Los Alamos NATIONAL LABORATORY EST. 1943

Conduct of Engineering
Request for Variance or Alternate Method

Assigned by SMPO or SMPOR: ☒ Alternate Method ☐ Variance Tracking number VAR- 2015-011

1.0 Affected Document(s)

☐ Engineering Processes (e.g., P 341) ☒ Engineering Standards (e.g., P 342) ☐ Engineering Training & Qualification (e.g., P 343) If against P documents themselves, revision: _____	Subordinate (Functional Series) document if applicable (ESM Chapter, Master Spec, AP, etc.): Document Title/Number: ESM Chapter 17 *Pressure Safety, ASME* Revision: 0 Document Title/Number: Engineering Standards Manual STD-342-001 Revision: 0

Section/Para

Section ASME-R0

"1.0 NEW FABRICATION

All boilers, pressure vessels, air receivers, and supporting piping shall meet the appropriate ASME Boiler and Pressure Vessel Code Section, and B31 piping section as applicable."

Section REF-3 ASME B31.3 Process Piping Guide
Piping Specifications 400, 401, 402, 403, and 404

Specific Requirement(s) as Written in the Document(s)

For new construction to ASME B31.3-2012, B31.5-2013, and B31.9-2011 require the use of listed items or unlisted items with alternative evaluations.

ASME B31.3-2012

> **326.1.2 Unlisted Piping Components.** Piping components not listed in Table 326.1 or Appendix A shall meet the pressure design requirements described in para. 302.2.3 and the mechanical strength requirements described in para. 302.5.

ASME B31.5-2013

> **526.2 Nonstandard Piping Components**
> The dimensions for nonstandard piping components shall, where possible, provide strength and performance equivalent to standard components, except as permitted under section 504. For convenience, dimensions shall conform to those of comparable standard components.

ASME B31.9-2011

926.3 Nonstandard Piping Components
When nonstandard piping components are used, pressure design shall be in accordance with para. 904. Adherence to the dimensional principles in American National Standards referenced in Table 926.1 is recommended to the greatest practicable extent.

2.0 Request

Brief descriptive title:

Accepting and limiting the use of Mueller/Streamline "Standard Tube" copper for LANL pressure systems.

NCR required (work has occurred)? ☐ Yes ☐ No	If Yes, NCR Number
TA-Bldg-(Room) and/or Project Affected LANL	System/Component Affected

Proposal

LANL has developed a table showing the lowest rated item including copper tube, copper fittings, and solder joint rating based on size. These tables will be used as the bounding condition for the maximum allowable working pressure for a system using these items.

Justification/Compensatory Measures

Mueller/Streamline states in their March 11, 2011 letter they meet the material requirements of ASTM B88 and B280. However the document continues and the "Standard Tube" product is not guaranteed to have the dimensional (minimum wall thickness) required by ASTM B88 or B280. Mueller/Streamline produced another letter dated April 17, 2012 that their product is UL tested and meets operating pressures of 700 psi at 250 ^{o}F.

The wall thicknesses of UL 207 and UL 1963 are less than the minimums allowed by ASTM B88 or B280. This evaluation is applicable for the tubing with a specified minimum in accordance with the UL 207 and UL 1963.

The ASME B31 codes allow for other calculations to be performed so that in this case the thin walled copper tubing supplied by Mueller/Streamline is evaluated and a definitive range allow.

ASME B31.3-2012

300 GENERAL STATEMENTS
(c) Intent of the Code
(3) Engineering requirements of this Code, while considered necessary and adequate for safe design, generally employ a simplified approach to the subject. A designer capable of applying a more rigorous analysis shall have the latitude to do so; however, the approach must be documented in the engineering design and its validity accepted by the owner. The approach used shall provide details of design, construction, examination, inspection, and testing for the design conditions of para. 301, with calculations consistent with the design criteria of this Code.

ASME B31.5-2013

INTRODUCTION
The Code sets forth engineering requirements deemed necessary for safe design and construction of refrigeration,

heat transfer components, and secondary coolant piping systems. While safety is the basic consideration of this Code, this factor alone will not necessarily govern the final specifications for any pressure piping system. The designer is cautioned that the Code is not a design handbook. The Code does not eliminate the need for the designer or competent engineering judgment.

ASME B31.9-2011

900 GENERAL

Engineering requirements of this Code, while considered necessary and adequate for safe design, generally employ a simplified approach. An engineer capable of applying a more rigorous analysis shall have the latitude to do so. He must be able to demonstrate the validity of his approach.

Assumptions

Copper tubing meets ASTM B88-2009 or ASTM B280-2013 material requirements.
Copper that is soldered will be considered annealed.
Corrosion allowance is zero.

Basis

The allowable stress for annealed copper is 6000 psi at 100 ^{o}F.
The allowable stress for annealed copper is 5100 psi at 150 ^{o}F.

Calculation

B31.3, B31.5, B31.9 (reference to B31.1), B16.18, and B16.22 all use the equation for rating tube as:

$P = 2 S t / (D - .8t)$

P = allowable pressure, psi
S = maximum allowable stress in tension, psi
t_{min} = wall thickness (min.), in.
D_{max} = outside diameter (max.), in.

Example for UL207 annealed copper.

S = 6000 psi
D_{max} = 0.377 in
t_{min} = 0.0265 in (from UL 203 or 1963)

$P = (2 * 6000 * 0.0265)/ (.377 – 0.8 * 0.0265)$

P = 894 psi

The UL 207 and UL 1963 do not duplicate the entire range of ASTM B88 or B280.

At 100 ^{o}F the annealed copper tubing using the allowable thicknesses from the UL 207 and UL 1963 controls three occurrences (see highlighted table cells below). In any case, the **lowest** rated item either the tubing/fitting or the solder joint size would controls the maximum allowable pressure at either 100 or 150 ^{o}F.

Maximum Allowable Pressures in Copper at 100 °F

Nominal Stardard Size (in)	Outside Diameter (in)	Lowest Rating from Fitting or Tube (psig)	Joint Rating (psig)			
			Solder Alloy Sn 50	Alloy Solder 95-5	Solder Alloy E	Solder Alloy HB
0.25	0.3750	894	200	1090	710	1035
0.375	0.5000	714	200	1090	710	1035
0.5	0.6250	628	200	1090	710	1035
0.625	0.7500	630	200	1090	710	1035
0.75	0.8750	580	200	1090	710	1035
1	1.1250	490	200	1090	710	1035
1.25	1.3750	435	175	850	555	805
1.5	1.6250	405	175	850	555	805
2	2.125	360	175	850	555	805
2.5	2.625	335	150	705	460	670

Maximum Allowable Pressures in Copper at 150 °F

Nominal Stardard Size (in)	Outside Diameter (in)	Lowest Rating from Fitting or Tube (psig)	Joint Rating (psig)			
			Solder Alloy Sn 50	Alloy Solder 95-5	Solder Alloy E	Solder Alloy HB
0.25	0.3750	760	150	625	475	710
0.375	0.5000	607	150	625	475	710
0.5	0.6250	534	150	625	475	710
0.625	0.7500	535	150	625	475	710
0.75	0.8750	490	150	625	475	710
1	1.1250	420	150	625	475	710
1.25	1.3750	370	125	485	370	555
1.5	1.6250	345	125	485	370	555
2	2.125	305	125	485	370	555
2.5	2.625	285	100	405	305	460

Summary: The “Standard Tube” provided by Mueller/Streamline may be used for B31.3, B31.5, B31.9 construction as long as the pressure ratings of the copper systems are less than the Lowest Rating from Fitting or Tube (psig) or the Joint Rating when using a value that is less, that is the Solder Allow Sn 50.

Similar comparison for other tubing dimensions and other temperature ranges must be performed by the design engineer for the specific case.

Attachments:
ASTM B88-2009 (page 3, Table 1)
ASTM B280-2013 (page 2 Table 1, page 3 Table 2)
ASME B16.18-12 (page 6 Table 1, page 46 Table A-1, page 47 wall thickness equation)

ASME B16.22-2012 (page 12 Table II-2, page 13 Table II-4, page 15 wall thickness equation)
UL 207-2009 (page 12, Table 5.1)
UL 1963-2012 (page 75, Table 46.1)
UL Mueller/Streamline
Mueller letter dated March 11, 2011
Mueller letter dated April 17, 2012
ASME B31.3-2012 (page 20 304.1.2 wall thickness equation, pages 184, 185 allowable stress)
ASME B31.5-2013 (page 24; 504.1.2 wall thickness equation, pages 14, 15 allowable stress)
ASME B31.9-2010 (page 12 904.1.1 reference to allow use of B31.1 equations, page 51 allowable stress)
ASME B31.1-2012 (page 19, 20, 21 104.1.2 wall thickness equation)
Section REF-3 ASME B31.3 Process Piping Guide: Piping Specifications 400, 401, 402, 403, and 404

Duration of Request: (Lifetime)	Start Date: 11/13/14		End Date: NA	☒ Lifetime
Requestor Ari Ben Swartz	Z Number 235211	Organization ES-EPD	Signature Signature on file	Date 11/13/14
USQD/USID required (Nucl. High/Mod Hazard)? ☐ Yes ☒ No		If Yes, USQD/USID Number		
Design Authority Representative Lawrence Kenneth Goen	Z Number 106351	Organization ES-DO	Signature Signature on file	Date 11/24/14
LANL Owning Manager (FOD or Programmatic) Lawrence Kenneth Goen	Z Number 106351	Organization ES-DO	Signature Signature on file	Date 11/24/14

3.0 Safety Management Program Owner (SMPO) Representative (SMPOR/POC)

☐ Decline ☒ Accept ☐ Accept Labwide ☐ with Modification:			
POC Ari Ben Swartz	Z Number 235211	Signature Signature on file	Date 11/13/14

4.0 Additional Approval for P341 and APs; P342, ESM, Code, and Regulation Matters; and P343

☒ Accepted ☐ Accepted with comments ☐ Declined			
Comments:			
Safety or Security Management Program Owner Lawrence Kenneth Goen	Z Number 106351	Signature Signature on file	Date 11/24/14

TABLE 1 Dimensions, Weights, and Tolerances in Diameter and Wall Thickness for Nominal or Standard Copper Water Tube Sizes
(All tolerances are plus and minus except as otherwise indicated)

Nominal or Standard Size, in.	Outside Diameter, in.	Average Outside Diameter[A] Tolerance, in.		Wall Thickness and Tolerances, in.						Theoretical Weight, lb/ft		
				Type K		Type L		Type M				
		Annealed	Drawn	Wall Thickness	Tolerance[B]	Wall Thickness	Tolerance[B]	Wall Thickness	Tolerance[B]	Type K	Type L	Type M
¼	0.375	0.002	0.001	0.035	0.0035	0.030	0.003	[C]	[C]	0.145	0.126	[C]
⅜	0.500	0.0025	0.001	0.049	0.005	0.035	0.004	0.025	0.002	0.269	0.198	0.145
½	0.625	0.0025	0.001	0.049	0.005	0.040	0.004	0.028	0.003	0.344	0.285	0.204
⅝	0.750	0.0025	0.001	0.049	0.005	0.042	0.004	[C]	[C]	0.418	0.362	[C]
¾	0.875	0.003	0.001	0.065	0.006	0.045	0.004	0.032	0.003	0.641	0.455	0.328
1	1.125	0.0035	0.0015	0.065	0.006	0.050	0.005	0.035	0.004	0.839	0.655	0.465
1¼	1.375	0.004	0.0015	0.065	0.006	0.055	0.006	0.042	0.004	1.04	0.884	0.682
1½	1.625	0.0045	0.002	0.072	0.007	0.060	0.006	0.049	0.005	1.36	1.14	0.940
2	2.125	0.005	0.002	0.083	0.008	0.070	0.007	0.058	0.006	2.06	1.75	1.46
2½	2.625	0.005	0.002	0.095	0.010	0.080	0.008	0.065	0.006	2.93	2.48	2.03
3	3.125	0.005	0.002	0.109	0.011	0.090	0.009	0.072	0.007	4.00	3.33	2.68
3½	3.625	0.005	0.002	0.120	0.012	0.100	0.010	0.083	0.008	5.12	4.29	3.58
4	4.125	0.005	0.002	0.134	0.013	0.110	0.011	0.095	0.010	6.51	5.38	4.66
5	5.125	0.005	0.002	0.160	0.016	0.125	0.012	0.109	0.011	9.67	7.61	6.66
6	6.125	0.005	0.002	0.192	0.019	0.140	0.014	0.122	0.012	13.9	10.2	8.92
8	8.125	0.006	+0.002 −0.004	0.271	0.027	0.200	0.020	0.170	0.017	25.9	19.3	16.5
10	10.125	0.008	+0.002 −0.006	0.338	0.034	0.250	0.025	0.212	0.021	40.3	30.1	25.6
12	12.125	0.008	+0.002 −0.006	0.405	0.040	0.280	0.028	0.254	0.025	57.8	40.4	36.7

[A] The average outside diameter of a tube is the average of the maximum and minimum outside diameter, as determined at any one cross section of the tube.
[B] Maximum deviation at any one point.
[C] Indicates that the material is not generally available or that no tolerance has been established.

TABLE 2 Chemical Composition—Weight %

Element	Copper UNS No.		
	C10200[A]	C12000	C12200
Copper,[B] min	99.95	99.90	99.9
Phosphorus	...	0.004–0.012	0.015–0.040

[A] Oxygen shall be 10 ppm max.
[B] Copper + silver.

8. Mechanical Property Requirements

8.1 The tube shall conform to the mechanical property requirements prescribed in Table 3. Tension tests and grainsize determinations need not be made except when indicated by the purchaser at the time of placing the order. A convenient method of indicating that these tests are to be made is to state that "Test Procedure 'T' is required" (see 4.2.1). Where agreement on the Rockwell hardness tests cannot be reached, the tensile strength and grain-size requirements of Table 3 shall be the basis for acceptance or rejection.

9. Performance Requirements

9.1 *Expansion Test*:

9.1.1 The annealed (O) tube shall be capable of being expanded in accordance with Test Method B153 with an expansion of the outside diameter in the following amount:

Nominal or Standard Size, in.	Expansion of Outside Diameter, %
⅝ and under	40
Over ⅝	30

The expanded tube shall show no cracking or rupture visible to the unaided eye.

9.2 *Flattening Test*:

9.2.1 As an alternative to the expansion test for tube standard sizes 4 in. and over in the annealed condition, a section 4 in. in length shall be cut from the end of one of the lengths for a flattening test. This 4-in. test specimen shall be flattened so that a gage set at three times the wall thickness will pass over the tube freely throughout the flattened part. The tube so tested shall develop no cracks or flaws visible to the unaided eye as a result of this test. In making the flattening test the elements shall be slowly flattened by one stroke of the press.

9.3 *Microscopical Examination for Susceptibility to Hydrogen Embrittlement*:

9.3.1 Tubes furnished in Copper UNS No. C10200 and C12000 shall be essentially free of cuprous oxide as determined by Procedure A of Test Methods B577. When Copper UNS No. C12200 is supplied, examination is not required. In case of a dispute, Procedure C of Test Methods B577 shall be used as the referee method.

9.3.2 Tubes furnished in all coppers shall be capable of passing the embrittlement test specified in Procedure B of Test Methods B577. The actual performance of the test is not required unless specifically requested in the ordering document. In case of a dispute, Procedure C of Test Methods B577 shall be used as the referee method.

10. Nondestructive Testing

10.1 Each tube up to and including 3⅛ in. in outside diameter shall be subjected to an eddy-current test. Testing shall follow the procedures of Practice E243, except for the determination of "end effect." Tubes shall be passed through an eddy-current test unit adjusted to provide information on the suitability of the tube for the intended application.

10.1.1 Notch-depth standards, rounded to the nearest 0.001 in., shall be 22 % of the wall thickness. The notch-depth tolerance shall be plus and minus 0.0005 in. Alternatively, at

3. Terminology

3.1 *Definitions:*

3.1.1 *average diameter (for round tubes only), n*—the average of the maximum and minimum outside diameters, or maximum and minimum inside diameters, whichever is applicable, as determined at any one cross section of the tube.

3.1.2 *bright anneal, n*—a thermal treatment carried out in a controlled atmosphere so that surface oxidation is reduced to a minimum and the surface remains relatively bright.

3.1.3 *coil, n*—a length of the product wound into a series of connected turns. The unqualified term "coil" as applied to tube usually refers to a bunched coil.

3.1.3.1 *bunched, n*—a coil in which the turns are bunched and held together such that the cross section of the bunched turns is approximately circular.

3.1.3.2 *level or traverse wound, n*—a coil in which the turns are wound into layers parallel to the axis of the coil such that successive turns in a given layer are next to one another. (Sometimes called "helical coil.")

3.1.3.3 *single layer flat, n*—a coil in which the product is spirally wound into a single disc-like layer. (Sometimes called "pancake coil" or "single layer spirally wound coil.")

3.1.3.4 *double layer flat, n*—a coil in which the product is spirally wound into two connected disc-like layers such that one layer is on top of the other. (Sometimes called "double layer pancake coil" or "double layer spirally wound coil.")

3.1.4 *lengths, n*—straight pieces of the product.

3.1.4.1 *specific, n*—straight lengths that are uniform in length, as specified, and subject to established length tolerances.

3.1.4.2 *standard, n*—uniform lengths recommended in a Simplified Practice Recommendation or established as a Commercial Standard.

3.1.5 *tube, seamless, n*—a tube produced with a continuous periphery in all stages of the operations.

3.1.5.1 *tube, air conditioning, n*—a seamless copper tube conforming to a standard series of sizes (Table 1) and to specified internal cleanness requirements, normally furnished in drawn temper straight lengths with the ends capped or sealed.

3.1.5.2 *tube, refrigeration service, n*—a seamless copper tube conforming to a standard series of sizes (Table 2) and to special internal cleanliness and dehydration requirements, normally furnished in soft temper coils and with ends capped or sealed.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *capable of*—the test need not be performed by the producer of the material. However, if subsequent testing by the purchaser establishes that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Include this information for contracts or purchase orders for products furnished to this specification:

4.1.1 ASTM designation and year of issue (for example, B280 – 03),

4.1.2 Copper UNS No. (not necessary unless a specific copper is desired),

4.1.3 Dimensions; wall thickness, diameter, and so forth (Section 13),

4.1.4 How furnished: coils or straight lengths,

4.1.5 Temper (for example, O60 or H58),

4.1.6 Size (Tables 1 and 2),

4.1.7 Length (Section 13),

4.1.8 Quantity (total pieces of each size and type),

4.1.9 When product purchased for agencies of the U.S. Government (Section 12).

4.2 The following options are available and shall be specified in the contract or purchase order when required:

4.2.1 Tensile test (Section 9),

4.2.2 Expansion test (Section 10.1),

4.2.3 Cleanness test (Sections 10.2 and 18.2.4),

TABLE 1 Standard Dimensions and Weights, and Tolerances in Diameter and Wall Thickness for Straight Lengths

NOTE 1—Applicable to drawn temper tube only.

Standard Size, in.	Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Weight, lb/ft (kg/m)	Tolerances	
				Average[A] Outside Diameter, Plus and Minus, in. (mm)	Wall[B] Thickness, Plus and Minus, in. (mm)
¼	0.250 (6.35)	0.025 (0.635)	0.068 (0.102)	0.001 (0.025)	0.0025 (0.06)
⅜	0.375 (9.52)	0.030 (0.762)	0.126 (0.187)	0.001 (0.025)	0.003 (0.08)
½	0.500 (12.7)	0.035 (0.889)	0.198 (0.295)	0.001 (0.025)	0.004 (0.10)
⅝	0.625 (15.9)	0.040 (1.02)	0.285 (0.424)	0.001 (0.025)	0.004 (0.10)
¾	0.750 (19.1)	0.042 (1.07)	0.362 (0.539)	0.001 (0.025)	0.004 (0.10)
⅞	0.875 (22.3)	0.045 (1.14)	0.455 (0.677)	0.001 (0.025)	0.004 (0.10)
1⅛	1.125 (28.6)	0.050 (1.27)	0.655 (0.975)	0.0015 (0.038)	0.004 (0.10)
1⅜	1.375 (34.9)	0.055 (1.40)	0.884 (1.32)	0.0015 (0.038)	0.006 (0.15)
1⅝	1.625 (41.3)	0.060 (1.52)	1.14 (1.70)	0.002 (0.051)	0.006 (0.15)
2⅛	2.125 (54.0)	0.070 (1.78)	1.75 (2.60)	0.002 (0.051)	0.007 (0.18)
2⅝	2.625 (66.7)	0.080 (2.03)	2.48 (3.69)	0.002 (0.051)	0.008 (0.20)
3⅛	3.125 (79.4)	0.090 (2.29)	3.33 (4.96)	0.002 (0.051)	0.009 (0.23)
3⅝	3.625 (92.1)	0.100 (2.54)	4.29 (6.38)	0.002 (0.051)	0.010 (0.25)
4⅛	4.125 (105)	0.110 (2.79)	5.38 (8.01)	0.002 (0.051)	0.011 (0.28)

[A] The average outside diameter of a tube is the average of the maximum and minimum outside diameters as determined at any one cross section of the tube.
[B] The tolerances listed represent the maximum deviation at any point.

TABLE 2 Standard Dimensions and Weights, and Tolerances in Diameter and Wall Thickness for Coil Lengths

Standard Size, in.	Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Weight, lb/ft (kg/m)	Tolerances	
				Average[A] Outside Diameter, Plus and Minus, in. (mm)	Wall[B] Thickness, Plus and Minus, in. (mm)
1/8	0.125 (3.18)	0.030 (0.762)	0.0347 (0.0516)	0.002 (0.051)	0.003 (0.08)
3/16	0.187 (4.75)	0.030 (0.762)	0.0575 (0.0856)	0.002 (0.051)	0.003 (0.08)
1/4	0.250 (6.35)	0.030 (0.762)	0.0804 (0.120)	0.002 (0.051)	0.003 (0.08)
5/16	0.312 (7.92)	0.032 (0.813)	0.109 (0.162)	0.002 (0.051)	0.003 (0.08)
3/8	0.375 (9.52)	0.032 (0.813)	0.134 (0.199)	0.002 (0.051)	0.003 (0.08)
1/2	0.500 (12.7)	0.032 (0.813)	0.182 (0.271)	0.002 (0.051)	0.003 (0.08)
5/8	0.625 (15.9)	0.035 (0.889)	0.251 (0.373)	0.002 (0.051)	0.004 (0.11)
3/4	0.750 (19.1)	0.035 (0.889)	0.305 (0.454)	0.0025 (0.064)	0.004 (0.11)
7/8	0.875 (22.3)	0.045 (1.14)	0.455 (0.677)	0.003 (0.076)	0.004 (0.11)
1 1/8	1.125 (28.6)	0.050 (1.27)	0.655 (0.975)	0.0035 (0.089)	0.005 (0.13)
1 3/8	1.375 (34.9)	0.055 (1.40)	0.884 (1.32)	0.004 (0.10)	0.006 (0.15)
1 5/8	1.625 (41.3)	0.060 (1.52)	1.14 (1.70)	0.0045 (0.11)	0.006 (0.15)

[A] The average outside diameter of a tube is the average of the maximum and minimum outside diameters as determined at any one cross section of the tube.
[B] The tolerances listed represent the maximum deviation at any point.

4.2.4 Microscopical Examination for Hydrogen Embrittlement, Procedure B (10.3.2),

4.2.5 Certification (Section 22), and

4.2.6 Test report (Section 23).

5. Materials and Manufacture

5.1 *Materials*—The material of manufacture shall be billets, bars, or tube and shall be of such soundness as to be suitable for processing into the tubular products described.

5.2 *Manufacture:*

5.2.1 The tube shall be manufactured by such hot or cold working processes as to produce a homogeneous uniform wrought structure in the finished product. The tube shall be cold drawn to the finished size and wall thickness.

5.2.2 Coiled lengths specified O60, soft annealed temper, shall be bright annealed after coiling, then dehydrated, and capped, plugged, crimped, or otherwise closed at both ends so as to maintain the internal cleanness of the tubing under normal conditions of handling and storage.

5.2.3 Straight lengths specified H58 hard-drawn temper shall be cleaned and capped, plugged, or otherwise closed at both ends so as to maintain the internal cleanness of the tubing under normal conditions of handling and storage.

6. Chemical Composition

6.1 The chemical composition shall conform to the chemical requirements in Table 3 for the specific type of copper.

6.1.1 These limits do not preclude the presence of other elements. When included in the contract or purchase order, and agreed upon by the manufacturer or supplier and the purchaser, limits shall be established and analysis required for unnamed elements.

TABLE 3 Chemical Composition—Weight %

Element	Copper UNS No.		
	C10200[A]	C12000	C12200
Copper,[B] min	99.95	99.90	99.9
Phosphorus	...	0.004–0.012	0.015–0.040

[A] Oxygen shall be 10 ppm max.
[B] Copper + silver.

7. Temper

7.1 Product under this specification shall be furnished in either O60 (soft annealed) or H58 (drawn general purpose) temper, as specified in the contract or purchase order and defined in Classification B601.

7.1.1 Coils are normally furnished in O60 temper and straight lengths in H58 temper.

8. Grain Size

8.1 Coiled lengths shall be furnished in the O60 temper and shall have a recrystallized grain size of 0.040 mm minimum when determined in accordance with Test Methods E112.

9. Tensile Requirements

9.1 The tube shall conform to the tensile requirements prescribed in Table 4.

9.2 Tensile tests need not be performed except when specified in the contract or purchase order.

10. Performance Requirements

10.1 *Expansion Test:*

10.1.1 Tube furnished in the O60 soft annealed temper shall be capable of being expanded in accordance with Test Method B153 to the following extent:

10.1.1.1 The expanded tube shall show no cracking or other defects visible to the unaided eye.

10.1.2 Unless specified in the contract or purchase order, this test is not required to be performed by the manufacturer.

10.2 *Cleanness of Interior Surface :*

TABLE 4 Tensile Requirements

Form	Temper Designation		Tensile Strength, min		Elongation in 2 in. (50.8 mm), min, %
	Standard	Former	ksi[A]	MPa[B]	
Coiled lengths	O60	soft annealed	30	205	40
Straight lengths	H58	drawn general purpose	36	250	...

[A] ksi = 1000 psi.
[B] See Appendix X1.

(12)

Table 1 Internal Pressure–Temperature Ratings for Cast Copper Alloy Fittings, psi (kPa)

Standard Water Tube Size	−20°F to 100°F (−29°C to 38°C)	150°F (66°C)	200°F (93°C)	250°F (121°C)	300°F (149°C)	350°F (177°C)	400°F (204°C)
1/4	910 (6 280)	770 (5 340)	745 (5 130)	725 (5 020)	710 (4 920)	605 (4 190)	455 (3 140)
3/8	775 (5 360)	660 (4 560)	635 (4 380)	620 (4 290)	610 (4 200)	515 (3 570)	385 (2 680)
1/2	720 (4 970)	610 (4 220)	585 (4 060)	575 (3 980)	565 (3 890)	480 (3 310)	360 (2 480)
5/8	630 (4 350)	535 (3 700)	515 (3 555)	505 (3 480)	490 (3 410)	420 (2 900)	315 (2 170)
3/4	580 (4 010)	490 (3 410)	475 (3 275)	465 (3 210)	455 (3 140)	385 (2 670)	290 (2 000)
1	490 (3 400)	420 (2 890)	400 (2 780)	395 (2 720)	385 (2 660)	325 (2 270)	245 (1 700)
1 1/4	435 (3 020)	370 (2 570)	355 (2 470)	350 (2 420)	340 (2 370)	290 (2 010)	215 (1 510)
1 1/2	405 (2 810)	345 (2 390)	330 (2 300)	325 (2 250)	315 (2 200)	270 (1 870)	200 (1 400)
2	360 (2 500)	305 (2 130)	295 (2 045)	290 (2 000)	280 (1 960)	240 (1 670)	180 (1 250)
2 1/2	335 (2 310)	285 (1 960)	270 (1 890)	265 (1 850)	260 (1 810)	220 (1 540)	165 (1 150)
3	315 (2 180)	265 (1 850)	255 (1 785)	250 (1 740)	245 (1 710)	210 (1 450)	155 (1 090)
3 1/2	300 (2 090)	255 (1 770)	245 (1 705)	240 (1 670)	235 (1 630)	200 (1 390)	150 (1 040)
4	290 (2 020)	245 (1 710)	240 (1 650)	230 (1 610)	225 (1 580)	195 (1 340)	145 (1 010)
5	265 (1 850)	225 (1 570)	220 (1 515)	215 (1 480)	210 (1 450)	175 (1 230)	130 (920)
6	250 (1 720)	210 (1 460)	205 (1 420)	200 (1 380)	195 (1 350)	165 (1 150)	125 (860)
8	270 (1 860)	225 (1 580)	220 (1 520)	215 (1 490)	210 (1 460)	180 (1 240)	135 (930)
10	270 (1 860)	230 (1 580)	220 (1 525)	215 (1 490)	210 (1 460)	180 (1 240)	135 (930)
12	250 (1 740)	215 (1 480)	205 (1 425)	200 (1 390)	195 (1 360)	165 (1 160)	125 (870)

GENERAL NOTES:

(a) For size designation of fittings, see section 4.

(b) The internal pressure rating applies to the largest opening of the fitting.

(c) The internal pressure rating is calculated, as shown in Nonmandatory Appendix B, then rounded down to the nearest unit of 5 for psi and 10 for kPa.

Table A-1 Pressure–Temperature Ratings

Joining Material	Working Temp. °F	Working Temp. °C	Maximum Working Gage Pressure, for Standard Water Tube Sizes (1)									
			1/8 Through 1		1 1/4 Through 2		2 1/2 Through 4		5 Through 8		10 Through 12	
			psi	kPa	psi	kPa	psi	kPa	psi	kPa	psi	kPa
Alloy Sn50 50-50 tin–lead solder (2)(3)	100	38	200	1 375	175	1 205	150	1 030	135	930	100	685
	150	66	150	1 030	125	860	100	685	90	620	70	480
	200	93	100	685	90	620	75	515	70	480	50	340
	250	120	85	585	75	515	50	340	45	310	40	275
Alloy Sb5 95-5 tin–antimony solder (4)	100	38	1,090 (8)	7 540 (8)	850 (9)	5 880 (9)	705 (9)	4 880 (9)	660 (9)	4 555 (9)	500 (8)	3 460 (8)
	150	66	625 (10)	4 315 (10)	485 (10)	3 365 (10)	405 (10)	2 790 (10)	375 (10)	2 605 (10)	285 (11)	1 975 (11)
	200	93	505 (11)	3 500 (11)	395 (10)	2 730 (10)	325 (10)	2 265 (10)	305 (10)	2 115 (10)	230 (11)	1 605 (11)
	250	120	270	1 885	210	1 475	175	1 220	165	1 135	125	865
Alloy E (5)	100	38	710 (10)	4 905 (10)	555 (10)	3 825 (10)	460 (10)	3 175 (10)	430 (10)	2 965 (10)	325 (11)	2 255 (11)
	150	66	475 (11)	3 275 (11)	370 (10)	2 550 (10)	305 (10)	2 115 (10)	285 (11)	1 975 (11)	215 (11)	1 500 (11)
	200	93	375	2 595	290	2 025	240 (11)	1 680 (11)	225 (11)	1 570 (11)	170	1 190
	250	120	320	2 230	250	1 735	205	1 440	195	1 340	145	1 020
Alloy HB (6)	100	38	1,035 (8)	7 135 (8)	805 (9)	5 560 (9)	670 (9)	4 615 (9)	625 (8)	4 305 (8)	475 (8)	3 275 (8)
	150	66	710 (10)	4 905 (10)	555 (10)	3 825 (10)	460 (10)	3 175 (10)	430 (10)	2 965 (10)	325 (10)	2 255 (10)
	200	93	440 (11)	3 045 (11)	345 (11)	2 375 (11)	285 (11)	1 970 (11)	265 (11)	1 840 (11)	200	1 400
	250	120	430 (11)	2 970 (11)	335 (11)	2 315 (11)	275 (11)	1 920 (11)	260 (11)	1 800 (11)	195	1 365
Joining materials melting at or above 1,100°F (593°C) (7)	Pressure–temperature ratings consistent with the materials and procedures employed.											

GENERAL NOTE: For extremely low working temperatures in the 0°F to −200°F (−18°C to −93°C) range, it is recommended that a joint material melting at or above 1,100°F (593°C) be employed [see Note (7)].

NOTES:

(1) Standard water tube sizes per ASTM B88.
(2) ASTM B32 Alloy Grade Sn50.
(3) The Safe Drinking Water Act Amendment of 1986 prohibits the use in potable water systems of any solder having a lead content in excess of 0.2%.
(4) ASTM B32 Alloy Grade Sb5.
(5) ASTM B32 Alloy Grade E.
(6) ASTM B32 Alloy Grade HB.
(7) These joining materials are defined as *brazing alloys* by the American Welding Society.
(8) The solder joint exceeds the strength of Types L and M tube in drawn temper and Type K tube in annealed temper.
(9) The solder joint exceeds the strength of Types K, L, and M tube in drawn and annealed tempers.
(10) The solder joint exceeds the strength of Type M tube in drawn temper and Types K and L tube in annealed temper.
(11) The solder joint exceeds the strength of Type L tube in annealed temper.

NONMANDATORY APPENDIX B
FITTING RATING

The rated internal working pressures of the fitting are shown in Table 1. These values are the same as those calculated for annealed temper ASTM B88 Type L copper water tube. The rated internal working pressures for annealed temper ASTM B88 Type L copper water tube are calculated as follows:

where

$$P = \frac{2St}{D - 0.8t}$$

D = maximum outside diameter, in. from annealed temper ASTM B88 for Type L copper water tube
P = rated working pressure at temperature, psi
S = allowable stress at temperature, psi from ASME B31.1 or ASME B31.9 for annealed temper ASTM B88 Type L copper water tube
t = minimum wall thickness, in. from annealed temper ASTM B88 for Type L copper water tube

(12)

Table II-2 Internal Pressure–Temperature Ratings for Copper Fittings, psi

Standard Water Tube Size [Note (1)]	−20°F to 100°F	150°F	200°F	250°F	300°F	350°F	400°F
1/4	910	770	740	725	710	605	455
3/8	775	660	635	620	610	515	385
1/2	720	610	585	575	565	480	360
5/8	630	535	515	505	490	420	315
3/4	580	490	475	465	455	385	290
1	490	420	400	395	385	325	245
1 1/4	435	370	355	350	340	290	215
1 1/2	405	345	330	325	315	270	200
2	360	305	295	290	280	240	180
2 1/2	335	285	270	265	260	220	165
3	315	265	255	250	245	210	155
3 1/2	300	255	245	240	235	200	150
4	290	245	235	230	225	195	145
5	265	225	215	215	210	175	130
6	250	210	200	200	195	165	125
8	270	225	220	215	210	180	135

GENERAL NOTES:

(a) The fitting pressure–temperature rating applies to the largest opening of the fitting.

(b) The fitting pressure–temperature rating is calculated as shown in Nonmandatory Appendix A, then rounded down to the nearest unit of 5.

NOTE:

(1) For size designation of fittings, see para. 4.1.

Table II-3 Inspection Tolerance

Standard Water Tube and Pipe Thread Sizes	Tolerance, in.
1/8, 1/4, 3/8 [Note (1)]	±0.05
1/2, 5/8, 3/4	±0.06
1, 1 1/4, 1 1/2, 2	±0.08
2 1/2, 3, 3 1/2	±0.11
4 and 5	±0.12
6 and 8	±0.16

NOTE:

(1) 1/8 size is 1/4 O.D. seamless copper tube for refrigeration service, etc., as listed in ASTM B280.

Table II-4 Pressure–Temperature Ratings (12)

Joining Material	Temperature, °F	Maximum Gage Pressure for Standard Water Tube Sizes, psi [Note (1)]			
		1/8 Through 1	1 1/4 Through 2	2 1/2 Through 4	5 Through 8
Alloy Sn50	100	200	175	150	135
50–50 tin–lead solder	150	150	125	100	90
[Notes (2), (3)]	200	100	90	75	70
	250	85	75	50	45
Alloy Sb5	100	1,090 [Note (4)]	850 [Note (5)]	705 [Note (5)]	660 [Note (5)]
95–5 tin–antimony solder	150	625 [Note (6)]	485 [Note (6)]	405 [Note (6)]	375 [Note (6)]
[Note (7)]	200	505 [Note (8)]	395 [Note (6)]	325 [Note (6)]	305 [Note (6)]
	250	270	210	175	165
Alloy E	100	710 [Note (6)]	555 [Note (6)]	460 [Note (6)]	430 [Note (6)]
[Note (9)]	150	475 [Note (8)]	370 [Note (6)]	305 [Note (6)]	285 [Note (8)]
	200	375	290	240 [Note (8)]	225 [Note (8)]
	250	320	250	205	195
Alloy HB	100	1,035 [Note (4)]	805 [Note (5)]	670 [Note (5)]	625 [Note (4)]
[Note (10)]	150	710 [Note (6)]	555 [Note (6)]	460 [Note (6)]	430 [Note (6)]
	200	440 [Note (8)]	345 [Note (8)]	285 [Note (8)]	265 [Note (8)]
	250	430 [Note (8)]	335 [Note (8)]	275 [Note (8)]	260 [Note (8)]
Joining materials melting at or above 1,100°F [Note (11)]		Pressure–temperature ratings consistent with the materials and procedures employed			

GENERAL NOTE: For temperatures in the 0°F to −200°F range, it is recommended that a joint material melting at or above 1,100°F be employed [see Note (9)].

NOTES:

(1) Standard water tube sizes per ASTM B88.
(2) ASTM B32 Alloy Grade Sn50.
(3) The Safe Drinking Water Act Amendments of 1986 prohibit the use of any solder having a lead content in excess of 0.2% in potable water systems.
(4) The solder joint exceeds the strength of Types L and M tube in drawn temper and Type K tube in annealed temper.
(5) The solder joint exceeds the strength of Types K, L, and M tube in drawn and annealed tempers.
(6) The solder joint exceeds the strength of Type M tube in drawn temper and Types L and K in annealed temper.
(7) ASTM B32 Alloy Grade Sb5.
(8) The solder joint exceeds the strength of Type L tube in annealed temper.
(9) ASTM B32 Alloy Grade E.
(10) ASTM B32 Alloy Grade HB.
(11) These joining materials are defined as "brazing alloys" by the American Welding Society.

NONMANDATORY APPENDIX A
FITTING RATING

(12)

The pressure–temperature ratings of the fittings are shown in Table 2 (Table I-2). These values are the same as those calculated for annealed temper ASTM B88 Type L copper water tube. The rated internal working pressures for annealed temper ASTM B88 Type L copper water tube are calculated as follows:

$$p = \frac{2St}{D - 0.8t}$$

where

D = maximum outside diameter, mm (in.), for annealed temper ASTM B88 Type L water tube
p = rated pressure at temperature, kPa (psi)
S = allowable stress at temperature, kPa (psi), from ASME B31.1 or ASME B31.9, for annealed temper ASTM B88 Type L copper water tube
t = minimum wall thickness, mm (in.), for annealed temper ASTM B88 Type L water tube

5.2 Special alloys or constructions used in component, including tubing with a wall thickness less than indicated in Table 5.1 may be considered acceptable. Among the factors taken into consideration when judging the acceptability are:

a) Resistance to mechanical abuse,

b) Strength against internal pressure,

c) Resistance to corrosion,

d) Protection against refrigerant contamination, and

e) Conformity with requirements of safety codes; such as the Safety Code for Mechanical Refrigeration, ASHRAE 15, as compared to tubing of the minimum wall thickness indicated.

5.3 In judging the protection of tubing, consideration is given to the likelihood of damage occurring during handling, packing and shipment. Shielding to prevent accidental damage from objects such as tools falling on or otherwise striking the tubing shall be provided in the form of baffles, channels, flanges, perforated metal, or similar means.

5.4 Copper or steel capillary tubing which is protected against mechanical damage by the assembly or other means shall have a wall thickness not less than 0.020 inch (0.51 mm).

5.4 revised July 12, 2013

Table 5.1
Wall thickness for copper and steel tubing

Outside Diameter,		Minimum wall thickness, inches[a](mm)					
		Copper				Steel	
Inches	(mm)	Protected		Unprotected[b]			
3/16	(4.76)	0.0245	(0.62)	0.0265	(0.67)	0.025	(0.64)
1/4	(6.35)	0.0245	(0.62)	0.0265	(0.67)	0.025	(0.64)
5/16	(7.94)	0.0245	(0.62)	0.0265	(0.67)	0.025	(0.64)
3/8	(9.53)	0.0245	(0.62)	0.0265	(0.67)	0.025	(0.64)
1/2	(12.70)	0.0245	(0.62)	0.0285	(0.72)	0.025	(0.64)
5/8	(15.88)	0.0315	(0.80)	0.0315	(0.80)	0.032	(0.81)
3/4	(19.05)	0.0315	(0.80)	0.0385	(0.98)	0.032	(0.81)
7/8	(22.23)	0.0410	(1.04)	0.0410	(1.04)	0.046	(1.17)
1	(25.40)	0.0460	(1.17)	0.0460	(1.17)	–	
1-1/8	(28.58)	0.0460	(1.17)	0.0460	(1.17)	0.046	(1.17)
1-1/4	(31.75)	0.0505	(1.28)	0.0505	(1.28)	0.046	(1.17)
1-3/8	(34.93)	0.0505	(1.28)	0.0505	(1.28)	–	
1-1/2	(38.10)	0.0555	(1.41)	0.0555	(1.41)	0.062	(1.58)
1-5/8	(41.28)	0.0555	(1.41)	0.0555	(1.41)	–	
2-1/8	(53.98)	0.0640	(1.63)	0.0640	(1.63)	–	
2-5/8	(66.68)	0.0740	(1.88)	0.0740	(1.88)	–	

[a] Nominal wall thickness of tubing will have to be greater than the thickness indicated to maintain the minimum wall thickness.
[b] See 3.4.30.

5.5 Tubing shall be constructed of corrosion-resistant material such as copper or shall be plated, dipped, coated, or otherwise treated to resist external corrosion. Aluminum tubing may be used. See 4.7 and 5.2.

46 Refrigerant Tubing and Hoses

46.1 Tubing

46.1.1 The wall thickness of copper or steel tubing used to connect components in the refrigerant systems shall be not less than indicated in Table 46.1.

Exception: Copper or steel capillary tubing that is protected against mechanical damage by the cabinet or assembly shall have a wall thickness not less than 0.020 in (0.51 mm).

46.1.2 Tubing shall be constructed of corrosion-resistant material such as copper, or shall be plated, dipped, coated, or equivalently treated to resist external corrosion. Aluminum may be used where the material is not subject to galvanic corrosion.

Table 46.1
Minimum wall thickness for copper, steel and aluminum tubing

Outside diameter,		Copper				Steel		Aluminum	
		Protected[a]		Unprotected		Protected or unprotected			
in	(mm)	in	(mm)	in	(mm)	in	(mm)	in	(mm)
3/16	(4.76)	0.0279	(0.71)	0.0299	(0.76)	0.0279	(0.71)	0.0350	(0.89)
1/4	(6.4)	0.0245	(0.622)	0.0265	(0.673)	0.025	(0.64)	0.0350	(0.89)
5/16	(7.9)	0.0245	(0.622)	0.0285	(0.724)	0.025	(0.64)	0.0350	(0.89)
3/8	(9.5)	0.0245	(0.622)	0.0285	(0.724)	0.025	(0.64)	0.0350	(0.89)
1/2	(12.7)	0.0245	(0.622)	0.0285	(0.724)	0.025	(0.64)	0.0350	(0.89)
5/8	(15.9)	0.0315	(0.800)	0.0315	(0.800)	0.032	(0.81)	0.0488	(1.24)
3/4	(19.1)	0.0315	(0.800)	0.0385	(0.978)	0.032	(0.81)	0.0488	(1.24)
7/8	(22.2)	0.0410	(1.041)	0.0410	(1.041)	0.046	(1.17)	0.0650	(1.65)
1	(25.4)	0.0460	(1.168)	0.0460	(1.168)	–	–	0.0720	(1.83)

NOTE – Nominal wall thickness of tubing will have to be greater than the thickness indicated to maintain the minimum wall thickness.

[a] Within the product.

46.1.3 Tubing forming part of components such as evaporators or condensers, where protection is afforded by inherent construction, shall be judged according to Strength Test – Pressure Containing Components, Section 76.

46.1.4 Special alloys or constructions used in components of the refrigerant system including tubing with a wall thickness less than indicated in 46.1.1 are acceptable, subject to an investigation that considers:

a) Resistance to mechanical abuse,

b) Strength against internal pressure,

c) Resistance to corrosion,

d) Protection against refrigerant contamination, and

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USE

This category covers tubing, tubing assemblies, vibration eliminators and refrigerant recovery/recycling hose assemblies intended for use with air conditioning and refrigeration equipment.

CONDITIONS OF ACCEPTABILITY

Consideration is to be given to the Conditions of Acceptability specified in the individual Reports when these components are employed in the end-use equipment.

REQUIREMENTS

The basic standard used to investigate tubing, tubing assemblies and vibration eliminators in this category is ANSI/UL 207, "Refrigerant-Containing Components and Accessories, Nonelectrical."

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* *

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MUELLER STREAMLINE CO SA32907
SUITE 150
8285 TOURNAMENT DR
MEMPHIS, TN 38125 USA

Model Series 008, 010, 012, 014, 018, 406, 408, 410, 412, 510, 512, 514, 518, 608, 610, 612, 614, 618, 810, 812, 814, 818. May be followed by additional alpha-numeric suffixes.

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Mueller Streamline Co.
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Memphis, TN 38125
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STANDARD COPPER TUBE

Mueller Copper Tube products are manufactured in the USA. All tubing produced in Fulton, MS, and Wynne, AR, is seamless and of UNS C12200 grade of copper and is manufactured to meet the chemical, mechanical, cleanness, and eddy current testing requirements of the applicable ASTM specifications set forth below.

Although Mueller Copper Tube strives to meet all requirements specified in ASTM, Standard Tube may not fully meet ASTM dimensional requirements. Standard Tube will be provided unless Certified Tube is clearly defined on the Purchase Order. When specified at order placement, Mueller Copper Tube can supply Certified Tube to meet all requirements of the current applicable ASTM specification, at an additional cost.

- Streamline Copper Water Tube (Types K,L,M) is produced in accordance with, ASTM B88 and ANSI/NSF 61**
- Streamline Copper Refrigeration Service Coils are produced in accordance with ASTM B280
- Streamline Nitrogenized ACR Hard Drawn Copper Tube is produced in accordance with ASTM B280
- Streamline Copper Drainage Tube (DWV) is produced in accordance with ASTM B306
- Oxygen & Medical Service Tube - To ASTM B819 (Types K & L) Hard Drawn Straight Lengths Only in accordance to CGA Cleanness Specification; CGA G4.1 (Compressed Gas Association); & NFPA 99 (Health Care Facilities).

** NSF 61 Restriction Statement Copper Tube (Alloy C12200) is certified by NSF to ANSI/NSF Standard 61 for public water supplies meeting or in the process of meeting the U.S. EPA Lead and Copper Rule (56FR 26460, June 7, 1991). Water supplies with pH less than 6.5 may require corrosion control to limit copper solubility in drinking water."

Last revision: March 11, 2011

Mueller Streamline Co.
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c UL us
700 PSI R410A

April 17, 2012

SUBJECT: **Streamline Copper Tube & Fittings UL Recognized to 700 PSI Operating Pressures to Support R410A and Sub Critical CO_2 Applications**

To Our Valued Customers:

Mueller Streamline Co. has long been a leader in providing copper tube and fittings for refrigerant-bearing applications in HVAC and refrigeration systems. The refrigerants used in these systems have evolved significantly since we developed and patented the braze/solder-type copper fitting back in 1930. While Streamline copper tube and fittings are proudly made in accordance with the applicable ASTM/ASME specifications, the evolution toward higher pressure refrigerants encouraged us to attain bolder thresholds.

To provide customers the highest level of assurance that our products will continue to meet the higher pressure demands of modern refrigerants like R410A and sub-critical CO_2, we have taken the additional step of expanding our already extensive testing procedures and implementing third-party verification through Underwriters Laboratories (UL).

Mueller Streamline Co. is now able to offer the only copper tube and fittings UL Recognized to 700PSI (see table below). This recognition follows years of testing that includes hoop strain, cyclic fatigue, hydrostatic burst, thermal cycling, and more. The testing and third-party certification validates performance of these products to operating pressures of 700psi at 250°F.

Product Line	*Product Type*	*Diameter*
Copper Tube	• Streamline Refrigeration Service Coils • Streamline Line Sets & Mini-Splits • Streamline ACR - Type L (Hard Lengths) • Streamline ACR - Type K (Hard Lengths)	1/8" – 1-1/8" 1/8" – 1-1/8" 1/8" – 1-3/8" 1/8" – 2-5/8"
Copper Fittings	• Streamline Wrot Solder-Joint Pressure	1/8" – 2-5/8"

As new technologies and refrigerants emerge, Mueller Streamline Co. is committed to being a resource to our customers and ensuring that our products are safe and reliable. If you have any product questions please contact your local sales representative.

for use at pressure–temperature ratings in accordance with para. 302.2.1 or para. 302.2.2, as applicable. The rules in para. 304 are intended for pressure design of components not covered in Table 326.1, but may be used for a special or more-rigorous design of such components, or to satisfy requirements of para. 302.2.2. Designs shall be checked for adequacy of mechanical strength as described in para. 302.5.

304 PRESSURE DESIGN OF COMPONENTS

304.1 Straight Pipe

304.1.1 General

(a) The required thickness of straight sections of pipe shall be determined in accordance with eq. (2):

$$t_m = t + c \tag{2}$$

The minimum thickness, T, for the pipe selected, considering manufacturer's minus tolerance, shall be not less than t_m.

(b) The following nomenclature is used in the equations for pressure design of straight pipe:

c = sum of the mechanical allowances (thread or groove depth) plus corrosion and erosion allowances. For threaded components, the nominal thread depth (dimension h of ASME B1.20.1, or equivalent) shall apply. For machined surfaces or grooves where the tolerance is not specified, the tolerance shall be assumed to be 0.5 mm (0.02 in.) in addition to the specified depth of the cut.

D = outside diameter of pipe as listed in tables of standards or specifications or as measured

d = inside diameter of pipe. For pressure design calculation, the inside diameter of the pipe is the maximum value allowable under the purchase specification.

E = quality factor from Table A-1A or A-1B

P = internal design gage pressure

S = stress value for material from Table A-1

T = pipe wall thickness (measured or minimum in accordance with the purchase specification)

t = pressure design thickness, as calculated in accordance with para. 304.1.2 for internal pressure or as determined in accordance with para. 304.1.3 for external pressure

t_m = minimum required thickness, including mechanical, corrosion, and erosion allowances

W = weld joint strength reduction factor in accordance with para. 302.3.5(e)

Y = coefficient from Table 304.1.1, valid for $t < D/6$ and for materials shown. The value of Y may be interpolated for intermediate temperatures. For $t \geq D/6$,

Table 304.1.1 Values of Coefficient Y for $t < D/6$

	Temperature, °C (°F)					
Materials	≤ 482 (900 & Lower)	510 (950)	538 (1,000)	566 (1,050)	593 (1,100)	≥ 621 (1,150 & Up)
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7
Other ductile metals	0.4	0.4	0.4	0.4	0.4	0.4
Cast iron	0.0	...	...	...	...	...

$$Y = \frac{d + 2c}{D + d + 2c}$$

304.1.2 Straight Pipe Under Internal Pressure

(a) For $t < D/6$, the internal pressure design thickness for straight pipe shall be not less than that calculated in accordance with either eq. (3a) or eq. (3b):

$$t = \frac{PD}{2(SEW + PY)} \tag{3a}$$

$$t = \frac{P(d + 2c)}{2[SEW - P(1 - Y)]} \tag{3b}$$

(b) For $t \geq D/6$ or for $P/SE > 0.385$, calculation of pressure design thickness for straight pipe requires special consideration of factors such as theory of failure, effects of fatigue, and thermal stress.

304.1.3 Straight Pipe Under External Pressure. To determine wall thickness and stiffening requirements for straight pipe under external pressure, the procedure outlined in the BPV Code, Section VIII, Division 1, UG-28 through UG-30 shall be followed, using as the design length, L, the running centerline length between any two sections stiffened in accordance with UG-29. As an exception, for pipe with $D_o/t < 10$, the value of S to be used in determining P_{a2} shall be the lesser of the following values for pipe material at design temperature:

(a) 1.5 times the stress value from Table A-1 of this Code, or

(b) 0.9 times the yield strength tabulated in Section II, Part D, Table Y-1 for materials listed therein

(The symbol D_o in Section VIII is equivalent to D in this Code.)

304.2 Curved and Mitered Segments of Pipe

304.2.1 Pipe Bends. The minimum required thickness, t_m, of a bend, after bending, in its finished form, shall be determined in accordance with eqs. (2) and (3c)

$$t = \frac{PD}{2[(SEW/I) + PY]} \tag{3c}$$

11/12/14 SWARTZ

B31.3-2012 Eq 3a rearranged for P

$$t = \frac{PD}{2(SEW + PY)}$$

$$2t(SEW + PY) = PD$$

$$2tSEW + 2tPY = PD$$

$$PD = 2tSEW + 2tPY$$

$$PD - 2tPY = 2tSEW$$

$$P(D - 2ty) = 2tSEW$$

$$P = \frac{2tSEW}{D - 2yt}$$

$y = .4$
$W = 1$
$E = 1$

$$P = \frac{2tS}{D - .8t}$$

Table A-1 Basic Allowable Stresses in Tension for Metals[1] (Cont'd)

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Nominal Composition	Product Form	Spec. No.	UNS No.	Class/ Condition/ Temper	Size Range, in.	P-No. (5)(46)	Notes	Min. Temp., °F (6)	Specified Min. Strength, ksi Tensile	Yield
Copper and Copper Alloy Pipes and Tubes (2)										
...	Pipe	B42	C10200	O61	...	31	...	−452	30	9
...	Pipe	B42	C12000	O61	...	31	...	−452	30	9
...	Pipe	B42	C12200	O61	...	31	...	−452	30	9
...	Tube	B75	C10200	O50	...	31	...	−452	30	9
...	Tube	B75	C10200	O60	...	31	...	−452	30	9
...	Tube	B75	C12000	O50	...	31	...	−452	30	9
...	Tube	B75	C12000	O60	...	31	...	−452	30	9
...	Tube	B75	C12200	O50	...	31	...	−452	30	9
...	Tube	B75	C12200	O60	...	31	...	−452	30	9
...	Tube	B68	C12200	O50	...	31	(24)	−452	30	9
...	Tube	B68	C12200	O60	...	31	(24)	−452	30	9
...	Tube	B88	C12200	O50	...	31	(24)	−452	30	9
...	Tube	B88	C12200	O60	...	31	(24)	−452	30	9
...	Tube	B280	C12200	O60	...	31	(24)	−452	30	9
Red brass	Pipe	B43	C23000	O61	...	32	...	−452	40	12
90Cu–10Ni	...	B467	C70600	WO50	> 4.5 O.D.	34	(14)	−452	38	13
90Cu–10Ni	...	B467	C70600	WO61	> 4.5 O.D.	34	(14)	−452	38	13
90Cu–10Ni	...	B466	C70600	Annealed	...	34	(14)	−452	38	13
90Cu–10Ni	...	B467	C70600	WO50	≤ 4.5 O.D.	34	(14)	−452	40	15
90Cu–10Ni	...	B467	C70600	WO61	≤ 4.5 O.D.	34	(14)	−452	40	15
70Cu–30Ni	...	B467	C71500	WO50	> 4.5 O.D.	34	(14)	−452	45	15
70Cu–30Ni	...	B467	C71500	WO61	> 4.5 O.D.	34	(14)	−452	45	15
80Cu–20Ni	...	B466	C71000	Annealed	≤ 4.5 O.D.	34	(14)	−452	45	16
...	Pipe	B42	C10200	H55	NPS 2½ thru 12	31	(14)(34)	−452	36	30
...	Pipe	B42	C12000	H55	NPS 2½ thru 12	31	(14)(34)	−452	36	30
...	Pipe	B42	C12200	H55	NPS 2½ thru 12	31	(14)(34)	−452	36	30
...	Tube	B75	C10200	H58	...	31	(14)(34)	−452	36	30
...	Tube	B75	C12000	H58	...	31	(14)(34)	−452	36	30
...	Tube	B75	C12200	H58	...	31	(14)(34)	−452	36	30
...	Tube	B88	C12200	H58	...	31	(14)(24)(34)	−452	36	30
70Cu–30Ni	...	B466	C71500	O60	...	34	(14)	−452	52	18
70Cu–30Ni	...	B467	C71500	WO50	≤ 4.5 O.D.	34	(14)	−452	50	20
70Cu–30Ni	...	B467	C71500	WO61	≤ 4.5 O.D.	34	(14)	−452	50	20
...	Pipe	B42	C10200	H80	NPS ⅛ thru 2	31	(14)(34)	−452	45	40
...	Pipe	B42	C12000	H80	NPS ⅛ thru 2	31	(14)(34)	−452	45	40
...	Pipe	B42	C12200	H80	NPS ⅛ thru 2	31	(14)(34)	−452	45	40
...	Tube	B75	C10200	H80	...	31	(14)(34)	−452	45	40
...	Tube	B75	C12000	H80	...	31	(14)(34)	−452	45	40
...	Tube	B75	C12200	H80	...	31	(14)(34)	−452	45	40
Plates and Sheets										
...	...	B152	C10200	O25	...	31	(14)(24)	−452	30	10
...	...	B152	C10400	O25	...	31	(14)(24)	−452	30	10
...	...	B152	C10500	O25	...	31	(14)(24)	−452	30	10
...	...	B152	C10700	O25	...	31	(14)(24)	−452	30	10
...	...	B152	C12200	O25	...	31	(14)(24)	−452	30	10
...	...	B152	C12300	O25	...	31	(14)(24)	−452	30	10

Table A-1 Basic Allowable Stresses in Tension for Metals[1] (Cont'd)

Numbers in Parentheses Refer to Notes for Appendix A Tables; Specifications Are ASTM Unless Otherwise Indicated

Basic Allowable Stress, *S*, ksi (1), at Metal Temperature, °F														
Min. Temp. to 100	150	200	250	300	350	400	450	500	550	600	650	700	UNS No.	Spec. No.
														Copper and Copper Alloy Pipes and Tubes (2)
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C10200	B42
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12000	B42
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12200	B42
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C10200	B75
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C10200	B75
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12000	B75
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12000	B75
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12200	B75
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12200	B75
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12200	B68
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12200	B68
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12200	B88
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12200	B88
6.0	5.1	4.9	4.8	4.7	4.0	3.0	2.3	1.7	...	...	...	...	C12200	B280
8.0	7.9	7.9	7.9	7.9	7.0	5.0	2.0	...	...	...	...	...	C23000	B43
8.7	8.4	8.2	8.0	7.8	7.7	7.5	7.4	7.3	7.0	6.0	...	...	C70600	B467
8.7	8.4	8.2	8.0	7.8	7.7	7.5	7.4	7.3	7.0	6.0	...	...	C70600	B467
8.7	8.4	8.2	8.0	7.8	7.7	7.5	7.4	7.3	7.0	6.0	...	...	C70600	B466
10.0	9.7	9.5	9.3	9.1	8.9	8.7	8.5	8.0	7.0	6.0	...	...	C70600	B467
10.0	9.7	9.5	9.3	9.1	8.9	8.7	8.5	8.0	7.0	6.0	...	...	C70600	B467
10.0	9.6	9.4	9.2	9.0	8.8	8.6	8.4	8.2	8.1	8.0	7.9	7.8	C71500	B467
10.0	9.6	9.4	9.2	9.0	8.8	8.6	8.4	8.2	8.1	8.0	7.9	7.8	C71500	B467
10.7	10.6	10.5	10.4	10.2	10.1	9.9	9.6	9.3	8.9	8.4	7.7	7.0	C71000	B466
12.0	11.6	10.9	10.4	10.0	9.8	9.5	...	...	...	...	...	...	C10200	B42
12.0	11.6	10.9	10.4	10.0	9.8	9.5	...	...	...	...	...	...	C12000	B42
12.0	11.6	10.9	10.4	10.0	9.8	9.5	...	...	...	...	...	...	C12200	B42
12.0	11.6	10.9	10.4	10.0	9.8	9.5	...	...	...	...	...	...	C10200	B75
12.0	11.6	10.9	10.4	10.0	9.8	9.5	...	...	...	...	...	...	C12000	B75
12.0	11.6	10.9	10.4	10.0	9.8	9.5	...	...	...	...	...	...	C12200	B75
12.0	11.6	10.9	10.4	10.0	9.8	9.5	...	...	...	...	...	...	C12200	B88
12.0	11.6	11.3	11.0	10.8	10.6	10.3	10.1	9.9	9.8	9.6	9.5	9.4	C71500	B466
13.3	12.9	12.6	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.7	10.5	10.4	C71500	B467
13.3	12.9	12.6	12.3	12.0	11.7	11.5	11.2	11.0	10.8	10.7	10.5	10.4	C71500	B467
15.0	14.5	13.6	13.0	12.6	12.2	4.3	...	...	...	...	...	...	C10200	B42
15.0	14.5	13.6	13.0	12.6	12.2	4.3	...	...	...	...	...	...	C12000	B42
15.0	14.5	13.6	13.0	12.6	12.2	4.3	...	...	...	...	...	...	C12200	B42
15.0	14.5	13.6	13.0	12.6	12.2	4.3	...	...	...	...	...	...	C10200	B75
15.0	14.5	13.6	13.0	12.6	12.2	4.3	...	...	...	...	...	...	C12000	B75
15.0	14.5	13.6	13.0	12.6	12.2	4.3	...	...	...	...	...	...	C12200	B75
														Plates and Sheets
6.7	5.7	5.4	5.3	5.0	4.0	3.0	2.3	1.7	...	...	...	...	C10200	B152
6.7	5.7	5.4	5.3	5.0	4.0	3.0	2.3	1.7	...	...	...	...	C10400	B152
6.7	5.7	5.4	5.3	5.0	4.0	3.0	2.3	1.7	...	...	...	...	C10500	B152
6.7	5.7	5.4	5.3	5.0	4.0	3.0	2.3	1.7	...	...	...	...	C10700	B152
6.7	5.7	5.4	5.3	5.0	4.0	3.0	2.3	1.7	...	...	...	...	C12200	B152
6.7	5.7	5.4	5.3	5.0	4.0	3.0	2.3	1.7	...	...	...	...	C12300	B152

502.4.4 Mechanical Strength. When necessary to prevent damage, collapse, or buckling due to superimposed loads from supports, backfill, or other causes, the pipe wall thickness shall be increased, or, if this is impractical or would cause excessive local stresses, the factors that would contribute to damage of the piping shall be compensated for by other design methods.

Section 502 pertains to ratings, stress values, stress criteria, design allowances, and minimum design values, and formulates the permissible variations to these factors used in the design of piping.

PART 2
DESIGN OF PIPING COMPONENTS

503 CRITERIA FOR DESIGN OF PIPING COMPONENTS

The design of piping components, considering the effects of pressure, and providing for mechanical, corrosion, and erosion allowances, shall be in accordance with section 504. In addition, the designs must be checked for adequacy of mechanical strength under other applicable loadings as given in section 501.

504 PRESSURE DESIGN OF PIPING COMPONENTS

504.1 Straight Pipe

504.1.1 General

(a) The required wall thickness of straight sections of pipe shall be determined in accordance with eq. (2). (Also, see section 503.)

$$t_m = t + c \tag{2}$$

(b) The notations described below are used in the equations for the pressure design of straight pipe.

c = for internal pressure, the sum, in. (mm), of the mechanical allowances (thread depth, groove depth, and manufacturer's minus tolerance) plus corrosion and erosion allowances. (See para. 502.4.1.) For threaded components, the nominal thread depth (dimension h of ASME B1.20.1, or equivalent) shall apply. For machined surfaces or grooves, where the tolerance is not specified, the tolerance shall be assumed to be $\frac{1}{64}$ in. (0.5 mm) in addition to the specified depth of the cut.

= for external pressure, the sum, in. (mm), of corrosion and erosion allowances plus manufacturer's minus tolerance (see para. 502.4.1)

D_o = outside diameter of pipe, in. (mm)

d = inside diameter of pipe, in. (mm), excluding metal required for corrosion or erosion allowance, manufacturer's minus tolerance, and any allowance required for the depth of internal threads or grooves

P = internal design pressure (see para. 501.2.2), psi (kPa), or external design pressure (see para. 501.2.3), psi (kPa)

S = applicable allowable hoop stress in accordance with para. 502.3.1 and Table 502.3.1, psi (kPa)

t = pressure design wall thickness, in. (mm), as calculated from eqs. (3a) and (3b) for internal pressure, or in accordance with the procedures given in para. 504.1.3 for external pressure

t_m = minimum required wall thickness, in. (mm), satisfying requirements for design pressure and mechanical, corrosion, and erosion allowances

y = coefficient for materials indicated: for ductile nonferrous materials, use $y = 0.4$ (see Note); for ferritic steels, use $y = 0.4$ (see Note); for austenitic steels, use $y = 0.4$ (see Note). For cast iron, use $y = 0.0$.

NOTE: If D_o/t is in the range of 4–6, use $y = d/(d + D_o)$ for ductile materials.

504.1.2 Straight Pipe Under Internal Pressure. For metallic pipe with diameter–thickness ratios $D_o/t > 4$, the internal pressure design wall thickness, t, shall be calculated using eq. (3a) or (3b).

$$t = \frac{PD_o}{2\,(S + Py)} \tag{3a}$$

or

$$t = \frac{Pd}{2\,(S + Py - P)} \tag{3b}$$

where

$$P = \frac{2St}{D_o - 2yt}$$

NOTE: The following simpler alternative equations, which give somewhat greater wall thickness, may be employed:

$$t = \frac{PD_o}{2\,S}$$

or

$$t = \frac{Pd}{2\,(S - P)}$$

where

$$P = \frac{2St}{D_o}$$

504.1.3 Straight Pipe Under External Pressure. To determine wall thickness and stiffening requirements for straight pipe under external pressure, the procedure outlined in the BPV Code, Section VIII, Division 1, UG-28 through UG-30 shall be followed, using as the design length, L, the running centerline length between any two sections stiffened in accordance with UG-29. As an exception, for pipe with $D_o/t < 10$, the value of S to be

Table 502.3.1 Maximum Allowable Stress Values, ksi (Cont'd)
(Multiply by 1,000 to Obtain psi)

Material	Spec. No.	Size or Wall, in.	Copper or Copper Alloy No.	Temper	Min. Tensile Strength, ksi [Note (3)]	Min. Yield Strength, ksi [Note (3)]
Seamless Copper and Copper Alloy Pipe and Tube						
Copper pipe	ASTM B42	All	C10200 C12200	Annealed (O61)	30.0	9.0
Copper pipe [Note (4)]	ASTM B42	1/8–2, incl.	C10200 C12200	Hard drawn (H80)	45.0	40.0
Copper pipe [Note (4)]	ASTM B42	2–12, incl.	C10200 C12200	Light drawn (H55)	36.0	30.0
Red brass pipe	ASTM B43	All	C23000	Annealed (O61)	40.0	12.0
Copper tube	ASTM B68	All	C10200 C12200	Light anneal, soft anneal (O50, O60)	30.0	9.0
Copper tube	ASTM B75	All	C10200 C12200	Light anneal, soft anneal (O50, O60)	30.0	9.0
Copper tube [Note (4)]	ASTM B75	All	C10200 C12200 C14200	Light drawn (H55)	36.0	30.0
Copper tube [Note (4)]	ASTM B75	Up to 4	C10200 C12200	Hard drawn (H80)	45.0	40.0
Copper tube [Note (4)]	ASTM B88	All	C10200 C12200	Drawn general purpose (H58)	36.0	30.0
Copper tube	ASTM B88	All	C10200 C12200	Light anneal (O50)	30.0	9.0
Copper tube [Note (4)]	ASTM B111	Up to 3 1/8, incl.	C10200 C12200 C14200	Light drawn (H55)	36.0	30.0
Copper tube [Note (4)]	ASTM B111	Up to 3 1/8, incl.	C10200 C12200 C14200	Hard drawn (H80)	45.0	40.0
Copper alloy	ASTM B111	Up to 3 1/8, incl.	C19200	Annealed (O61)	38.0	12.0
Red brass condenser tube	ASTM B111	Up to 3 1/8, incl.	C23000	Annealed (O61)	40.0	12.0

Table 502.3.1 Maximum Allowable Stress Values, ksi (Cont'd)
(Multiply by 1,000 to Obtain psi)

For Metal Temperatures, °F							
100	150	200	250	300	350	400	Spec. No.
							Seamless Copper and Copper Alloy Pipe and Tube
6.0	5.1	4.9	4.8	4.7	4.0	3.0	ASTM B42
12.9	12.9	12.9	12.9	12.5	11.8	4.3	ASTM B42
10.3	10.3	10.3	10.3	10.0	9.7	9.4	ASTM B42
8.0	8.0	8.0	8.0	8.0	7.0	5.0	ASTM B43
6.0	5.1	4.9	4.8	4.7	4.0	3.0	ASTM B68
6.0	5.1	4.9	4.8	4.7	4.0	3.0	ASTM B75
10.3	10.3	10.3	10.3	10.0	9.7	9.4	ASTM B75
12.9	12.9	12.9	12.9	12.5	11.8	4.3	ASTM B75
10.3	10.3	10.3	10.3	10.0	9.7	9.4	ASTM B88
6.0	5.1	4.9	4.8	4.7	4.0	3.0	ASTM B88
10.3	10.3	10.3	10.3	10.0	9.7	9.4	ASTM B111
12.9	12.9	12.9	12.9	12.5	11.8	4.3	ASTM B111
8.0	7.1	6.7	6.4	6.2	...	...	ASTM B111
8.0	8.0	8.0	8.0	8.0	7.0	5.0	ASTM B111

Design pressure shall not exceed that determined by eq. (2).

$$P = \frac{2SE\,(t_m - A)}{D} \qquad (2)$$

The engineer may, at his option, use the values of t_m and P determined by the applicable equations in ASME B31.1.

(1) If pipe is ordered by its nominal wall thickness, the manufacturing tolerances on wall thickness must be taken into account. After the minimum wall thickness t_m is determined, this minimum thickness shall be increased to provide the manufacturing tolerance allowed in the applicable pipe specification. The next heavier commercial wall thickness shall then be selected.

(2) When computing the design pressure for a pipe of a definite minimum wall thickness t_m, the value of pressure obtained by eq. (2) may be rounded to the next higher increment of 10 psi (69 kPa).

(b) Ductile Iron Pipe. The thickness of ductile iron pipe shall be determined from one of the following:

(1) ANSI/AWWA C150/A21.50 or C151/A21.51

(2) ANSI A21.14 or A21.52

(3) Federal Specification WW-P-421

The tabulated thicknesses in these standards include allowances for foundry tolerances and water hammer.

(c) Straight Nonmetallic Pipe. The maximum pressure ratings for plastic and other nonmetallic pipe shall be as given in the applicable standards listed in Table 926.1.

904.1.2 Straight Metallic Pipe Under External Pressure. In determining wall thickness and stiffening requirements for straight pipe under external pressure, the procedures outlined in UG-28 of Section VIII, Division 1 of the ASME BPV Code shall be followed.

904.2 Curved and Mitered Segments of Pipe

904.2.1 Pipe Bends

(a) Thickness of Bends. The minimum wall thickness t_m at any point in a completed pipe bend shall not be less than that required by para. 904.1.1. Table 904.2.1 may be used as a guide in specifying wall thickness for ordering pipe to be bent.

(b) Flattening of Bends. Flattening of a bend, as measured by the difference of maximum and minimum diameters, shall not exceed 8% of the average measured outside diameter of the pipe before bending.

Greater flattening may be permitted or less flattening may be required if specified by the engineering design.

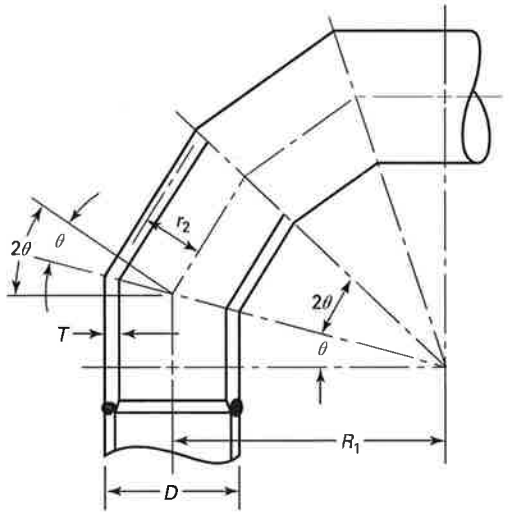
904.2.2 Miter Joints. Thickness determined in accordance with para. 904.1.1 does not allow for discontinuity stresses at the joint between mitered segments of pipe. These discontinuity stresses are negligible for miter angles of 3 deg or less in any service, and may be neglected for miters in nonflammable, nontoxic liquid service at pressures of 50 psig (345 kPa) or less, and for unvalved vents to atmosphere. See Fig. 904.2.2 for nomenclature.

Table 904.2.1 Pipe Thickness for Bends

Radius of Bends, Pipe Diameters, D_n [Note (1)]	Minimum Thickness Recommended Prior to Bending, t_m
6 or greater	1.06
5	1.08
4	1.14
3	1.24

NOTE:
(1) Interpolation is permissible for a radius other than those listed.

Fig. 904.2.2 Nomenclature for Miter Joints



(a) Allowable Pressure. For other services and for pressures in excess of 50 psig (345 kPa), the maximum allowable pressure for miter joints where θ does not exceed 22½ deg shall be the lower positive value calculated by eqs. (3A) and (3B).

$$P = \frac{SET}{r_2}\left(\frac{T}{T + 0.64\tan\theta\sqrt{r_2 T}}\right) \qquad (3A)$$

$$P = \frac{SET}{r_2}\left(\frac{R_1 - r_2}{R_1 - 0.5r_2}\right) \qquad (3B)$$

Equations (3A) and (3B) apply only when R_1 is at least as great as the value calculated by eq. (4).

Table I-1 Allowable Stresses (Cont'd)

Material	Spec. No.	Alloy No.	Condition	P-No.	Notes	Strengths: Min. Tensile, ksi	Strengths: Min. Yield, ksi	Max. Allowable Stress Value in Tension *SE*, ksi, for Metal Temperature, °F, Not Exceeding: 0 to 100	150	200	250	300	350	400
Copper and Copper Alloys														
Seamless Pipe and Tube														
Copper Pipe, Size range NPS $\frac{1}{8}$–2 incl.	ASTM B 42	102, 122	Annealed	31	...	30.0	9.0	6.0	5.1	4.9	4.8	4.7	4.0	3.0
Copper Pipe, Size range NPS $\frac{1}{8}$–2 incl.	ASTM B 42	102, 122	Hard drawn	31	(12)	45.0	40.0	12.9	12.9	12.9	12.9	12.5	11.8	4.3
Copper Pipe, Size range NPS $2\frac{1}{2}$–12 incl.	ASTM B 42	102, 122	Light drawn	31	(12)	36.0	30.0	10.3	10.3	10.3	13.3	10.0	9.7	9.4
Red Brass Pipe	ASTM B 43	230	Annealed	32	...	40.0	12.0	8.0	8.0	8.0	8.0	8.0	7.0	5.0
Copper Tube	ASTM B 68	102, 122	Annealed	31	(1)	30.0	9.0	6.0	5.1	4.9	4.8	4.7	4.0	3.0
Copper Tube	ASTM B 75	102, 122	Annealed	31	...	30.0	9.0	6.0	5.1	4.9	4.8	4.7	4.0	3.0
Copper Tube	ASTM B 75	102, 122	Light drawn	31	(12)	36.0	30.0	10.3	10.3	10.3	10.3	10.0	9.7	9.4
Copper Tube	ASTM B 75	102, 122	Hard drawn	31	(12)	45.0	40.0	11.3	11.3	11.3	11.3	11.0	10.3	4.3
Copper Tube	ASTM B 88	102, 122	Annealed	31	(1)	30.0	9.0	6.0	5.1	4.9	4.8	4.7	4.0	3.0
Copper Tube	ASTM B 88	102, 122	Drawn	31	(1)(12)	36.0	30.0	10.3	10.3	10.3	10.3	10.0	9.7	9.4
Brass Tube	ASTM B 135	230	Annealed	32	...	40.0	12.0	8.0	8.0	8.0	8.0	8.0	7.0	5.0
Copper Tube	ASTM B 280	102, 122	Annealed	31	(1)	30.0	9.0	6.0	5.1	4.8	4.8	4.7	4.0	3.0
Copper Pipe, Threadless	ASTM B 302	102, 122	Drawn	32	(1)	36.0	30.0	10.3	10.3	10.3	10.3	10.0	9.7	9.4

GENERAL NOTES:

(a) See para. 902.3 for discussion of allowable stress values.

(b) The tabulated specifications are ASTM, except as noted. For boiler external piping, the corresponding ASME specifications shall be used. See Section II of the ASME BPV Code.

(c) The stress values may be interpolated to determine allowable stresses for intermediate temperatures.

(d) The P-Numbers indicated in this Appendix are identical to those adopted in Section IX of the ASME BPV Code.

(e) All stress values are shown in units of thousands of pounds-force per square in. (ksi). Multiply by 1000 to obtain values in psi.

(f) Materials listed in Table 926.1 for which allowable stress values are not tabulated in Appendix I may be used at allowable stresses found in ASME B31.1 or in Section I or Section VIII, Division 1 of the ASME BPV Code. However, the temperature limits in this Code shall apply.

metal has been magnetic particle or dye penetrant inspected to ensure complete removal of discontinuities. [Refer to para. 127.4.11(A).]

(B.2.4) All weld repairs of depth exceeding 1 in. (25 mm) or 20% of the section thickness, whichever is the lesser, shall be inspected by radiography in accordance with (B.2.2) above and by magnetic particle or dye penetrant inspection of the finished weld surface. All weld repairs of depth less than 20% of the section thickness, or 1 in. (25 mm), whichever is the lesser, and all weld repairs of section that cannot be effectively radiographed shall be examined by magnetic particle or dye penetrant inspection of the first layer, of each ¼ in. (6 mm) thickness of deposited weld metal, and of the finished weld surface. Magnetic particle or dye penetrant testing of the finished weld surface shall be done after postweld heat treatment.

(C) For cast iron and nonferrous materials, no increase of the casting quality factor is allowed except when special methods of examination, prescribed by the material specification, are followed. If such increase is specifically permitted by the material specification, a factor not exceeding 1.0 may be applied.

102.4.7 Weld Strength Reduction Factors. At elevated temperatures, seam welds on longitudinal-welded or spiral-welded pipe can have lower creep strength than the base material. This reduction is a factor in determining the minimum wall thickness for longitudinal-welded or spiral-welded pipe (i.e., not seamless), whether fabricated in accordance with a material specification or fabricated in accordance with the rules of this Code. The weld strength reduction factor, W, is given in Table 102.4.7. The designer is responsible to assess application of weld strength reduction factor requirements for welds other than longitudinal and spiral, as applicable (e.g., circumferential welds).

PART 2
PRESSURE DESIGN OF PIPING COMPONENTS

103 CRITERIA FOR PRESSURE DESIGN OF PIPING COMPONENTS

The design of piping components shall consider the effects of pressure and temperature, in accordance with paras. 104.1 through 104.7, including the consideration of allowances permitted by paras. 102.2.4 and 102.4. In addition, the mechanical strength of the piping system shall be determined adequate in accordance with para. 104.8 under other applicable loadings, including but not limited to those loadings defined in para. 101.

104 PRESSURE DESIGN OF COMPONENTS

104.1 Straight Pipe

104.1.1 Straight Pipe Under Internal Pressure. Straight pipe under internal pressure shall have a minimum wall thickness calculated per para. 104.1.2 if the pipe is of seamless construction or is designed for sustained operation below the creep range. Straight pipe under internal pressure shall have a minimum wall thickness calculated per para. 104.1.4 if the pipe is of longitudinal-welded or spiral-welded construction designed for sustained operation within the creep range. (See para. 123.4 for definition of the creep range.)

104.1.2 Straight Pipe Under Internal Pressure — Seamless, Longitudinal Welded, or Spiral Welded and Operating Below the Creep Range

(A) Minimum Wall Thickness. The minimum thickness of pipe wall required for design pressures and for temperatures not exceeding those for the various materials listed in the Allowable Stress Tables, including allowances for mechanical strength, shall not be less than that determined by eq. (7) or (8), as follows:

$$t_m = \frac{PD_o}{2(SE + Py)} + A \qquad (7)^3$$

$$t_m = \frac{Pd + 2SEA + 2yPA}{2(SE + Py - P)} \qquad (8)^3$$

Design pressure shall not exceed

$$P = \frac{2SE(t_m - A)}{D_o - 2y(t_m - A)} \qquad (9)^3$$

$$P = \frac{2SE(t_m - A)}{d - 2y(t_m - A) + 2t_m} \qquad (10)^3$$

where the nomenclature used above is:

(A.1) t_m = minimum required wall thickness, in. (mm)

(A.1.1) If pipe is ordered by its nominal wall thickness, the manufacturing tolerance on wall thickness must be taken into account. After the minimum pipe wall thickness t_m is determined by eq. (7) or (8), this minimum thickness shall be increased by an amount sufficient to provide the manufacturing tolerance allowed in the applicable pipe specification or required by the process. The next heavier commercial wall thickness shall then be selected from thickness schedules such as contained in ASME B36.10M or from manufacturers' schedules for other than standard thickness.

(A.1.2) To compensate for thinning in bends, refer to para. 102.4.5.

(A.1.3) For cast piping components, refer to para. 102.4.6.

[3] SF shall be used in place of SE where casting quality factors are intended. See definition of SE. Units of P and SE must be identical. Mandatory Appendix A values must be converted to kPa when the design pressure is in kPa.

Table 102.4.7 Weld Strength Reduction Factors to Be Applied When Calculating the Minimum Wall Thickness or Allowable Design Pressure of Components Fabricated With a Longitudinal Seam Fusion Weld

Steel Group	Weld Strength Reduction Factor for Temperature, °F (°C) [Notes (1)–(6)]										
	700 (371)	750 (399)	800 (427)	850 (454)	900 (482)	950 (510)	1,000 (538)	1,050 (566)	1,100 (593)	1,150 (621)	1,200 (649)
Carbon (Norm.) [Notes (7), (8)]	1.00	0.95	0.91	NP	NP	NP	NP	NP	NP	NP	NP
Carbon (Sub Crit) [Notes (8), (9)]	1.00	0.95	0.91	NP	NP	NP	NP	NP	NP	NP	NP
CrMo [Notes (8), (10), (11)]	...	...	1.00	0.95	0.91	0.86	0.82	0.77	0.73	0.68	0.64
CSEF (N+T) [Notes (8), (12), (13)]	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77
CSEF (Sub Crit) [Notes (8), (9)]	...	...	...	...	1.00	0.73	0.68	0.64	0.59	0.55	0.50
Austenitic stainless (incl. 800H & 800HT) [Notes (14), (15)]	...	...	...	...	...	1.00	0.95	0.91	0.86	0.82	0.77
Autogenously welded austenitic stainless [Note (16)]	...	...	...	...	...	1.00	1.00	1.00	1.00	1.00	1.00

NOTES:

(1) NP = not permitted.

(2) Longitudinal welds in pipe for materials not covered in this Table operating in the creep regime are not permitted. For the purposes of this Table, the start of the creep range is the highest temperature where the nonitalicized stress values end in Mandatory Appendix A for the base material involved.

(3) All weld filler metal shall be a minimum of 0.05% C for CrMo and CSEF materials, and 0.04% C for austenitic stainless in this Table.

(4) Materials designed for temperatures below the creep range [see Note (2)] may be used without consideration of the WSRF or the rules of this Table. All other Code rules apply.

(5) Longitudinal seam welds in CrMo and CSEF materials shall be subjected to, and pass, a 100% volumetric examination (RT or UT). For materials other than CrMo and CSEF, see para. 123.4(B).

(6) At temperatures below those where WSRFs are tabulated, a value of 1.0 shall be used for the factor W where required by the rules of this Section. However, the additional rules of this Table and Notes do not apply.

(7) Norm. = normalizing postweld heat treatment (PWHT) is required.

(8) Basicity index of SAW flux ≥ 1.0.

(9) Sub Crit = subcritical PWHT is required. No exemptions from PWHT are permitted. The PWHT time and temperature shall meet the requirements of Table 132; the alternate PWHT requirements of Table 132.1 are not permitted.

(10) The CrMo steels include ½Cr–½Mo, 1Cr–½Mo, 1¼Cr–½Mo–Si, 2¼Cr–1Mo, 3Cr–1Mo, and 5Cr–½Mo. Longitudinal welds shall either be normalized, normalized and tempered, or subjected to proper subcritical PWHT for the alloy.

(11) Longitudinal seam fusion welded construction is not permitted for C–½Mo steel for operation in the creep range [see Notes (2) and (4)].

(12) The CSEF (creep strength enhanced ferritic) steels include Grades 91, 92, 911, 122, and 23.

(13) N+T = normalizing + tempering PWHT.

(14) WSRFs have been assigned for austenitic stainless (including 800H and 800HT) longitudinally welded pipe up to 1,500°F as follows:

Temperature, °F	Temperature, °C	Weld Strength Reduction Factor
1,250	677	0.73
1,300	704	0.68
1,350	732	0.64
1,400	760	0.59
1,450	788	0.55
1,500	816	0.5

(15) Certain heats of the austenitic stainless steels, particularly for those grades whose creep strength is enhanced by the precipitation of temper-resistant carbides and carbo-nitrides, can suffer from an embrittlement condition in the weld heat affected zone that can lead to premature failure of welded components operating at elevated temperatures. A solution annealing heat treatment of the weld area mitigates this susceptibility.

(16) Autogenous SS welded pipe (without weld filler metal) has been assigned a WSRF up to 1,500°F of 1.00, provided that the product is solution annealed after welding and receives nondestructive electric examination, in accordance with the material specification.

(A.1.4) Where ends are subject to forming or machining for jointing, the wall thickness of the pipe, tube, or component after such forming or machining shall not be less than t_m minus the amount provided for removal by para. 104.1.2 (A.6.1).

(A.2) P = internal design pressure, psig [kPa (gage)]

NOTE: When computing the design pressure for a pipe of a definite minimum wall thickness by eq. (9) or (10), the value of P obtained by these formulas may be rounded out to the next higher unit of 10. For cast iron pipe, see para. 104.1.2(B).

(A.3) D_o = outside diameter of pipe, in. (mm). For design calculations, the outside diameter of pipe as given in tables of standards and specifications shall be used in obtaining the value of t_m. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured outside diameter and actual measured minimum wall thickness at the thinner end of the pipe may be used to calculate this pressure.

(A.4) d = inside diameter of pipe, in. (mm). For design calculations, the inside diameter of pipe is the maximum possible value allowable under the purchase specification. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured inside diameter and actual measured minimum wall thickness at the thinner end of the pipe may be used to calculate this pressure.

(A.5) SE or SF = maximum allowable stress in material due to internal pressure and joint efficiency (or casting quality factor) at the design temperature, psi (MPa). The value of SE or SF shall not exceed that given in Mandatory Appendix A, for the respective material and design temperature. These values include the weld joint efficiency, E, or the casting factor, F.

(A.6) A = additional thickness, in. (mm)

(A.6.1) To compensate for material removed in threading, grooving, etc., required to make a mechanical joint, refer to para. 102.4.2.

(A.6.2) To provide for mechanical strength of the pipe, refer to para. 102.4.4 (not intended to provide for extreme conditions of misapplied external loads or for mechanical abuse).

(A.6.3) To provide for corrosion and/or erosion, refer to para. 102.4.1.

(A.7) y = coefficient having values as given in Table 104.1.2(A)

(B) Thickness of gray and ductile iron fittings conveying liquids may be determined from ANSI/AWWA C110/A21.10 or ANSI/AWWA C153/A21.53. The thickness of ductile iron pipe may be determined by ANSI/AWWA C115/A21.15 or ANSI/AWWA C150/A21.50. These thicknesses include allowances for foundry tolerances and water hammer.

(C) While the thickness determined from eq. (7) or (8) is theoretically ample for both bursting pressure and material removed in threading, the following minimum requirements are mandatory to furnish added mechanical strength:

(C.1) Where steel pipe is threaded and used for steam service at pressure above 250 psi (1 750 kPa) or for water service above 100 psi (700 kPa) with water temperature above 220°F (105°C), the pipe shall be seamless having the minimum ultimate tensile strength of 48,000 psi (330 MPa) and a weight at least equal to Schedule 80 of ASME B36.10M.

(C.2) Where threaded brass or copper pipe is used for the services described in (C.1) above, it shall comply with pressure and temperature classifications permitted for these materials by other paragraphs of this Code and shall have a wall thickness at least equal to that specified above for steel pipe of corresponding size.

(C.3) Plain end nonferrous pipe or tube shall have minimum wall thicknesses as follows:

(C.3.1) For nominal sizes smaller than NPS $\frac{3}{4}$, the thickness shall not be less than that specified for Type K of ASTM B88.

(C.3.2) For nominal sizes NPS $\frac{3}{4}$ and larger, the wall thickness shall not be less than 0.049 in. (1.25 mm). The wall thickness shall be further increased, as required, in accordance with para. 102.4.

104.1.3 Straight Pipe Under External Pressure. For determining wall thickness and stiffening requirements for straight pipe under external pressure, the procedures outlined in UG-28, UG-29, and UG-30 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code shall be followed.

104.1.4 Longitudinal-Welded or Spiral-Welded Pipe Operating in the Creep Range. The minimum thickness of pipe wall required for design pressures and for temperature not exceeding that for the various materials listed in the Allowable Stress Tables shall not be less than that determined by eq. (11) or (12) as follows:

$$t_m = \frac{PD_o}{2(SEW + Py)} + A \tag{11}$$

$$t_m = \frac{Pd + 2SEWA + 2yPA}{2(SEW + Py - P)} \tag{12}$$

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DESIGN PARAMETERS

P-Spec	PS-400
Design Pressure (psig)	150
Design Temperature (°F)	250
Minimum Temperature (°F)	-20
Minimum Test Pressure (psig)	280
Maximum Test Pressure (psig)	295

Calculation Reference:	00-00-CALC-M-0004-R0
Code of Reference:	B31.3, 2002
Fluid Service:	Category D
Material:	Copper
Pressure Rating:	150 psi
External Pressure Rating:	15 psi

GENERAL NOTES

Refer to General Notes 1, 3, 5-10, 20-24.

ALLOWABLE TUBE MATERIALS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Tubing	¼ - 4	Type L	ASTM B88	ASTM B88	Temper 050,060,H	Seamless
Tubing	¼ - 4	Type K	ASTM B88	ASTM B88	Temper 050,060,H	Seamless

REQUIRED SCHEDULES FOR TUBE

P-Spec	Corrosion Allowance	Pipe Size	¼	⅜	½	⅝	¾	1	1 ¼	1 ½	2	2 ½	3	3 ½	4
400	0.00	Thickness	0.030	0.035	0.040	0.042	0.045	0.050	0.055	0.060	0.070	0.080	0.090	0.100	0.110
Bend Radius			3D	3D	3D	3D	3D	3D	3D	3D	3D	3D	3D	3D	3D

FITTINGS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Threaded Fittings	¼ - 4	Class 125	ASME B16.15	AST B62	N/A	Max Temperature 350°
Soldered Fittings	¼ - 4	Type L	ASME B16.18	ASTM B62	N/A	
Soldered Fittings	¼ - 4	Type L	ASME B16.22	ASME B16.22	N/A	
Flared Fittings	⅜ - 2	175 psig	ASME B16.26	ASTM B62	N/A	Max Temperature 100°
Flared Fittings	¼ - 2	500 psig	SAE J513	SAE J513	N/A	With Flare Nuts, Max Temp 200 °
Tube Fittings	¼ - 2	Manufacture's	Manufacturer's	Brass per Manufacturer's	N/A	Swagelok/Cajon/ or Parker

FLANGES

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Threaded Flange	½ - 4	Class 150	ASME B16.24	ASTM B61	N/A	
Threaded Flanges	½ - 4	Class 150	ASME B16.24	ASTM B62	N/A	

MECHANICAL FASTENERS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Fasteners	½ - ⅝	N/A	ASME B18.2.1	ASTM A193	B8 Cl. 1-HH	Refer to General Note 10.
Nuts	½ - ⅝	N/A	ASME B18.2.2	ASTM A194	8F-HH	

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DESIGN PARAMETERS

P-Spec	PS-401						
Design Pressure (psig)	225	225	210	195	180	165	130
Design Temperature (°F)	100	150	200	250	300	350	400
Minimum Temperature (°F)	-452	-452	-452	-452	-452	-452	-452
Minimum Test Pressure (psig)	340	400	395	365	345	370	390
Maximum Test Pressure (psig)	410						

Calculation Reference:	00-00-CALC-M-0004-R0
Code of Reference:	B31.3, 2002
Fluid Service:	Normal
Material:	Copper
Pressure Rating:	225 psi
External Pressure Rating:	N/A

GENERAL NOTES

Refer to General Notes 1, 3, 5-10, 21, 22, 24-26.

ALLOWABLE TUBE MATERIALS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Tubing	¼ - 4	Type L	ASTM B88	ASTM B88	Temper 050,060, H	Seamless
Tubing	¼ - 4	Type K	ASTM B88	ASTM B88	Temper 050,060, H	Seamless

REQUIRED SCHEDULES FOR TUBE

P-Spec	Corrosion Allowance	Pipe Size	¼	⅜	½	⅝	¾	1	1 ¼	1 ½	2	2 ½	3	3 ½	4
401	0.00	Thickness	0.030	0.035	0.040	0.042	0.045	0.050	0.055	0.060	0.070	0.080	0.090	0.100	0.110
Bend Radius			3D	3D	3D	3D	3D	3D	3D	3D	3D	3D	5D	5D	-

FITTINGS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Threaded Fittings	¼ - 4	Class 125	ASME B16.15	AST B62	N/A	Max Temperature 350°
Soldered Fittings	¼ - 4	Type L	ASME B16.18	ASTM B62	N/A	
Soldered Fittings	¼ - 4	Type L	ASME B16.22	ASME B16.22	N/A	
Flared Fittings	¼ - 2	500 psig	SAE J513	SAE J513	N/A	With Flare Nuts, Max Temp 200 °
Tube Fittings	¼ - 2	Manufacture's	Manufacturer's	Brass per Manufacturer's	N/A	Swagelok/Cajon/ or Parker

FLANGES

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Threaded Flange	½ - 4	Class 150	ASME B16.24	ASTM B61	N/A	
Threaded Flanges	½ - 4	Class 150	ASME B16.24	ASTM B62	N/A	

MECHANICAL FASTENERS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Fasteners	½ - ⅝	N/A	ASME B18.2.1	ASTM A193	B8 Cl. 1-HH	Refer to General Note 10.
Nuts	½ - ⅝	N/A	ASME B18.2.2	ASTM A194	8F-HH	

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DESIGN PARAMETERS

P-Spec	PS-402						
Design Pressure (psig)	355	300	280	280	275	235	175
Design Temperature (°F)	100	150	200	250	300	350	400
Minimum Temperature (°F)	-452	-452	-452	-452	-452	-452	-452
Minimum Test Pressure (psig)	535	530	525	525	525	530	525
Maximum Test Pressure (psig)	560						

Calculation Reference:	00-00-CALC-M-0004-R0
Code of Reference:	B31.3, 2002
Fluid Service:	Normal
Material:	Copper
Pressure Rating:	355 psi
External Pressure Rating:	N/A

GENERAL NOTES

Refer to General Notes 1, 3, 5-10, 21, 22, 24-26.

ALLOWABLE TUBE MATERIALS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Tubing	¼ - 2	Type L	ASTM B88	ASTM B88	Temper 050,060, H	Seamless
Tubing	¼ - 2	Type K	ASTM B88	ASTM B88	Temper 050,060, H	Seamless

REQUIRED SCHEDULES FOR TUBE

P-Spec	Corrosion Allowance	Pipe Size	¼	⅜	½	⅝	¾	1	1 ¼	1 ½	2
402	0.00	Thickness	0.030	0.035	0.040	0.042	0.045	0.050	0.055	0.060	0.070
Bend Radius			3D	3D	3D	3D	3D	3D	5D	5D	-

FITTINGS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Threaded Fittings	¼ - 2	Class 250	ASME B16.15	AST B62	N/A	Max Temperature 350°
Soldered Fittings	¼ - 2	Type L	ASME B16.18	ASTM B62	N/A	Brazed
Soldered Fittings	¼ - 2	Type L	ASME B16.22	ASME B16.22	N/A	Brazed
Flared Fittings	¼ - 2	500 psig	SAE J513	SAE J513	N/A	With Flare Nuts, Max Temp 200 °
Tube Fittings	¼ - 2	Manufacture's	Manufacturer's	Brass per Manufacturer's	N/A	Swagelok/Cajon/ or Parker

FLANGES

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Threaded Flange	½ - 2	Class 300	ASME B16.24	ASTM B61	N/A	
Threaded Flanges	½ - 2	Class 300	ASME B16.24	ASTM B62	N/A	

MECHANICAL FASTENERS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Fasteners	½ - ¾	N/A	ASME B18.2.1	ASTM A193	B8 Cl. 1- HH	Min temperature - 325°F, See note 10
Nuts	½ - ¾	N/A	ASME B18.2.2	ASTM A194	8F- HH	

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DESIGN PARAMETERS

P-Spec	PS-403						
Design Pressure (psig)	320	270	255	255	250	210	160
Design Temperature (°F)	100	150	200	250	300	350	400
Minimum Temperature (°F)	-452	-452	-452	-452	-452	-452	-452
Minimum Test Pressure (psig)	480	475	480	480	480	475	480
Maximum Test Pressure (psig)	495						

Calculation Reference:	00-00-CALC-M-0004-R0
Code of Reference:	B31.3, 2002
Fluid Service:	Normal
Material:	Copper
Pressure Rating:	400 psi
External Pressure Rating:	N/A

GENERAL NOTES

Refer to General Notes 1, 3, 5-10, 21, 22, 24-27.

ALLOWABLE TUBE MATERIALS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Tubing	¼ - ⅝	Type L	ASTM B88	ASTM B88	Temper 050,060, H	Seamless, Clean per ASTM B280
Tubing	¼ - 2	Type K	ASTM B88	ASTM B88	Temper 050,060, H	Seamless, Clean per ASTM B280

REQUIRED SCHEDULES FOR TUBE

P-Spec	Corrosion Allowance	Pipe Size	¼	⅜	½	⅝	¾	1	1 ¼	1 ½	2
403	0.00	Thickness	0.030	0.035	0.040	0.042	0.065	0.065	0.065	0.072	0.083
Bend Radius			3D	3D	3D	3D	1.5D	3D	3D	3D	5D

FITTINGS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Threaded Fittings	¼ - 2	Class 250	ASME B16.15	AST B62	N/A	Max Temperature 350°
Soldered Fittings	¼ - 2	Type L	ASME B16.18	ASTM B62	N/A	Brazed
Soldered Fittings	⅛ - 2	Type L	ASME B16.22	ASME B16.22	N/A	Brazed
Flared Fittings	⅛ - 2	500 psig	SAE J513	SAE J513	N/A	With Flare Nuts, Max Temp 200°
Tube Fittings	⅛ - 2	Manufacture's	Manufacturer's	Brass per Manufacturer's	N/A	Swagelok/Cajon/ or Parker

FLANGES

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Threaded Flange	½ - 2	Class 300	ASME B16.24	ASTM B61	N/A	
Threaded Flanges	½ - 2	Class 300	ASME B16.24	ASTM B62	N/A	

MECHANICAL FASTENERS

Component	Size	Rating	Standard	Material	Material Grade	Additional Requirements
Fasteners	½ - ¾	N/A	ASME B18.2.1	ASTM A193	B8 Cl. 1- HH	Min temperature - 325°F, See note 10
Nuts	½ - ¾	N/A	ASME B18.2.2	ASTM A194	8F- HH	