$f = 0.25, L_1 = L_3 + L_4$ [Note 1]



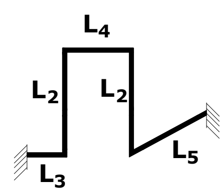
Z-bend, Out-plane
$f = 0.25, L_1 = L_3 + L_4$ [Note 1]



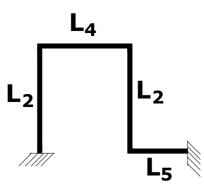
Expansion Loop, Equal Tangents
$f = 0.35, L_1 = (L_3 + L_4 + L_5)/2$ [Note 2]



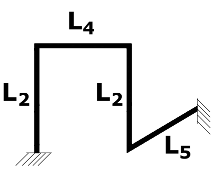
Expansion Loop, Unequal Tangents
$f = 0.35, L_1 = (L_3 + L_4 + L_5)/2$ [Note 3]



Expansion Loop, Unequal Tangents, Out-plane
$f = 0.35, L_1 = (L_3 + L_4 + L_5)/2$ [Note 3]



Expansion Loop, Single Tangent
$f = 0.35, L_1 = (L_4 + L_5)/2$ [Note 4]



Expansion Loop, Single Tangent, Out-plane
$f = 0.35, L_1 = (L_4 + L_5)/2$ [Note 4]

Notes:

1. $L_1 > L_2$
2. $L_3 > L_4 / 8$ and $L_3 < 8L_4$
3. $L_3 > L_4 / 16$ and $L_3 < 8L_4$
4. $L_3 > L_4 / 16$ and $L_3 < 8L_4$ and $L_3 > L_5 / 8$ and $L_3 < 8L_5$
5. $L_4 > L_5 / 16$ and $L_4 < 8L_5$

5.3 Simplified Thermal Expansion (Flexibility) Design Using B31 Screening Criteria

Various B31 books have thermal expansion (flexibility) analysis screening rules. The various B31 books state in essence that no formal analysis (e.g., computer-aided analysis) is necessary if the piping system is of uniform size, has no more than two anchors and no intermediate restraints and meets the following generalized equation:

(a) U.S. Customary Units

$Dy/(L-U)^2 \leq 0.03$ (Eq. 5.3a)

(b) SI Units

$Dy/(L-U)^2 \leq 208$ (Eq. 5.3b)

where:

- D = Nominal outside diameter of matching pipe, inch (mm)
- y = Displacement to be absorbed by the piping layout between the anchors, $U\alpha\Delta T$, inch (mm),
- L = Developed length of piping between the anchors, ft (m).
- U = Distance in a straight line between the anchors, ft (m).
- α = Coefficient of thermal expansion, inch/inch/°F (mm/mm/°C),
- ΔT = Change in temperature from ambient to the operating temperature, °F (°C),

The screening criteria should not be used under severe cyclic conditions and it should be used with caution in configurations such as unequal leg U-bends (Figure 5.3-1) or near straight “saw-tooth” runs (Figure 5.3-2) or where extraneous displacements (not in the direction connecting anchor points) constitute a large part of the total thermal displacement (Figure 5.3-3).

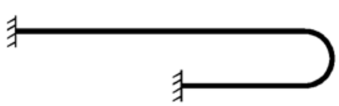


Figure 5.3-1

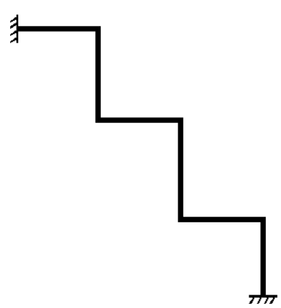


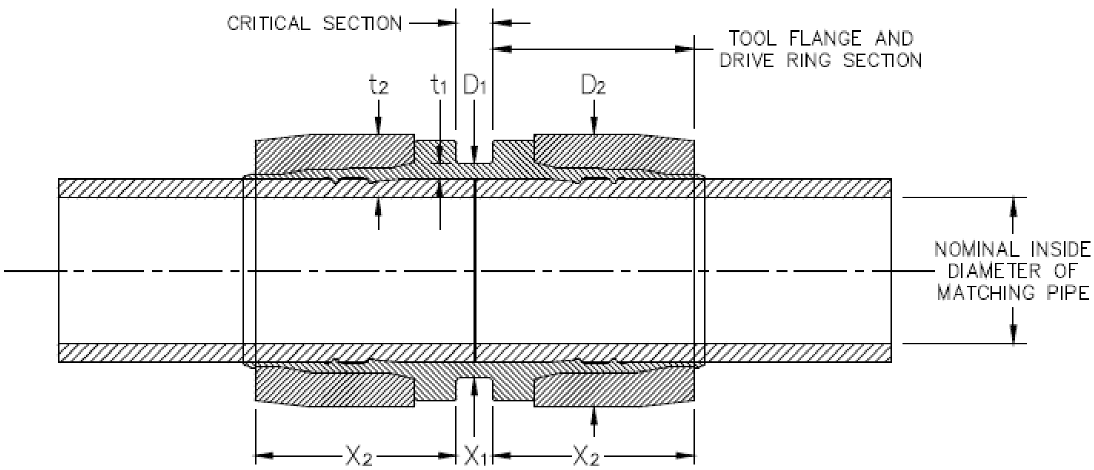
Figure 5.3-2

Figure 5.3-3

5.4 Formal Thermal Expansion (Flexibility) Design—CAD Method

If a more rigorous thermal expansion (flexibility) design is desired, a computer-aided analysis of the piping can be performed using any of the variety of commercially available computer programs. In developing the program analysis piping system model, the designer may model Lokring fittings using the dimensions shown in Figure 5.4-1 for Lokring SS40 fittings and Figure 5.4-2 for Lokring MAS-3000 and LTCS-333 fittings.

Figure 5.4-1: SS40 Lokring Fitting Computer-Aided Modeling Dimensions



where:

t_2 = (D_2 - nominal inside diameter of matching pipe)/2, inch (mm)

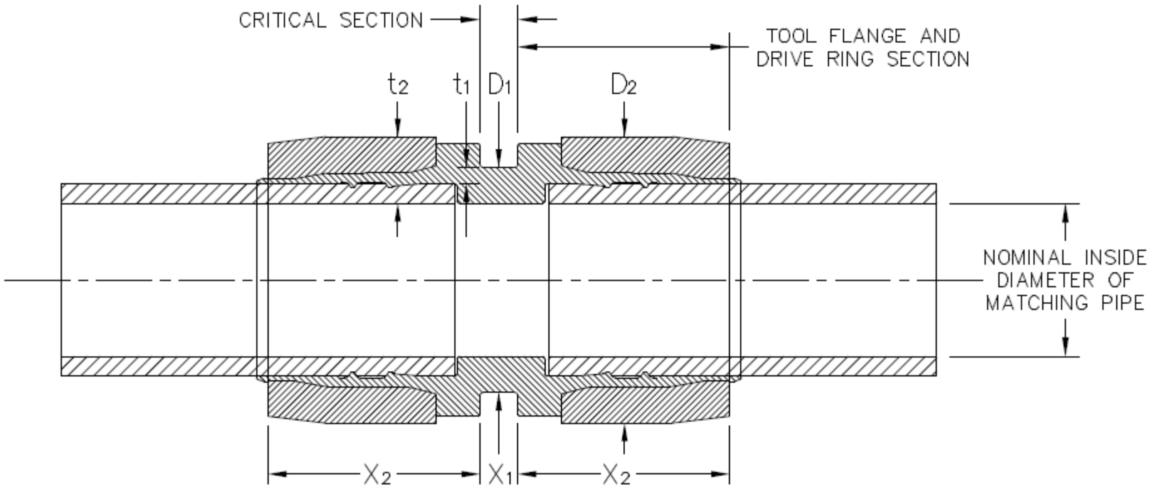
and all other dimensions are taken from Table 5.4-1: SS40.

Table 5.4-1: Stainless Steel, SS40, Lokring Fitting Computer-Aided Modeling Dimensions

Fitting Size	Tool Flange + Drive Ring Outside Diameter		Tool Flange + Drive Ring Length		Tool Groove Outside Diameter		Tool Groove Section Wall Thickness		Tool Groove Length	
NPS (DN)	D_2		X_2		D_1		t_1		X_1	
	in	(mm)	in	(mm)	in	(mm)	in	(mm)	in	(mm)
1/4 (8)	1.050	(26.7)	0.909	(23.1)	0.764	(19.4)	0.100	(2.5)	0.203	(5.2)
3/8 (10)	1.240	(31.5)	1.012	(25.7)	0.830	(21.1)	0.068	(1.7)	0.203	(5.2)
1/2 (15)	1.460	(37.1)	1.114	(28.3)	1.010	(25.7)	0.075	(1.9)	0.203	(5.2)
3/4 (20)	1.625	(41.3)	1.229	(31.2)	1.240	(31.5)	0.085	(2.2)	0.278	(7.1)
1 (25)	1.960	(49.8)	1.451	(36.9)	1.538	(39.1)	0.102	(2.6)	0.263	(6.7)
1-1/4 (32)	2.360	(59.9)	1.633	(41.5)	1.860	(47.2)	0.086	(2.2)	0.273	(6.9)
1-1/2 (40)	2.583	(65.6)	1.778	(45.2)	2.075	(52.7)	0.077	(2.0)	0.283	(7.2)
2 (50)	3.250	(82.6)	2.203	(56.0)	2.574	(65.4)	0.080	(2.0)	0.325	(8.3)
3 (80)	4.500	(114.3)	3.014	(76.6)	3.791	(96.3)	0.126	(3.2)	0.500	(12.7)

5.4 Formal Thermal Expansion (Flexibility) Design—CAD Method (cont.)

Figure 5.4-2: MAS-3000 and LTCS-333 Lokring Fitting Computer-Aided Modeling Dimensions



where:

t_2 = (D_2 - nominal inside diameter of matching pipe)/2, inch (mm)
and all other dimensions are taken from Table 5.4-2: MAS-3000 for MAS-3000 fittings and Table 5.4-3: LTCS-333 for LTCS-333 fittings

Table 5.4-2: Microalloyed Steel, MAS-3000, Lokring Fitting Computer-Aided Modeling Dimensions

Fitting Size	Tool Flange + Drive Ring Outside Diameter		Tool Flange + Drive Ring Length		Tool Groove Outside Diameter		Tool Groove Section Wall Thickness		Tool Groove Length	
NPS (DN)	D_2		X_2		D_1		t_1		t_1	
	in	(mm)	in	(mm)	in	(mm)	in	(mm)	in	(mm)
1/4 (8)	1.050	(26.7)	0.909	(23.1)	0.764	(19.4)	0.100	(2.5)	0.203	(5.2)
3/8 (10)	1.240	(31.5)	1.012	(25.7)	0.830	(21.1)	0.068	(1.7)	0.203	(5.2)
1/2 (15)	1.460	(37.1)	1.080	(27.4)	1.004	(25.5)	0.068	(1.7)	0.203	(5.2)
3/4 (20)	1.600	(40.6)	1.212	(30.8)	1.235	(31.4)	0.079	(2.0)	0.278	(7.1)
1 (25)	1.954	(49.6)	1.500	(38.1)	1.524	(38.7)	0.091	(2.3)	0.263	(6.7)
1-1/4 (32)	2.285	(58.0)	1.633	(41.5)	1.813	(46.1)	0.062	(1.6)	0.273	(6.9)
1-1/2 (40)	2.610	(66.3)	1.795	(45.6)	2.064	(52.4)	0.068	(1.7)	0.283	(7.2)
2 (50)	3.250	(82.6)	2.203	(56.0)	2.574	(65.4)	0.075	(1.9)	0.303	(7.7)
2 1/2 (65)	3.800	(96.5)	2.900	(73.7)	3.201	(81.3)	0.141	(3.6)	0.500	(12.7)
3 (80)	4.339	(110.2)	3.014	(76.6)	3.791	(96.3)	0.126	(3.2)	0.500	(12.7)
4 (100) ①	5.515	(140.1)	3.534	(89.8)	5.154	(130.9)	0.300	(7.6)	0.500	(12.7)

①MAS-3000 4-inch coupling is a pass-through design, i.e. does not have an internal center stop.

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5.4 Formal Thermal Expansion (Flexibility) Design—CAD Method (cont.)

Table 5.4-3: 4130 Alloy Steel, LTCS-333, Lokring Fitting Computer-Aided Modeling Dimensions

Fitting Size	Tool Flange + Drive Ring Outside Diameter		Tool Flange + Drive Ring Length		Tool Groove Outside Diameter		Tool Groove Section Wall Thickness		Tool Groove Length	
NPS (DN)	D_2		X_2		D_1		t_1		t_1	
	in	(mm)	in	(mm)	in	(mm)	in	(mm)	in	(mm)
1/2 (15)	1.460	(37.1)	1.080	(27.4)	1.004	(25.5)	0.068	(1.7)	0.203	(5.2)
3/4 (20)	1.750	(44.5)	1.215	(30.9)	1.189	(30.2)	0.056	(1.4)	0.278	(7.1)
1 (25)	1.980	(50.3)	1.500	(38.1)	1.524	(38.7)	0.091	(2.3)	0.263	(6.7)
1-1/2 (40)	2.700	(68.6)	1.795	(45.6)	2.064	(52.4)	0.065	(1.6)	0.283	(7.2)
2 (50)	3.280	(83.3)	2.291	(58.2)	2.574	(65.4)	0.065	(1.6)	0.303	(7.7)
3 (80)	4.475	(113.7)	3.014	(76.6)	3.791	(96.3)	0.126	(3.2)	0.500	(12.7)
4 (100) ①	5.515	(140.1)	3.534	(89.8)	5.154	(130.9)	0.300	(7.6)	0.500	(12.7)

①Note: LTCS-333 4-inch coupling is a pass-through design i.e. does not have an internal center stop.

CAD models are also available of Lokring fittings in 2D and 3D file formats. Contact your Lokring representative for further details.

5.5 Formal Thermal Expansion (Flexibility) Design—Stress Intensification Factor (i) Method

An ASME B31 stress intensification factor (SIF) is an empirically derived parameter that allows the designer to estimate the fatigue performance of a piping component or joint. The SIF (i) parameter is determined through testing by applying a reversing displacement to, i.e. developing an alternating stress in, an assembly of piping elements containing the piping component or joint under consideration. The reversing displacement is applied to the assembly until a fatigue failure occurs. The process is repeated by applying various reversing displacements to similar assemblies, developing an alternating stress/number of cycles to failure curve for the piping component or joint. The resulting curve is compared to a reference curve to determine the SIF. The reference curve is the failure curve for an as-welded circumferential butt weld, where the SIF for the butt weld is assigned a value of unity (i = 1.0).

The following tables provide stress intensification factors for the listed fitting sizes. These stress intensification factors are determined under controlled laboratory conditions in accordance with the applicable B31 code requirements for nonstandard components and, in particular, the stress intensification factor determination methodology as is published in *B31J, Standard Test Method for Determining Stress Intensification Factors (i-Factors) for Metallic Piping Components*. Please refer to the following tables:

- Table 5.5-1: Stainless Steel, SS40—Stress Intensification Factors, i, for SS40 Couplings
- Table 5.5-2: Microalloyed Steel, MAS-3000—Stress Intensification Factors, i, for MAS-3000 Couplings
- Table 5.5-3: 4130 Alloy Steel, LTCS-333—Stress Intensification Factors, i, for LTCS-333 Couplings

Table 5.5-1: Stainless Steel, SS40—Stress Intensification Factors, i, for SS40 Couplings

Fitting Size NPS (DN)	Pipe Schedule	Stress Intensification Factor, i	Pipe Schedule	Stress Intensification Factor, i	Pipe Schedule	Stress Intensification Factor, i
1/4 (8)	10 or 10S	1.2	40 or 40S	1.2	80 or 80S	1.2
3/8 (10)	10 or 10S	1.2	40 or 40S	1.2	80 or 80S	1.2
1/2 (15)	10 or 10S	1.2	40 or 40S	1.2	80 or 80S	1.2
3/4 (20)	10 or 10S	1.2	40 or 40S	1.2	80 or 80S	1.2
1 (25)	10 or 10S	1.2	40 or 40S	1.2	80 or 80S	1.2
1-1/4 (32)	10 or 10S	1.2	40 or 40S	1.2	80 or 80S	1.2
1-1/2 (40)	10 or 10S	1.2	40 or 40S	1.2	80 or 80S	1.4
2 (50)	10 or 10S	1.2	40 or 40S	1.2	80 or 80S	1.4
3 (80)	10 or 10S	1.5	40 or 40S	1.5	80 or 80S	1.6

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5.5 Formal Thermal Expansion (Flexibility) Design—Stress Intensification Factor (i) Method (cont.)

Table 5.5-2: Microalloyed Steel, MAS-3000—Stress Intensification Factors, i, for MAS-3000 Couplings

Fitting Size NPS (DN)	Pipe Schedule	Stress Intensification Factor, i	Pipe Schedule	Stress Intensification Factor, i	Pipe Schedule	Stress Intensification Factor, i
1/4 (8)	40	1.0	80	1.0	—	—
3/8 (10)	40	1.0	80	1.0	—	—
1/2 (15)	40	1.0	80	1.0	160	1.1
3/4 (20)	40	1.0	80	1.0	160	1.2
1 (25)	40	1.0	80	1.0	160	1.4
1-1/4 (32)	40	1.0	80	1.1	—	—
1-1/2 (40)	40	1.0	80	1.1	—	—
2 (50)	40	1.0	80	1.1	—	—
2-1/2 (65)	40	1.0	80	1.3	—	—
3 (80)	40	1.0	80	1.3	—	—
4 (100)	40	1.0	80	1.3	—	—

Table 5.5-3: 4130 Alloy Steel, LTCS-333—Stress Intensification Factors, i, for LTCS-333 Couplings

Fitting Size NPS (DN)	Pipe Schedule	Stress Intensification Factor, i	Pipe Schedule	Stress Intensification Factor, i	Pipe Schedule	Stress Intensification Factor, i	Pipe Schedule	Stress Intensification Factor, i
1/2 (15)	40	1.0	80	1.0	160	1.0	XXS	1.1
3/4 (20)	40	1.0	80	1.0	160	1.0	XXS	1.2
1 (25)	40	1.0	80	1.0	160	1.1	—	—
1-1/2 (40)	40	1.0	80	1.1	160	1.4	—	—
2 (50)	40	1.0	80	1.1	160	1.4	—	—
3 (80)	40	1.0	80	1.1	—	—	—	—
4 (100)	40	1.0	80	1.1	—	—	—	—

5.6 End Reactions

Usually, the highest end reactions derive from thermal expansion effects (it is customary to have the pipe supports support the total pipe weight). Without knowing the explicit acceptable reactions on the piping anchors and comparing them to calculated values, there is no assurance that anchor reactions will be acceptably low, particularly using the simplified rules of Sections 5.2 and 5.3. Even when end reactions are calculated by a formal analysis without knowing the explicit acceptable reactions, the acceptability of the calculated end reactions is unknown. Contact your Lokring representative for further information.

6.0 Weight Design

6.1 Support Location Guidelines

Locate pipe supports using Lokring Recommended Spans, Table 6.2.

Decrease pipe support spacing (i.e. add extra support) for concentrated loads or support concentrated loads directly, on both sides of a heavy valve. Note: A 35 lb (16 kg) valve in 9.5 lb/ft (14.5 kg/m) piping is an equivalent 3.7 ft (1.1 m) of pipe.

Locate pipe supports near changes in direction, i.e., bends and branch connections.

Locate pipe supports on short risers - near top preferable (for stability), second choice near bottom.

Locate pipe supports on long risers - near top first, near bottom second, then intermediate points.

Select type of support (rigid, variable, or constant spring, etc.) based on thermal expansion analysis displacements (see Section 8.0 below).

Lateral restraints in long horizontal piping runs with offsets supported by rigid supports, e.g., shoes or rod hangers, may be necessary to limit lateral thermal expansion movements.

Three-way translational stops are often considered as full anchors (restraining the three translational and three rotational directions).

6.2 Simplified Weight Design

The following spans between supports will limit stresses to B31 book allowable stresses and a maximum sag between supports of 1/2 in. (13 mm) or 0.1 in. (3 mm).

Table 6.2: Guide to Horizontal Span Design

Fitting Size NPS (DN)	Maximum Weight Span with Maximum Sag of 1/2 in. (13 mm)		Maximum Weight Span with Maximum Sag of 0.1 in. (3 mm)	
	ft	(m)	ft	(m)
1/4 (8)	7	(2.1)	4	(1.2)
3/8 (10)	8	(2.4)	5	(1.5)
1/2 (15)	9	(2.7)	6	(1.8)
3/4 (20)	10	(3.0)	7	(2.1)
1 (25)	11	(3.4)	7	(2.1)
1-1/4 (32)	12	(3.7)	8	(2.4)
1-1/2 (40)	12	(3.7)	9	(2.7)
2 (50)	15	(4.6)	10	(3.0)
2-1/2 (65)	15	(4.6)	10	(3.0)
3 (80)	15	(4.6)	12	(3.7)
4 (100)	15	(4.6)	12	(3.7)

These spans assume calcium silicate insulation of an appropriate thickness up to 850 °F (455 °C) and water contents at 39 °F (4 °C) and include consideration of a sustained stress bending stress index that is essentially the same as that of straight pipe. Note: The Lokring recommended spans for a maximum sag of 0.1 in. (3 mm) agree with ASME B31.1 Table 121.5.

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6.3 Formal Weight Design

If a more rigorous weight design is desired, a computer-aided analysis of the piping can be performed by the user using any of the variety of commercially available computer programs. In developing the program analysis piping system model, the designer may model Lokring fittings using the dimensions discussed in Section 5.4.

Additionally, the weights of various Lokring fittings (e.g. coupling, tee, and 90° elbow fittings) are listed in the below tables. Please refer to the following tables:

Table 6.3-1: The Weight of a Stainless Steel, SS40, Lokring Fitting
Table 6.3-2: The Weight of a Microalloyed Steel, MAS-3000, Lokring Fitting
Table 6.3-3: The Weight of a 4130 Alloy Steel, LTCS-333, Lokring Fitting

Note: If weight values are not listed for Lokring products you wish to evaluate, please contact your Lokring representative for further information.

Table 6.3-1: The Weight of a Stainless Steel, SS40, Lokring Fitting

Fitting Size NPS (DN)	Fitting Designation	Coupling		Tee		Elbow, 90°	
		lb	(kg)	lb	(kg)	lb	(kg)
1/4 (8)	P04	0.3	(0.14)	1.1	(0.50)	0.6	(0.27)
3/8 (10)	P06	0.5	(0.23)	1.3	(0.59)	0.8	(0.36)
1/2 (15)	P08	0.7	(0.32)	1.7	(0.77)	1.1	(0.50)
3/4 (20)	P12	0.8	(0.36)	2.1	(0.95)	1.6	(0.73)
1 (25)	P16	1.3	(0.59)	2.1	(0.95)	1.4	(0.64)
1-1/4 (32)	P20	2.3	(1.04)	4.4	(2.00)	2.7	(1.22)
1-1/2 (40)	P24	2.9	(1.32)	4.6	(2.09)	3.4	(1.54)
2 (50)	P32	4.7	(2.13)	11	(4.81)	6.8	(3.08)
3 (80)	P48	10	(4.63)	24	(11.07)	16	(7.35)

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6.3 Formal Weight Design (cont.)

Table 6.3-2: The Weight of a Microalloyed Steel, MAS-3000, Lokring Fitting

Fitting Size NPS (DN)	Fitting Designation	Coupling		Tee		Elbow, 90°	
		lb	(kg)	lb	(kg)	lb	(kg)
1/4 (8)	P04	0.3	0.1	0.8	0.4	0.6	0.3
3/8 (10)	P06	0.5	0.2	1.7	0.8	0.8	0.4
1/2 (15)	P08	0.7	0.3	1.6	0.7	1.1	0.5
3/4 (20)	P12	0.9	0.4	2.9	1.3	1.4	0.6
1 (25)	P16	1.5	0.7	3.3	1.5	2.0	0.9
1-1/4 (32)	P20	1.9	0.8	5.6	2.5	3.4	1.5
1-1/2 (40)	P24	2.6	1.2	6.1	2.7	3.9	1.8
2 (50)	P32	4.7	2.1	10.4	4.7	7.2	3.3
2 1/2 (65)	P40	8.4	3.8	18.9	8.6	13.2	6.0
3 (80)	P48	9.1	4.1	27.5	12.5	18.0	8.2
4 (100)	P64	16.2	7.3	40.8	18.5	30.9	14.0

Table 6.3-3: The Weight of a 4130 Alloy Steel, LTCS-333, Lokring Fitting

Fitting Size NPS (DN)	Fitting Designation	Coupling		Elbow, 90°	
		lb	(kg)	lb	(kg)
1/2 (15)	P08	0.7	0.3	1.6	0.7
3/4 (20)	P12	1.1	0.5	2.5	1.1
1 (25)	P16	1.6	0.7	2.8	1.3
1-1/2 (40)	P24	2.8	1.3	4.8	2.2
2 (50)	P32	5.0	2.3	8.0	3.6
3 (80)	P48	10.5	4.7	—	—
4 (100)	P64	16.6	7.5	—	—

7.0 Other Loads Design

Ductile small diameter pipe has a history of robustness such that, as stated in Section 2 above, loads other than pressure, weight, and thermal expansion may not need to be evaluated. For example, ASCE 7 *Minimum Design Loads for Buildings and Other Structures* exempts ductile B31 NPS 1 (DN 25) and smaller piping from seismic design for all Seismic Design Categories. It also exempts ductile B31 NPS 2 (DN 50) and smaller piping containing hazardous contents or required to be functional after an earthquake from seismic design in lower Seismic Design Categories (see ASCE 7 for specifics).

ASME B31E *Standard for the Seismic Design and Retrofit of Above-Ground Piping Systems* is also available to provide guidelines for the design of B31 piping systems.

If lateral supports are deemed to be necessary for lateral loads, B31 code considers short hangers, 12 in. (305 mm) and less, as lateral supports for the restraint of loads such as wind or earthquake, if due consideration is given to interaction (impact) with near piping, equipment, and structures.

Further, the effects of other possible piping loads, such as thermal hydraulic loads, typically may be mitigated by proper sloping of the pipe and/or designing and installing lateral and longitudinal pipe supports.

8.0 Pipe Supports

Small diameter pipe is typically hung with rod hangers, or bottom supported on shoes or insulation saddles. Infrequently, but of necessity for long risers or downcomers, small diameter pipe supports may need to be variable or constant spring hangers. Pipe supports meeting MSS SP-58 *Pipe Hangers and Supports - Materials, Design, and Manufacture* meet the requirements of B31. Consult MSS SP-58 and hanger manufacturer's catalogs for guidance.

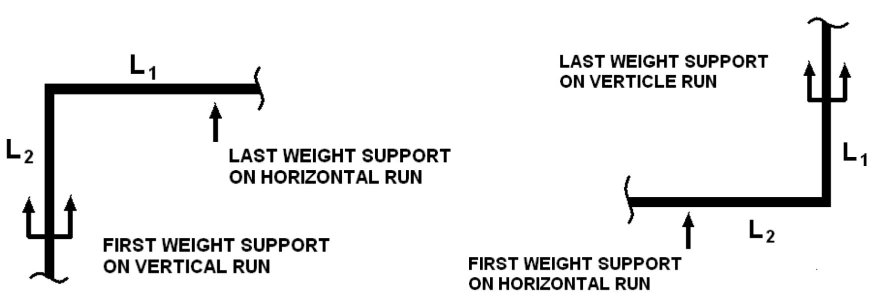
Supports with Lokring fittings on long risers and downcomers should not exceed the vertical spans given in Table 8.0.

Table 8.0: Lokring Recommended Vertical Spans

Fitting Size, NPS (DN)	Maximum Vertical Weight Span ft	(m)
1/4 (8)	14	(4.3)
3/8 (10)	16	(4.9)
1/2 (15)	18	(5.5)
3/4 (20)	20	(6.1)
1 (25)	22	(6.7)
1-1/4 (32)	24	(7.3)
1-1/2 (40)	24	(7.3)
2 (50)	30	(9.1)
2-1/2 (65)	30	(9.1)
3 (80)	30	(9.1)
4 (100)	30	(9.1)

The supports at the top and bottom of risers and downcomers should be in accordance with Figure 8.0 where L1 + L2 $\leq$ the Lokring recommended maximum weight spans given in Table 6.2.

Figure 8.0: Location of Supports Near the Top and Bottom of Risers and Downcomers



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9.0 Special Fittings

Larger special fittings are fabricated by Lokring using standard B16.9 elbow and tee fittings with Lokring fittings welded on the ends of the fittings. Smaller special fittings are fabricated out of block forgings. See Lokring "Pipe Solutions" catalog for fitting types and dimensional details including take-out dimensions. Special fittings using B16.9 fittings are fabricated using ASME B31 welding and examination methods. Special fittings fabricated from block forgings are fabricated from a single forgings and do not involve fabrication welding. In evaluating the Lokring special fittings using computer-aided analysis methods, the stress intensification factors for the B16.9 fittings should be used for the fittings themselves from Table 9.0 and the stress intensification factor from Section 5.5 for the Lokring fitting.

Table 9.0: Lokring Special Fittings Stress Intensification Factors ①

Fitting Size, NPS (DN)	Elbow ②		Tee ③	
	In-Plane	Out-Plane	In-Plane	Out-Plane
1/4 (8)	1.00	1.00	1.00	1.00
3/8 (10)	1.00	1.00	1.00	1.00
1/2 (15)	1.00	1.00	1.00	1.00
3/4 (20)	1.00	1.00	1.00	1.00
1 (25)	1.08	1.00	1.00	1.01
1-1/4 (32)	1.17	1.00	1.02	1.08
1-1/2 (40)	1.20	1.00	1.04	1.12
2 (50)	1.25	1.04	1.08	1.19
2-1/2 (65)	1.26	1.05	1.09	1.20
3 (80)	1.26	1.05	1.10	1.21
4 (100)	1.30	1.08	1.12	1.23

① The Lokring fitting on the ends of elbows and tees will affect the stiffness and stress intensification factor of the elbows and tees in a manner similar to the way flanges affect elbows. Thus, the stress intensification factors for both elbows and tees are modified using the ASME B31 "2 ends flanged" stress intensification factor correction factors in Appendix D of both B31.1 and B31.3. However, by not applying the pressure correction factor, which also affects the stiffness and stress-intensification factors in B31, to the components the combined effect is considered conservative. See also Sections 3.0 and 4.3 for temperature limitations.

② The stress intensification factors provided are for both B16.9 fittings and block forgings, both long radius and short radius elbows, and both 90° and 45° elbows as shown in the Lokring "Pipe Solutions" catalog.

③ The stress intensification factors provided are for both B16.9 full outlet and reducing outlet tees as shown in the Lokring "Pipe Solutions" catalog.

10.0 Pull-Out and Torsion

The ASME B31 Code for Pressure Piping primarily addresses welded and flanged piping construction and the major failure modes of these constructions. However, there are failure modes not discussed in any explicit way in any B31 document: such as pull-out (pipe and fitting disengagement) and torsion (rotational slippage with attendant contents leakage).

Lokring has performed significant testing to determine maximum pull-out and torsional loads for the U.S. Government and to meet National Standards. Testing of pull-out and torsional loads has been performed based on ASTM F-1387 methods and qualification criteria.

With regard to industry torsional failures, because the flexibility due to bending is much higher than the flexibility due to torsion, particularly in small bore piping (piping joined by Lokring fittings is considered small bore piping), high torsional moments and slippage has not been observed in the laboratory. Refer to Section 5.2 for Simplified Thermal Expansion (Flexibility) Design and Piping Layout Design.

Proper piping design (i.e. pipe support) is necessary to address axial and or torsional loading on piping systems.

11.0 Manufacture of Lokring Fittings

Use of Lokring fittings is consistent with U.S. industry accepted practices in the design and construction of piping systems. Where pressures, temperatures, or services require conformance with national standards for pressure piping, Lokring fittings have been designed and manufactured to meet the requirements of those standards.

Lokring elbows, tees, flanges and other fittings that cannot conveniently be manufactured integral with the Lokring end connection are fabricated by butt welding one or more machined Lokring “half bodies” onto ASME B16.9 butt weld fittings or an ASME B16.5 flange with weld end preparation in accordance with ASME B16.25. The weld end preparation on all components has been specifically designed to produce consistent high quality welds using automatic, machinek type, and manual TIG welding machines.

All welding is performed in accordance the applicable construction Code with welding qualifications in accordance with ASME Section IX, *Welding and Brazing Qualifications*. Lokring maintains Welding Procedure Specifications, Procedure Qualification Records, and Welder Qualification Test Records in accordance with ASME Section IX. All personnel performing welds are qualified in accordance to ASME Section IX.

SS40 fittings other than integral elbows, tees, and reducers are fabricated using ASME B16.9 schedule 40 butt weld fittings. Materials for these fittings are either ASTM A403 WP Class k S or WP Class k W type 316L. Lokring flanges are fabricated using ASME B16.5 weld neck flanges with a schedule 40 bore. The material for the flanges is ASTM A182 Gr. F316L.

MASk 3000 fittings other than integral elbows, tees, and reducers are fabricated using ASME B16.9 schedule 80 butt weld fittings. Materials for these fittings are ASTM A234 Grade WPB. MASk 3000 elbows and tees that are not wrought bar machined from barstock or forgings are made from microalloyed steel material according to Lokring Material Specification LMS92k 10 that complies with ASTM A675 with material composition according to ASTM A576 Grade 1524. MASk 3000 flanges are fabricated using ASME B16.5 weld neck flanges with a schedule 80 bore. The material for the flanges is ASTM A105 Grade WPB.

Every weld is visually inspected on both the outside and inside diameters for penetration, surface porosity and other identifiable defects and 5 % of the designated lot of fittings is subjected to random radiography as defined in ASME B31.3, paragraph 344.1.3. A lot is defined as a grouping of the same type of fittings that are welded in the same weld production run. The acceptance criteria of all applicable B31 construction Codes are met for the visual examination. Visual examination is performed to Lokring Procedure VTk 1 in accordance with the ASME Section V, Article 9. The acceptance criteria of ASME B31.3, Table 341.3.2 are met for the random radiography requirements. The radiography is performed in accordance with ASME Section V, Article 2.

11.0 Manufacture of Lokring Fittings (cont.)

If a customer has a B31.1 application using stainless steel fittings at temperatures greater than or equal to 750 °F (400 °C), Lokring offers the product lines designated as "SS-3300" or SS40 with the suffix "-XR" that do undergo 100 % Radiographic examination.

LTCS-333 fittings are fabricated from AISI 4130 (UNS G41300) in bar form or mechanical tubing according to ASTM A519 Grade 4130 or API 5CT Grade L80 Type 1(or) API 5L X80. Raw material mechanical requirements are according to Lokring Material Specifications. LTCS-333 flanges are fabricated using ASME B16.5 long weld neck flanges with a schedule 80 bore. The material for the flanges is AISI 4130 (UNS G41300) with additional restrictions to the material mechanical requirements according to Lokring Material Specification LMS10-01. The LTCS-333 product line is fabricated without welding of components.

12.0 Installation

Lokring fittings are suited for the fabrication and installation of new small-bore piping and tubing systems and field modification and repair of existing piping and tubing systems. Lokring fittings provide an effective alternative to field welding or flanging. By using Lokring fittings (e.g., couplings, tees, elbows, reducers, and flanges) with matching straight pipe or tube, an entire piping system can be mechanically assembled without any hot work. This reduces costs and rework especially for pre-fabricated spools.

The handling, installation, and inspection of Lokring fittings should be carried out only by qualified trained personnel. The LP-105 *Lokring Installation Procedure* provides the instruction and procedures necessary to qualify an individual as a trained Lokring installer. The installation requires preparation of the pipe and inspection of the pipe using a multi-purpose gage supplied by Lokring. A hydraulically activated tool is used to pull up the drive rings onto the body creating the metal-to-metal seal with the pipe. Post-installation validation of the assembled joint consists of visual inspection as outlined in LP-105 *Lokring Installation Procedure* and inspection as determined by the system owner.

Refer to www.lokring.com for additional information regarding installation of Lokring fittings.

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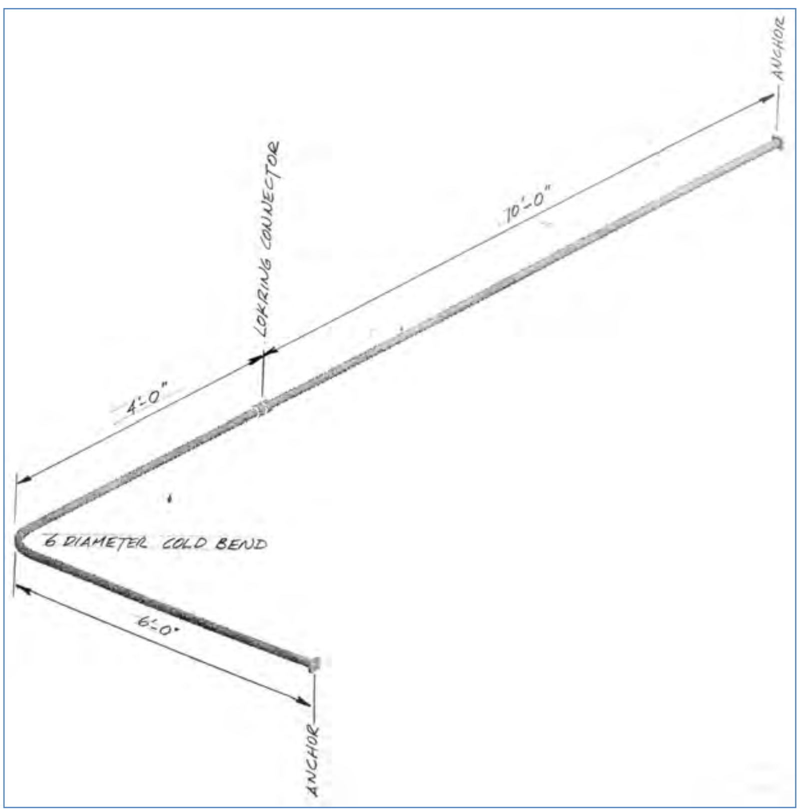
13.0 Example Problems

13.1 Example Problem 1

Specified Design Data

ASME Code:	B31.3-- 2008
Pipe:	NPS 1
Pipe material:	Seamless A-- 53, Grade B
Lokring fitting:	NPS1 SS40
Lokring fitting materials:	A276 and A479 WP316
Design pressure:	3200 psig (22.1 MPa)
Design temperature:	100 °F (38 °C)
Normal operating pressure:	3000 psig (20.7 MPa)
Normal operating temperature:	70 °F (21 °C)
Ambient pressure:	0 psig (0 MPa)
Ambient temperature:	70 °F (21 °C)
Contents:	Hydrocarbon fluid not expected to erode or corrode pipe

Proposed Layout



13.1 Example Problem 1 (cont.)

Pressure Design

Given a design temperature of 100 °F (38 °C), the B31.3 allowable stress for A-53 Grade B carbon steel is 20 000 psi (138 MPa). Since the pipe is seamless, the weld joint efficiency factor, E equal 1.0. The contents are such that no erosion or corrosion is expected so the additional thickness, A is assumed to be 0 in. (0 mm). The outside diameter of NPS 1 pipe is 1.315 in. (33 mm). Substituting these values into Eq. 4.1:

$$t_m = \frac{(3200)(1.315)}{2[(20\,000)(1.0) + 0.4(3200)]} + 0 = 0.099 \text{ in. } (2.5 \text{ mm})$$

After determining t_m a thickness amount sufficient to provide the allowed manufacturing tolerance (12.5 %) is added to obtain a minimum specified wall thickness, t_{min}. t_{min} is then equal to or greater than 0.099/(1 - 0.125) = 0.113 in. (2.9 mm). The pipe schedule having a wall thickness, t_{nom}, equal to or greater than t_{min}, is then selected as the minimum required pipe schedule. In this case, schedule 40 pipe has a nominal wall thickness, t_{nom}, of 0.133 in. (3.4 mm); carbon steel pipe is generally not available in thinner form.

The maximum design pressures for the Lokring fitting, when matched with the required NPS 1 schedule 40 pipe, are found in Table 4.2.1-2: SS40-40. There the specified design pressure of 3200 psig (22.1 MPa) at the specified design temperature of 100 °F (38 °C) is less than the Table 4.2.1-2: SS40-40 listed value of 3660 psig (25.2 MPa) at design temperatures up to 300 °F (150 °C) and thus the Lokring fitting meets the B31.3 pressure design acceptance criterion.

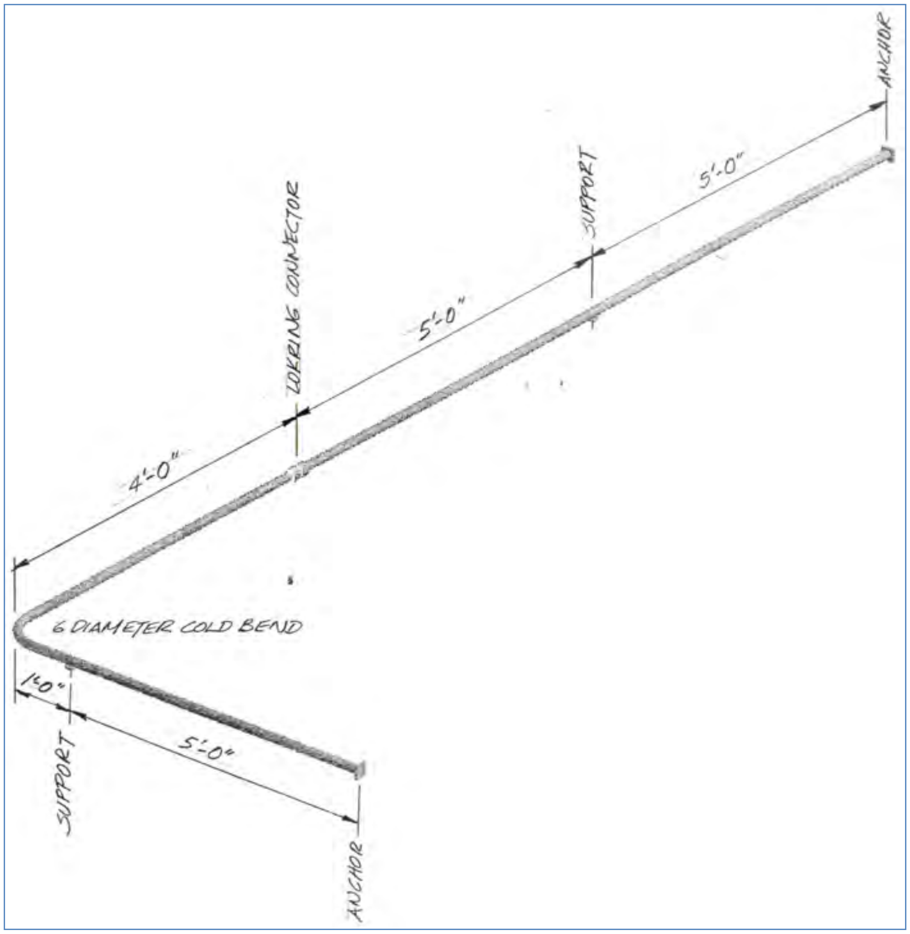
Thermal Expansion (Flexibility) Design

Since the specified normal operating temperature is ambient, a thermal expansion (flexibility) analysis does not appear necessary and the layout appears acceptable.

13.1 Example Problem 1 (cont.)

Weight Design

Proposed Supports



From Table 6.2 the Lokring recommended spans between supports for NPS 1 pipe (DN 25) is 11 ft (3.4 m) and supports will be required. The Support Location Guidelines, Section 6.1, recommends locating "pipe supports near changes in direction, i.e., bends and branch connections," so a support should be placed near the bend. In addition, the Support Location Guidelines recommends, decreasing "pipe support spacing by one-half off of, or adjacent to, equipment." Assuming the anchors at each end of the layout are equipment nozzles and the total length of pipe is 20 ft (7.0 m), locating supports at 5 ft (1.5 m) from either anchor will leave 10 ft (3.0 m) of pipe between the supports which is slightly less than the Lokring recommended spans and therefore the support locations appear to be acceptable.

In this example, locating the support near the bend limits torsion on the Lokring fitting and there appears to be no appreciable pull-out loads on the Lokring fitting.

13.1 Example Problem 1 (cont.)

Conclusion

With the proposed supports the system piping including the Lokring fitting meets B31.3-2008 criteria. This example problem is for instruction only, and is not intended to endorse any specific system applications.

Check of Example Problem 1

Using computer-aided analysis:

(1) The maximum sustained stress is 10 196 psi (70.3 MPa) which is less than the B31.3 allowable stress for A-53 Grade B of 20 000 psi (138 MPa) at ambient temperature;

(2) No thermal expansion (flexibility) stresses were evaluated as the pipe operates at ambient temperature; and

(3) The maximum displacement near the Lokring fitting is 0.062 in. (1.6 mm) at the Lokring fitting which is less than (or equal to) B31 code design practice maximum displacement of 1/2 in. (13 mm) for hydrocarbon services.

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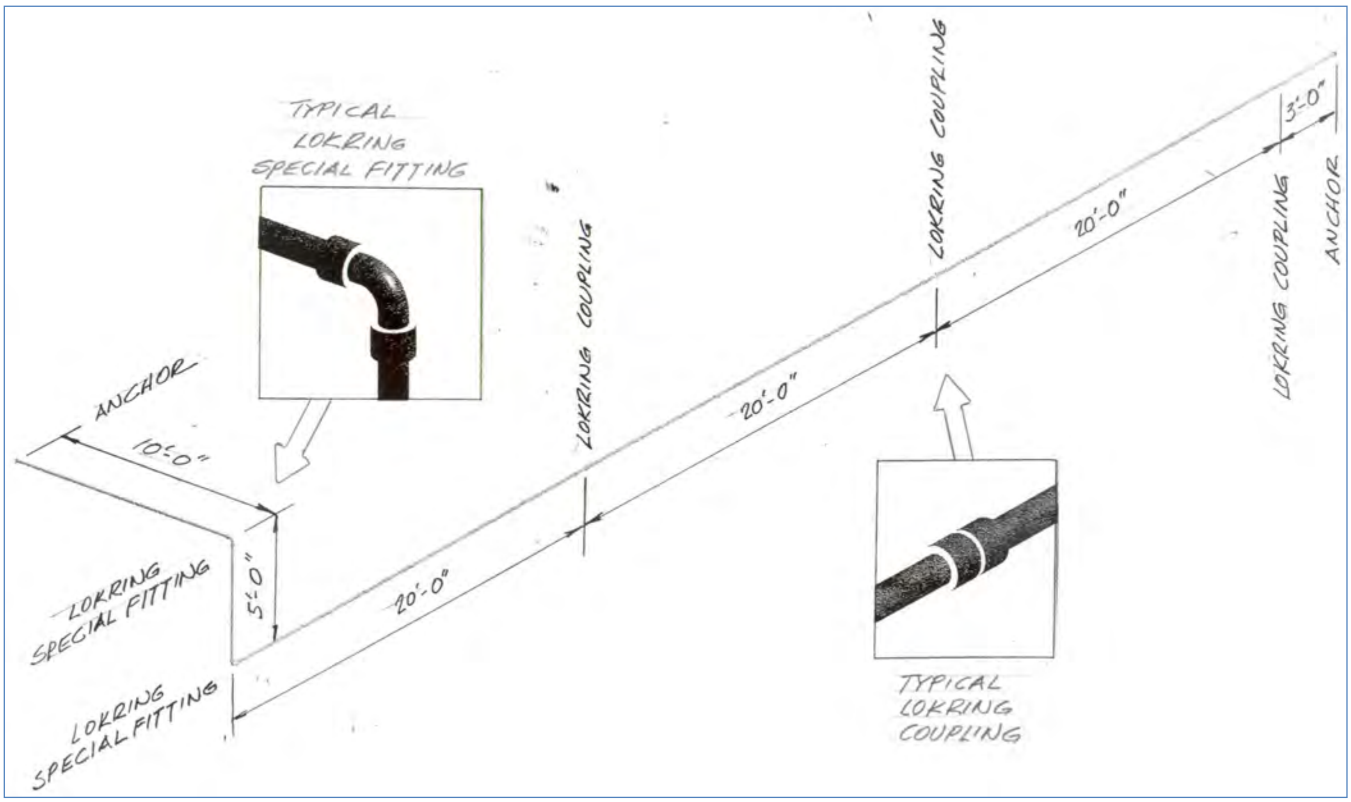
13.2 Example Problem 2

NPS 1, B31.1 low-pressure, low-temperature, offset Z-bend, Lokring (special) fittings at bends with computer-aided analysis check comparing modeling of Lokring fittings vs. square corner results

Specified Design Data and Layout

ASME Code:	B31.1-2007 with addenda through 2009
Pipe:	NPS 1
Pipe material:	Seamless A-312 TP304
Lokring fittings:	NPS 1 FS40 and NPS 1 SS-EL-90-P16
Lokring fitting materials:	Coupling – A276 and A479 WP316 and elbow - A-403 WP316L
Design pressure:	50 psig (0.34 MPa)
Design temperature:	300 °F (150 °C)
Normal operating pressure:	45 psig (0.31 MPa)
Normal operating temperature:	290 °F (143 °C)
Ambient pressure:	0 psig (0 MPa)
Ambient temperature:	70 °F (21 °C)
Insulation:	1 in. (25.5 mm) calcium silicate
Contents:	Saturated steam treated to inhibit corrosion

Proposed Layout



13.2 Example Problem 2 (cont.)

Pressure Design

Given a Design temperature of 300 °F (150 °C), the B31.1 allowable stress for A-312 TP304 stainless steel is 18 900 psi (130 MPa). (Note: There are two allowable stresses for A-312 TP 304 in B31.1. In this case, the higher value was used.) Since the pipe is seamless, the weld joint efficiency factor, E equals 1.0. The contents are such that no corrosion (or erosion) is expected, however, because of the low design pressure a very thin wall thickness is expected that might be easily damaged so an additional thickness, A, for mechanical strength of 1/16 in. (1.6 mm) is added. The outside diameter of NPS 1 pipe is 1.315 in. (33 mm). Substituting these values into Eq. 4.1:

$$t_m = \frac{(50)(1.315)}{2[(18\ 900)(1.0) + 0.4(50)]} + 0.063 = 0.065 \text{ in. } (1.7 \text{ mm})$$

After determining t_m a thickness amount sufficient to provide the allowed manufacturing tolerance (12.5 %) is added to obtain a minimum specified wall thickness, t_{min}. t_{min} is then equal to or greater than 0.065/(1 - 0.125) = 0.074 in. (1.9 mm). The pipe schedule having a wall thickness, t_{nom}, equal to or greater than t_{min}, is then selected as the minimum required pipe schedule. In this case, schedule 10S has a nominal wall thickness of 0.109 in. (2.8 mm); schedule 5S stainless steel pipe with a nominal wall thickness of 0.065 (1.7 mm) is too thin.

The maximum design pressures for the Lokring fitting when matched with the required NPS 1 schedule 10 or 10S pipe are found in Table 4.2.1-1: SS40-10 where the specified design pressure of 50 psig (0.34 MPa) at the specified design temperature of 300 °F (150 °C) is less than the Table 4.2.1-1: SS40-10 listed value of 3550 psig (24.5 MPa) at design temperatures up to 300 °F (150 °C) and thus the Lokring fitting meets the B31.1 pressure design acceptance criterion.

13.2 Example Problem 2 (cont.)

Thermal Expansion (Flexibility) Design

Since the specified normal operating temperature of 290 °F (143 °C) is less than 300 °F (150 °C) the simplified thermal expansion procedure of Section 5.2 may be used. The piping layout conforms to that of the out-of-plane Z-bend included in Figure 5.2. The Section 5.2 inequality is evaluated:

$L_2 > f(c)(DL_1)^{0.5}$; where $f(c) = 0.25$ and $L_1 = L_3 + L_4$

From the proposed layout above:

$L_2 = 5$ ft, $L_1 = 10$ ft + 63 ft or 73 ft, D = 1.315 in.

Substituting into the inequality results in:

$L_2 = 5 > 2.45 = f(DL_1)^{0.5} = 0.25[(1.315)(73)]^{0.5}$

The inequality is met and this segment meets the simplified thermal expansion (flexibility) requirements.

Weight Design

Begin weight design evaluation by referring to Table 6.2, which recommends a maximum span between supports of 11 ft (3.4 m) for NPS 1 (DN 25) pipe and a maximum sag of 0.1 in. (3mm), which is customary for B31.1 applications.

Support of the long pipe run will be required. Assume that the pipe does not attach to equipment at its ends so that the recommendation of the Support Location Guidelines, Section 6.1 that spans need to be decreased by one-half off of, or adjacent to, equipment need not be followed. Also, assume the structural steel suitable for attachment of pipe supports is available such that the supports of the proposed layout below can be readily installed.

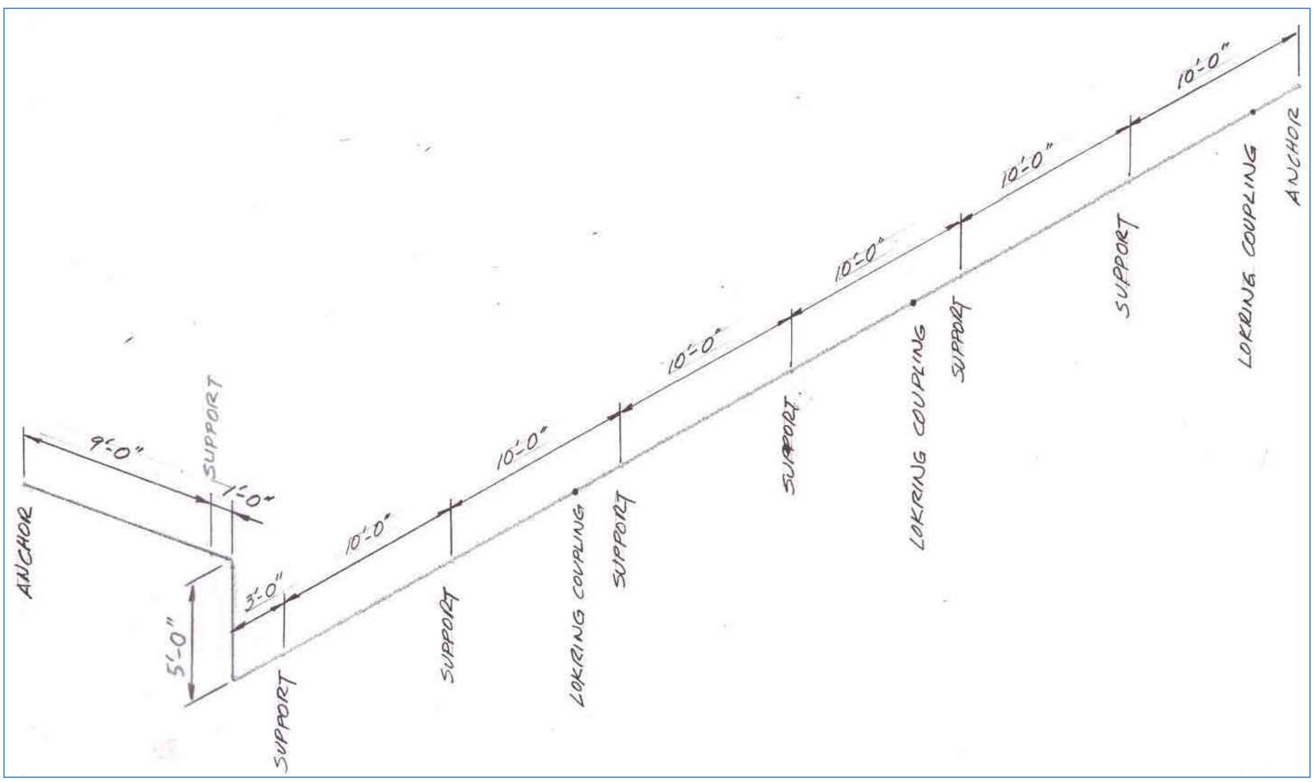
Small-bore pipe typically is manufactured and purchased in 20 ft (6.1 m) lengths so the long run can be divided in three 20 ft (6.1 m) lengths leaving 3 ft (0.91 m) to the anchor end of the run. With a 10 ft (3.1 m) span (which is a little less than the 11 ft [3.4 m] span from Table 6.2) the long run can be divided into six spans leaving a 3 ft (0.91 m) span in this case to the Lokring special elbow fitting at the bottom of the short riser. Having the 3 ft (0.91 m) span to the anchor at one end of the run and the 3 ft (0.91 m) span to the Lokring fitting at the other end of the run allows an offset of the Lokring couplings from the support locations so that the couplings do not interfere with the support hardware and support configuration.

13.2 Example Problem 2 (cont.)

At the short riser the Support Location Guidelines, Section 6.1, recommends supporting risers “near top preferable (for stability)” so locating a support 1 ft (0.3 m) from the Lokring fitting offsets the fitting from the support avoiding any potential interference. This leaves a 9 ft (2.7 m) span to the anchor (which is a little less than the 11 ft (3.4 m) span from Table 6.2). At the bottom of the riser, there is the 3 ft (0.91 m) span to the first support assuring that the riser will be primarily supported from the top. Note also that summing the lengths from the riser to the supports on either side of the riser and the riser length itself yields an equivalent span of 9 ft (2.7 m) which is recommended span from Table 6.2.

Regarding torsion and pull-out, while there is obviously torsion in the short riser, the bending flexibility in the long run is greater than the torsional flexibility of the short riser limiting torsion on the Lokring special fittings at the top and bottom of the riser. In addition, there are no appreciable pull-out loads on the Lokring connector other than internal pressure which is already accounted for in the pressure design by testing.

Proposed Supports



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13.2 Example Problem 2 (cont.)

Conclusion

The system piping including the Lokring fitting with the proposed supports meets B31.1-2007 criteria. This example problem is for instruction only, and is not intended to endorse any specific system applications.

Check of Example Problem 2

Using computer-aided analysis:

(1) The maximum sustained stress is 2176 psi (15.0 MPa) which is less than the interpolated B31.1 allowable stress of 19 010 psi (131 MPa) for A-312 TP304 material at the normal operating temperature of 290 °F (143 °C) and occurs at the north anchor;

(2) The maximum thermal expansion stress range is 5965 psi (41.1 MPa), which is less than the calculated B31.1 allowable stress range of 47 187 psi (325 MPa) for A-312 TP 304 using B31.1 Eq. (1B) based on a “cold” allowable stress, S_c, of 20 000 psi (138 MPa) at ambient, a “hot” allowable stress, S_h, of 19 010 psi (131 MPa) at 290 °F (143 °C) for A-312 TP304 material, and the sustained stress, S_L, of 1576 psi (10.9 MPa) which occurs at the same location, the east anchor; and

(3) At the operating condition, the maximum upward displacement of 0.023 inch (0.6 mm) occurs at the top of the riser. The maximum downward displacement calculated is 0.093 inch (2.4 mm) at the bottom of the riser, which is less than a design maximum displacement of 0.1 inch (2.5 mm) for B31.1 services. (Note: Sag limits are not given in the B31 books but too much sag will not allow drainage of the contents, or may cause the holdup of liquid contents creating thermal hydraulic problems. Pooling may concentrate corrosive elements. In computer analyses, locations of maximum sag may not be found unless model analysis nodes are placed between supports.)