SAE International™

SURFACE VEHICLE INFORMATION REPORT

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(R) Nominal Reference Working Pressures for Steel Hydraulic Tubing

1. ***Scope—***This SAE Information Report is intended to provide design guidance in the selection of steel tubing and related tube fittings for general hydraulic system applications. The information presented herein is based on tubing products which conform to SAE standards listed in the reference section.

1.1 **Purpose—**The purpose of this document is to provide nominal reference working pressures for selecting tube material, OD size and wall thickness for given hydraulic system working pressures based on desired 4 to 1 design factor of the applicable burst pressure rating.

1.2 **Information Report—**Since many factors influence the pressure at which a hydraulic system will or will not perform satisfactorily, this document should not be used as a "standard" nor a "specification," and the values shown herein should not be construed as "guaranteed" minimum or absolutes. This document is an information report only. See SAE J2551 for information concerning designing, bending, fabrication and routing of fluid conductor metallic tube assemblies.

1.3 **Minimum Tensile Strength—**Within the fluid power industry, many criteria are used for determining the pressure capability of steel tubing. In this document, consideration is given to specified minimum tensile strength of the materials to calculate the nominal minimum burst pressure of the specified steel tubing. The actual tensile strength of the material can be easily determined by common methods of testing.

1.4 **Straight Tube Sections—**The nominal reference working pressures listed in this document are for straight tube sections of the listed tubing materials only. Factors such as the thinning of tube walls due to forming operations, shock loads, and vibration characteristics of the system should also be considered when designing all hydraulic tubes and tube assemblies, especially in high pressure applications.

1.5 **Operating at 100% of the Reference Working Pressures—**When designing systems that operate at 100% of the charted reference working pressure, in conjunction with the materials being subjected to bending, cold forming, wall thinning, brazing, welding, side loads, shock loads and extreme vibrations, the maximum yield strength of the material may be compromised and may cause premature failure of the tube material. Therefore, a good recommended practice is to design hydraulic systems to operate at a level less than the calculated maximum reference working pressures of the materials used. This diminished level may vary from application to application, depending on the operating conditions, pressure spikes and designer discretion, 90% is commonly used.

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1.6 Endurance Testing—It is impractical to specify in this report guaranteed allowable working pressures that will satisfy all design criteria for every hydraulic system. Therefore, endurance testing in accordance with SAE J343 and/or ISO 6605 is recommended.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J343—Test and Test Procedures for SAE 100R Series Hydraulic Hose and Hose Assemblies
SAE J356—Welded Flash-Controlled Low-Carbon Steel Tubing Normalized for Bending, Double Flaring, and Beading
SAE J524—Seamless Low-Carbon Steel Tubing Annealed for Bending and Flaring
SAE J525—Welded and Cold Drawn for Low-Carbon Steel Tubing Annealed for Bending and Flaring
SAE J526—Welded Low-Carbon Steel Tubing
SAE J527—Brazed Double Wall Low-Carbon Steel Tubing
SAE J533—Flares for Tubing
SAE J2435—Welded Flash Controlled, SAE 1021 Carbon Steel Tubing, Normalized for Bending, Double Flaring, and Beading
SAE J2467—Welded and Cold-Drawn, SAE 1021 Carbon Steel Tubing Normalized for Bending and Flaring
SAE J2551—Recommended Practices for Fluid Conductor Metallic Tubing Applications
SAE J2613—Welded Flash Controlled High Strength Low Alloy Steel Hydraulic Tubing, Sub-Critically Annealed for Bending, Flaring and Beading
SAE J2614—Welded and Cold Drawn High Strength Low Alloy Steel Hydraulic Tubing, Sub-Critically Annealed for Bending and Flaring

2.1.2 ISO PUBLICATIONS—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ISO 6605—Tests and test procedures

2.2 Related Publications—The following publications are provided for informational purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J246—Spherical and Flanged Sleeve (Compression) Tube Fittings
SAE J514—Hydraulic Tube Fittings
SAE J515—Specification for Hydraulic O-Ring Materials, Properties, and Sizes for Metric and inch Stud Ends, Face Seal Fitting and Four-Screw Flange Tube Connections
SAE J518—Hydraulic Flanged Tube, Pipe, and Hose Connections, Four-Bolt Split Flange Type
SAE J1231—Formed Tube Ends for Hose Connections and Hose Fittings
SAE J1273—Recommended Practices for Hydraulic Hose Assemblies
SAE J1290—Automotive Hydraulic Brake System—Metric Tube Connections
SAE J1453—Fitting—O-Ring Face Seal
SAE J1644—Metallic Tube Connections for Fluid Power and General Use—Test Methods for Threaded Hydraulic Fluid Power Connectors
SAE J1677—Tests and Procedures for SAE Low-Carbon Steel and Copper-Nickel Tubing

2.2.2 ISO PUBLICATIONS—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ISO 2944—Fluid power systems and components - Nominal pressures
ISO 3304—Plain end seamless precision steel tubes - Technical conditions for delivery
ISO 3305—Plain end welded precision steel tubes - Technical conditions for delivery
ISO 4397—Connectors and associated components - Nominal outside diameters of tubes and nominal inside diameters of hoses
ISO 4399—Connectors and associated components - Nominal pressures
ISO 5598—Fluid power systems and components - Vocabulary
ISO 6162—Four-screw split-flange connections
ISO 6163—Round Flange, 8 and 12 screw connections
ISO 6164—Four-screw, one-piece square-flange connections
ISO 8434—Metallic tube connections for fluid power and general Use
ISO 10583—Test Methods for tube connections
ISO 10763—Plain-end, seamless and welded steel tubes - Dimensions and nominal working pressures

2.2.3 DIN PUBLICATIONS—Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

DIN 17120—Welded Circular Steel Tubing
DIN 17121—Seamless Circular Steel Tubing

3. ***Tube Selection—***Tube material, size and wall thickness may be selected from Tables 1 through 4.

4. ***Nominal Pressures—***See Tables 1 through 4 for nominal reference working pressures. The nominal reference working pressures listed are based on a design factor ratio of 4 to 1 between the calculated nominal static reference burst pressure and the calculated nominal reference working pressure using the following formulas:

$$\text{Burst Pressure -- } Pb = Rm,min\left(\ln\frac{D}{d}\right) \qquad \text{(Eq. 1)}$$

$$\text{Working Pressure -- } Pw = \frac{Pb}{4} \qquad \text{(Eq. 2)}$$

where:

Pb is the nominal static reference burst pressure in MPa (megapascals)
Pw is the nominal reference working pressure in MPa (megapascals)
Rm, min is the minimum tensile strength in MPa (megapascals)
ln is the natural logarithm, also referred to as log e
D is the nominal tube outside diameter in millimeters
d is the nominal tube inside diameter in millimeters

NOTE— These formulae and the derived nominal reference working pressures are only applicable to the listed tube materials, of which, all have at least a 50% ratio of the minimum yield strength to the minimum tensile strength. When calculating nominal reference pressures for tube materials where this ratio falls below a 50% ratio, formulae listed in “Appendix A” should be used.

TABLE 1—NOMINAL REFERENCE WORKING PRESSURES IN MPa (MPa X 145 = PSI), FOR SAE J526 AND SAE J527 HYDRAULIC STEEL HYDRAULIC TUBING AT 4 TO 1 DESIGN FACTOR, MATERIAL STRENGTH = 290 MPa MINIMUM TENSILE

Inch Size Tubing Nom SAE Dash Size	Inch Size Tubing Nom Tube OD mm	Inch Size Tubing Nom Tube OD Inch	Nominal Wall Thick-ness in mm 0.71	Nominal Wall Thick-ness in mm 0.89	Nominal Wall Thick-ness in mm 1.24	Nominal Wall Thick-ness in mm 1.65	Nominal Wall Thick-ness in mm 2.11	Nominal Wall Thick-ness in mm 2.41	Nominal Wall Thick-ness in mm 2.77	Nominal Wall Thick-ness in mm 3.05	Nominal Wall Thick-ness in mm 3.40	Nominal Wall Thick-ness in mm 3.76	Nominal Wall Thick-ness in mm 3.96	Nominal Wall Thick-ness in mm 4.76	Nominal Wall Thick-ness in mm 6.35
–2	3.18	0.125	42.9	59.5											
–3	4.76	0.188	25.4	33.7	53.0										
–4	6.35	0.250	18.3	23.8	35.9	53.1									
–5	7.94	0.312	14.5	18.6	27.4	39.2	55.3								
–6	9.52	0.375	11.7	15.0	21.8	32.0	42.4	51.1							
–8	12.70	0.500		10.9	15.7	21.8	29.2	34.6	41.5	47.4					
–10	15.88	0.625		8.6	12.3	16.8	22.4	26.2	31.1	35.1	40.5	46.5			
–12	19.05	0.750		7.1	10.1	13.8	18.1	21.1	24.9	28.0	32.0	36.4	39.0		
–14	22.23	0.875		6.0	8.5	11.6	15.2	17.7	20.7	23.2	26.4	29.9	31.9	40.5	
–16	25.40	1.000		5.2	7.4	10.1	13.1	15.2	17.8	19.9	22.6	25.4	27.1	34.0	50.2
–18	28.58	1.125			6.6	8.9	11.6	13.4	15.6	17.4	19.7	22.1	23.5	29.4	42.6
–20	31.75	1.250			5.9	7.9	10.3	11.9	13.9	15.5	17.4	19.6	20.8	25.8	37.0
–24	38.10	1.500				6.5	8.5	9.8	11.4	12.6	14.2	15.9	16.9	20.8	29.4
–28	44.45	1.750				5.6	7.2	8.3	9.6	10.7	12.0	13.4	14.2	17.4	24.4
–32	50.80	2.000				4.9	6.3	7.2	8.3	9.3	10.4	11.6	12.3	15.0	20.8
–36	57.15	2.250				4.3	5.5	6.4	7.4	8.2	9.2	10.2	10.8	13.2	18.2
–40	63.50	2.500				3.9	5.0	5.7	6.6	7.3	8.2	9.1	9.6	11.8	16.2
–48	76.20	3.000				3.2	4.1	4.7	5.5	6.0	6.8	7.5	8.0	9.7	13.2

NOTE— Tube sizes for pressures shown to the right of the bold line are not considered suitable for flaring to SAE J533.

TABLE 2—NOMINAL REFERENCE WORKING PRESSURES IN MPa (MPa X 145 = PSI), FOR SAE J356, SAE J524, AND SAE J525 LOW CARBON STEEL HYDRAULIC TUBING AT 4 TO 1 DESIGN FACTOR, MATERIAL STRENGTH = 310 MPa MINIMUM TENSILE

Inch Size Tubing Nom SAE Dash Size	Inch Size Tubing Nom Tube OD mm	Inch Size Tubing Nom Tube OD Inch	Nominal Wall Thick-ness in mm 0.71	Nominal Wall Thick-ness in mm 0.89	Nominal Wall Thick-ness in mm 1.24	Nominal Wall Thick-ness in mm 1.65	Nominal Wall Thick-ness in mm 2.11	Nominal Wall Thick-ness in mm 2.41	Nominal Wall Thick-ness in mm 2.77	Nominal Wall Thick-ness in mm 3.05	Nominal Wall Thick-ness in mm 3.40	Nominal Wall Thick-ness in mm 3.76	Nominal Wall Thick-ness in mm 3.96	Nominal Wall Thick-ness in mm 4.76	Nominal Wall Thick-ness in mm 6.35
–2	3.18	0.125	45.8	63.6											
–3	4.76	0.188	27.4	36.2	56.9										
–4	6.35	0.250	19.6	25.5	38.4	56.8									
–5	7.94	0.312	15.3	19.7	29.1	41.8	60.0								
–6	9.52	0.375	12.5	16.0	23.4	33.0	45.4	54.7							
–8	12.70	0.500		11.7	16.8	23.3	31.3	37.0	44.4	50.7					
–10	15.88	0.625		9.2	13.2	18.1	23.9	28.0	33.3	37.6	43.3	49.7			
–12	19.05	0.750		7.6	10.8	14.7	19.4	22.6	26.6	29.9	34.2	38.9	41.7		
–14	22.23	0.875		6.5	9.2	12.5	16.3	18.9	22.2	24.9	28.3	32.0	34.1	43.3	
–16	25.40	1.000		5.6	8.0	10.8	14.1	16.3	19.1	21.3	24.2	27.2	29.0	36.4	53.7
–18	28.58	1.125			7.0	9.5	12.4	14.3	16.7	18.6	21.1	23.7	25.1	31.4	45.5
–20	31.75	1.250			6.3	8.5	11.1	12.8	14.9	16.5	18.7	20.9	22.2	27.6	39.6
–24	38.10	1.500				7.0	9.1	10.5	12.2	13.5	15.2	17.0	18.1	22.3	31.4
–28	44.45	1.750				6.0	7.7	8.9	10.3	11.4	12.9	14.4	15.2	18.7	26.1
–32	50.80	2.000				5.2	6.7	7.7	8.9	9.9	11.1	12.4	13.1	16.1	22.3
–36	57.15	2.250				4.6	5.9	6.8	7.9	8.7	9.8	10.9	11.6	14.1	19.5
–40	63.50	2.500				4.1	5.3	6.1	7.1	7.8	9.2	9.8	10.3	12.6	17.3
–48	76.20	3.000				3.4	4.4	5.1	5.8	6.5	7.2	8.1	8.5	10.3	14.1

NOTE— Tube sizes for pressures shown to the right of the bold line are not considered suitable for flaring to SAE J533.

TABLE 3—NOMINAL REFERENCE WORKING PRESSURES IN MPa (MPa X 145 = PSI), FOR SAE J2435 AND SAE J2467 MEDIUM CARBON STEEL HYDRAULIC TUBING AT 4 TO 1 DESIGN FACTOR, MATERIAL STRENGTH = 415 MPa MINIMUM TENSILE

Inch Size Tubing Nom SAE Dash Size	Inch Size Tubing Nom Tube OD mm	Inch Size Tubing Nom Tube OD Inch	Nominal Wall Thick-ness in mm 0.71	Nominal Wall Thick-ness in mm 0.89	Nominal Wall Thick-ness in mm 1.24	Nominal Wall Thick-ness in mm 1.65	Nominal Wall Thick-ness in mm 2.11	Nominal Wall Thick-ness in mm 2.41	Nominal Wall Thick-ness in mm 2.77	Nominal Wall Thick-ness in mm 3.05	Nominal Wall Thick-ness in mm 3.40	Nominal Wall Thick-ness in mm 3.76	Nominal Wall Thick-ness in mm 3.96	Nominal Wall Thick-ness in mm 4.76	Nominal Wall Thick-ness in mm 6.35
–2	3.18	0.125	61.4	104											
–3	4.76	0.188	36.7	48.5	76.1										
–4	6.35	0.250	26.3	34.1	51.4	76.1									
–5	7.94	0.312	20.5	26.4	39.0	55.9	79.0								
–6	9.52	0.375	16.8	21.5	31.3	44.2	60.8	73.2							
–8	12.70	0.500		15.7	22.5	31.1	41.9	49.5	59.5	67.9					
–10	15.88	0.625		12.3	17.6	24.2	32.0	37.5	44.5	50.3	58.0	66.5			
–12	19.05	0.750		10.2	14.5	19.7	26.0	30.3	35.7	40.0	45.8	52.1	55.8		
–14	22.23	0.875		8.7	12.3	16.7	21.8	25.4	29.7	33.3	37.9	42.8	45.7	58.0	
–16	25.40	1.000		7.5	10.7	14.4	18.9	21.8	25.5	28.5	32.3	36.4	38.8	48.7	71.9
–18	28.58	1.125			9.4	12.7	16.6	19.2	22.4	24.9	28.2	31.7	33.7	42.0	61.0
–20	31.75	1.250			8.4	11.4	14.8	17.1	19.9	22.1	25.0	28.0	29.8	37.0	53.0
–24	38.10	1.500				9.4	12.2	14.0	16.3	18.1	20.4	22.8	24.2	29.8	42.1
–28	44.45	1.750				8.0	10.3	11.9	13.8	15.3	17.2	19.2	20.4	25.0	34.9
–32	50.80	2.000				7.0	9.0	10.3	12.0	13.3	14.9	16.6	17.6	21.5	29.8
–36	57.15	2.250				6.2	8.0	9.1	10.6	11.7	13.1	14.6	15.5	18.9	26.1
–40	63.50	2.500				5.5	7.1	8.2	9.5	10.5	11.8	13.1	13.8	16.9	23.2
–48	76.20	3.000				4.6	5.9	6.8	7.8	8.7	9.7	10.8	11.4	13.8	18.9

NOTE— Tube sizes for pressures shown to the right of the bold line are not considered suitable for flaring to SAE J533.

TABLE 4—NOMINAL REFERENCE WORKING PRESSURES IN MPa (MPa X 145 = PSI), FOR SAE J2613 AND SAE J2614 ALLOY STEEL HYDRAULIC TUBING AT 4 TO 1 DESIGN FACTOR, MATERIAL STRENGTH = 500 MPa MINIMUM TENSILE

Inch Size Tubing Nom SAE Dash Size	Inch Size Tubing Nom Tube OD mm	Inch Size Tubing Nom Tube OD Inch	Nominal Wall Thick-ness in mm 0.71	Nominal Wall Thick-ness in mm 0.89	Nominal Wall Thick-ness in mm 1.24	Nominal Wall Thick-ness in mm 1.65	Nominal Wall Thick-ness in mm 2.11	Nominal Wall Thick-ness in mm 2.41	Nominal Wall Thick-ness in mm 2.77	Nominal Wall Thick-ness in mm 3.05	Nominal Wall Thick-ness in mm 3.40	Nominal Wall Thick-ness in mm 3.76	Nominal Wall Thick-ness in mm 3.96	Nominal Wall Thick-ness in mm 4.76	Nominal Wall Thick-ness in mm 6.35
–2	3.18	0.125	73.9	102											
–3	4.76	0.188	43.9	58.1	91.4										
–4	6.35	0.250	31.6	41.1	61.9	91.6									
–5	7.94	0.312	24.7	31.8	46.9	67.3	95.1								
–6	9.52	0.375	20.2	25.8	37.7	53.2	73.2	88.2							
–8	12.70	0.500		18.9	27.2	37.6	50.5	59.7	71.6	81.8					
–10	15.88	0.625		14.8	21.2	29.1	38.6	45.2	53.6	60.6	69.8	80.2			
–12	19.05	0.750		12.2	17.4	23.8	31.3	36.4	42.9	48.2	55.2	62.7	67.2		
–14	22.23	0.875		10.4	14.8	20.1	26.3	30.5	35.8	40.1	45.6	51.6	55.0	69.9	
–16	25.40	1.000		9.1	12.8	17.4	22.7	26.3	30.7	34.3	38.9	43.9	46.7	58.7	86.6
–18	28.58	1.125			11.3	15.3	20.0	23.1	26.9	30.0	34.0	38.1	40.5	50.6	73.4
–20	31.75	1.250			10.1	13.7	17.8	20.6	24.0	26.7	30.1	33.8	35.9	44.5	63.8
–24	38.10	1.500				11.3	14.7	16.9	19.6	21.8	24.6	27.5	29.1	35.9	50.7
–28	44.45	1.750				9.6	12.5	14.3	16.6	18.4	20.7	23.2	24.5	30.1	42.0
–32	50.80	2.000				8.4	10.8	12.5	14.4	16.0	18.0	20.0	21.2	25.9	36.0
–36	57.15	2.250				7.4	9.6	11.0	12.7	14.1	15.8	17.6	18.6	22.8	31.4
–40	63.50	2.500				6.7	8.6	9.9	11.4	12.6	14.1	15.7	16.6	20.3	27.9
–48	76.20	3.000				5.5	7.1	8.2	9.4	10.4	11.7	13.0	13.7	16.7	22.8

NOTE— Tube sizes for pressures shown to the right of the bold line are not considered suitable for flaring to SAE J533.

5. Notes

5.1 Marginal Indicia—The (R) is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the specification. If the symbol is next to the specification title, it indicates a complete revision of the specification.

PREPARED BY THE SAE METALLIC TUBING SUBCOMMITTEE S5 OF THE SAE FLUID CONDUCTORS AND CONNECTORS TECHNICAL COMMITTEE

APPENDIX A

A.1 ***Formerly Accepted Formulae—***When calculating nominal reference pressures for tube materials where the ratio of the minimum yield strength to the minimum tensile strength falls below a 50% ratio, formulae listed in this annex should be used.

A.1.1 Formulae

A.1.1.1 THE BARLOW FORMULA

$$P = \frac{2ST}{D} \qquad \text{(Eq. A1)}$$

A.1.1.2 THE BOARDMAN FORMULA

$$P = \frac{2ST}{D - 0.8T} \qquad \text{(Eq. A2)}$$

A.1.1.3 THE LAME FORMULA

$$P = S\left(\frac{D^2 - d^2}{D^2 + d^2}\right) \qquad \text{(Eq. A3)}$$

where:

D = Nominal Outside Diameter of Tubing, mm
d = Nominal Inside Diameter of Tubing, mm
P = Hydrostatic Working Pressure, MPa
T = Nominal Wall Thickness of Tubing, mm
S = Allowable Fiber Stress of Material, MPa

Use 86 MPa Fiber Stress for 4 to 1 Design Factor (Burst Pressure to Working Pressure)
Use 117 MPa Fiber Stress for 3 to 1 Design Factor (Burst Pressure to Working Pressure)