SAE International™ SURFACE VEHICLE STANDARD

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Welded Flash Controlled, High Strength Low Alloy Steel Hydraulic Tubing, Sub-Critically Annealed for Bending, Double Flaring, and Bending

1. *Scope*—

This SAE Standard covers sub-critically annealed electric resistance welded flash controlled single-wall high strength low alloy steel tubing intended for use in hydraulic pressure lines and in other applications requiring tubing of a quality suitable for bending, double flaring, cold forming, welding and brazing. Material produced to this specification is not intended to be used for single flare applications due to the potential leak path that would be caused by the ID weld bead.

The grade of material produced to this specification is of micro-alloy content and is considerably stronger and intended to service higher pressure applications than like sizes of the grades of material specified in SAE J356 and SAE J2435. Due to the alloy content of the material, the forming characteristics of the finished tube are equal to or better, when compared to SAE J356 and SAE J2435. Nominal reference working pressures for this tubing are listed in SAE J1065.

2. *References*

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

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

SAE J356—Welded Flash-Controlled Low-Carbon Steel Tubing Normalized for Bending, Double Flaring, and Beading
SAE J409—Product Analysis—Permissible Variations from Specified Chemical Analysis of a Heat or Cast of Steel
SAE J533—Flares for Tubing
SAE J1065—Pressure Rating for Hydraulic Tubing and Fittings
SAE J1677—Tests and Procedures for SAE Low-Carbon Steel and Copper Nickel Tubing
SAE J2435—Welded Flash Controlled, SAE 1021 Carbon Steel Tubing, Normalized for Bending, Flaring, and Beading

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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 J514—Hydraulic Tube Fittings
SAE J518—Hydraulic Flanged Tube, Pipe and Hose Connections; 4-Bolt Type
SAE J1453—Fitting - O-Ring Face Seal
SAE J2551—Recommended Practices for Fluid Conductor Metallic Tubing Applications

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

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 4200—Plain end steel tubes, welded and seamless - General tables of dimensions and masses per unit length
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 6605—Tests and test procedures
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. ***Manufacture—***The tubing shall be made from a single strip of steel shaped into a tubular shape, the edges of which are joined and fused by electric resistance welding. After forming and welding, the outside flash shall be removed to provide a smooth surface. The inside flash shall be of uniform contour, free from saw-tooth peaks and controlled in height by seam-welding techniques or by cutting, not by hammering or rolling. The inside flash height shall conform to the following as in Table 1.

The tubing shall be sub-critically annealed via a controlled method to produce a finished product, which will meet all requirements of this document.

Sub-critically anneal - An annealing treatment in which steel is heated to below the A1 temperature, then slowly cooled to room temperature. A1 temperature is the critical transformation temperature depending on steel classification.

TABLE 1—INSIDE FLASH HEIGHT

Nominal Wall Thickness mm	Maximum Flash Height[1][2] Through 25.4 mm OD mm	Maximum Flash Height Over 25.4 mm OD mm
Less than 0.90	0.13	0.25
0.90 through 1.65	0.20	0.25
Greater than 1.65	0.25	0.25

1. For tubes having an ID greater than 8 mm, the height of the inside weld flash shall be measure with a ball micrometer having a 3.96 mm ± 0.41 mm radius from the anvil or ballpoint. For tubes having an ID 8 mm or less, screw thread micrometers shall be used. The height of the flash shall be the difference between the thickness of the tube wall at the point of maximum height of the flash and the average of the wall thickness measured at points adjacent to both sides of the flash.
2. Tubing with an ID that is smaller than the producer's capability to scarf the ID weld bead, shall be produced as "flash in" tubing. Seam welding techniques may be applied to control the ID flash height. The maximum ID flash height, however, will be determined by agreement between the producer and the purchaser.

4. Dimensions and Tolerances—The tolerances applicable to tubing outside diameter are shown in Table 2. The tolerances applicable to tubing wall thickness are shown in Table 3. Particular attention shall be given to areas adjacent to the weld to insure against thin spots and/or sharp indentations.

TABLE 2—TUBING OUTSIDE DIAMETER TOLERANCE

Nominal Tubing OD[1][2] mm	Tube OD and ID Tolerance ±mm
Up to 9.50	0.06
Over 9.50 to 15.88	0.08
Over 15.88 to 28.57	0.09
Over 28.57 to 50.80	0.13
Over 50.80 to 63.50	0.15
Over 63.50 to 76.20	0.20
Over 76.20 to 88.90	0.23
Over 88.90 to 101.60	0.25

1. OD measurements shall be taken at least 50 mm from the end of tubing.
2. For nominal tubing OD's to be used in conjunction with this tubing, refer to the various fluid carrier connector standards and SAE J533 for recommended maximum nominal wall thickness for double flaring.

TABLE 3—TUBING WALL THICKNESS TOLERANCES

Nominal Wall Thickness[1] mm	Nominal Tubing Outside Diameter Through 22 mm ±mm[2]	Nominal Tubing Outside Diameter Over 22 mm Through 48 mm ±mm[2]	Nominal Tubing Outside Diameter Over 48 mm Through 101.60 ±mm[2]
0.71	0.05/0.08	0.05/0.08	0.05/0.08
0.89	0.05/0.10	0.05/0.10	0.05/0.10
1.00	0.05/0.10	0.05/0.10	0.05/0.10
1.24	0.10/0.13	0.08/0.13	0.10/0.20
1.25	0.10/0.13	0.08/0.13	0.10/0.20
1.50	0.15/0.15	0.10/0.20	0.10/0.20
1.65	0.15/0.15	0.10/0.20	0.10/0.20
2.00	0.15/0/25	0.15/0.25	0.15/0.25
2.11	0.15/0/25	0.15/0.25	0.15/0.25
2.41	0.15/0/25	0.15/0.25	0.15/0.25
2.50	0.15/0/25	0.15/0.25	0.15/0.25
2.77	0.15/0/25	0.15/0.25	0.15/0.25
3.00	0.15/0/25	0.15/0.25	0.15/0.25
3.05	0.15/0/25	0.15/0.25	0.15/0.25
3.40	0.15/0/25	0.15/0.25	0.15/0.25
3.75	---	0.18/0.28	0.18/0.28
3.76	---	0.18/0.28	0.18/0.28
3.96	---	0.18/0.28	0.18/0.28
4.00	---	0.18/0.28	0.18/0.28
4.19	---	0.18/0.28	0.18/0.28
4.57	---	0.18/0.28	0.18/0.28
4.76	---	0.18/0.28	0.18/0.28
5.00	---	0.20/0.30	0.20/0.30
5.16	---	0.20/0.30	0.20/0.30
5.59	---	0.20/0.30	0.20/0.30
6.00	---	0.36/0.46	0.36/0.46
6.05	---	0.36/0.46	0.36/0.46
6.35	---	0.36/0.46	0.36/0.46
6.58	---	0.36/0.51	0.36/0.51

1. For intermediate wall thickness, the tolerance for the next heavier wall thickness shall apply.
2. Plus tolerances include allowance for crown on flat-rolled steel.

5. Manufacturing Standards

5.1 Straightness—Tubing shall be straightened to a tolerance of 0.8 mm in 1000 mm. Straightness tolerances shall be measured by placing a 915 mm straight edge against the tube while lying on it's neutral axis. The point of maximum deflection of the tube from the straight edge should not be more than allowed by the specification when measured with a feeler gauge.

5.2 Tubing End Condition—The tubing will be produced using normal mill cut off practices. This shall include, but not limited to, punch-cut ends, double-cut ends and rotary-cut ends. Care shall be taken to minimize the distortion of the tube ends. Distortion of the tube must not affect the normal re-cutting processes that will be performed by the end user. Ends that require further processing will be addressed by agreement between the producer and the tube purchaser.

5.3 Finish—The outside surface finish of the tube is critical to prevent possible leak paths on double flare connections, mechanical formed connections or applications where the outside surface of the tube becomes the sealing surface of the finished connection. The outside surface finish of the tube shall be free of excessive roll marks, score marks, chatter marks or other surface imperfections that may be considered detrimental to the function of the finished tube.

5.4 Thermal Treatment—The tubing is to be sub-critically annealed by heating to a temperature below the transformation point and then slowly cooled to room temperature. Special attention to the mechanical properties, especially the Rockwell B85 Hardness Target, should be made to produce tubing suitable for bending and forming for hydraulic pressure applications. However, to obtain acceptable hardness characteristics, the yield strength and the tensile strength shall not be compromised and 30% minimum elongation shall be maintained.

6. ***Material—***The tubing shall be made from alloy steel strip conforming to the chemical composition in Table 4. The steel shall be made by the open-hearth basic oxygen or electric furnace process. A ladle analysis of each heat shall be made to determine the percentages of the elements specified. The chemical composition thus determined shall be reported to the purchaser or purchaser's representative, if requested, and shall be conform to the requirements specified. If a check analysis is required, the tolerances shall be as specified in SAE J409, Table 3.

TABLE 4—CHEMICAL REQUIREMENTS

Element	Cast or Heat Analysis, Weight %
Carbon	0.18 Max
Manganese	1.50 Max
Sulfur	0.035 Max
Phosphorus	0.035 Max
Silicon	0.35 Max
Aluminum	0.020 Min
Micro Alloying Elements	0.15 Max

7. ***Mechanical Properties—***The finished tubing shall have mechanical properties as shown in Table 5.

TABLE 5—MECHANICAL PROPERTIES

Properties	Values
Yield Strength, Minimum	345 MPa
Tensile Strength, Minimum	500 MPa
Elongation in 50 mm, Minimum	30% Minimum
Hardness, Target	Rockwell B85(1)
Hardness, Maximum	Rockwell B90[1]

1. The hardness test shall not be required on tubing with a nominal wall thickness of less than 1.65 mm. Such tubing shall meet all other mechanical properties and performance requirements.

8. ***Performance Requirements—***The finished tubing shall satisfactorily meet the following performance tests. All tests are to be conducted in accordance with the procedures in SAE J1677.

8.1 **Flattening Test—**See SAE J1677.

8.2 **Flaring Test—**See SAE J1677.

8.3 **Reverse Flattening Test—**See SAE J1677.

8.4 **Expansion Test—**See SAE J1677.

8.5 **Hardness Test—**See SAE J1677.

8.6 **Tensile Test—**See SAE J1677.

8.7 **Elongation Test—**See SAE J1677.

8.8 **Pressure Proof Test—**See SAE J1677.

8.9 **Nondestructive Electronic—**See SAE J1677. The tests referenced in SAE J1677, paragraph 5.9, are to be conducted after all cold-working tube manufacturing operations are performed on the tubing.

9. ***Test Certificates—***A certificate of compliance to the performance requirements shall be furnished to the purchaser by the producer if requested in the purchase agreement. The tube producer shall be able to certify that each heat lot of the material used to produce the tubing complies with the performance requirements.

10. ***Cleanliness—***The inside and outside surfaces of the finished tubing shall be commercially bright, clean and free from grease, oxide scale, carbon deposits, and any other contamination that can not readily be removed by cleaning agents normally used in manufacturing plants.

11. ***Corrosion Protection—***The inside and outside surfaces of the finished tubing shall be protected against corrosion during shipment and normal storage. If a corrosion preventive compound is applied, it shall be such that after normal periods, it can be readily removed by cleaning agents normally used in manufacturing plants.

12. ***Packaging—***The tubing is to be packaged in such a way to allow it to be transported and stored, with normal care, without being damaged. Any special packaging shall be by agreement between the producer and the purchaser.

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