SAE International

SURFACE VEHICLE RECOMMENDED PRACTICE

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Recommended Practices for Fluid Conductor Carbon, Alloy and High Strength Low Alloy Steel Tubing Applications-Part 2: General Specifications and Performance Requirements

RATIONALE

The user community has expressed a need for additional documented knowledge associated with the design, expected performance and procurement of metallic fluid conductors. This revision to SAE J2551 reorganizes the document into three parts, design and fabrication, general specifications and performance requirements and procurement. The following changes and additional information is intended to bring this document up to date with current industry technology and provide comprehensive application and procurement information requested by the user community. In addition, the document title has been revised to include steel tube materials that have been recently added as SAE standards.

FOREWORD

The May2010 edition of SAE J2551 was published as a single document covering the design and fabrication of carbon, alloy and high strength low allow tube assemblies. SAE J2551 has been organized into three sections as follows:

1. SAE J2551-1 - Recommended Practices for Fluid Conductor Carbon, Alloy and High Strength Low Alloy Steel Tubing Applications-Part 1: Design and Fabrication

2. SAE J2551-2 - Recommended Practices for Fluid Conductor Carbon, Alloy and High Strength Low Alloy Steel Tubing Applications-Part 2: General Specifications and Performance Requirements

3. SAE J2551-3 - Recommended Practices for Fluid Conductor Carbon, Alloy and High Strength Low Alloy Steel Tubing Applications-Part 3: Procurement

This SAE Recommended Practice is intended as a guide to consider when defining the general specification and performance requirements of carbon, alloy and high strength low alloy steel tube assemblies for fluid power and general applications. It is subject to change to keep pace with experience and technical advances. Experienced designers and users skilled in achieving proper results, as well as the less experienced may use this outline as a list of recommendations to consider when defining general specifications and performance requirements.

Fluid power systems are complex and require extensive knowledge of both the system requirements and the various types of tube. Therefore, all-inclusive, detailed, step-by-step instructions are not practical and are beyond the scope of this document. Less experienced designers and users who need more information may consult specialists such as experienced tube designers and fabricators. This guide may improve the communication process.

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SAE WEB ADDRESS: http://www.sae.org

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/J2551/2_201302

Following this document is highly recommended by the participating SAE/ISO organizations and their members. Adherence to these guidelines may assure the users they will create tube assemblies that can be efficiently manufactured, conveniently packaged/shipped, proficiently installed on their equipment, will perform adequately and safer to established industry standards and they will be using common practices and components that may be easily serviced anywhere globally.

Safety Considerations - These documents include considerations to facilitate safer conditions when these products are in use; note these carefully during all phases of design and use of the tube assemblies. Improper selection, fabrication, installation, or maintenance of tube assemblies for fluid-power systems may result in serious personal injury or property damage. Adherence to these recommended practices could reduce the likelihood of component or system failure, thereby reducing the risk of injury or damage. The application of hydraulic tubing with fluids under pressure exposes users to risk due to mechanical or injection hazards and the environment to contamination from leakage. Users are reminded to consider the proper selection of components, fabrication of tubes, installation and maintenance procedures to address this potential risk.

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1. SCOPE

1.1 Purpose

These recommended practices provide recommendations for general specifications and performance requirements of carbon, alloy and high strength low alloy steel tube assemblies for fluid power applications utilizing commonly available manufacturing methods and general guidelines for tube selection and application.

1.2 Field of Application

These recommended practices are intended for general application and hydraulic systems on industrial equipment and commercial products. Aircraft and Aerospace applications were not considered during the preparation of this document.

Since many factors influence the pressure at which a hydraulic system will or will not perform satisfactorily, these recommended practices should not be construed as guaranteed minimums. For any application, it is recommended that sufficient testing be conducted and reviewed by both the user and supplier to ensure that required performance levels are met.

For use of these recommended practices and connectors in conditions outside the pressure and temperature of limits specified, the fabricator must be consulted. Both metric and inch tubing should be considered to accommodate hydraulic system design requirements. In the past, these requirements have been met predominantly with inch tubing; for new designs, metric tubing should be considered.

2. REFERENCES

2.1 Applicable Documents

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 International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J426 Liquid Penetrant Test Methods

SAE J512 Automotive Tube Fittings

SAE J514 Hydraulic Tube Fittings

SAE J518 Hydraulic Flanged Tube, Pipe, and Hose Connections, Four-Bolt Split Flange Type

SAE J533 Flares for Tubing

SAE J1065 Nominal Reference Working Pressures for Steel Hydraulic Tubing

SAE J1231 Formed Tube Ends for Hose Connections and Hose Fittings

SAE J1273 Recommended Practices for Hydraulic Hose Assemblies

SAE J1453-1 Specification for O-Ring Face Seal Connectors: Part 1—Tube Connection Details and Common Requirements for Performance and Tests

SAE J1453-2 Specification for O-Ring Face Seal Connectors: Part 2—Requirements, Dimensions, and Tests for Steel Unions, Bulkheads, Swivels, Braze Sleeves, Caps, and Connectors with ISO 6149-2 Metric Stud Ends

SAE J1453-3 Specification for O-Ring Face Seal Connectors: Part 3—Requirements, Dimensions, and Tests for Steel Unions, Bulkheads, Swivels, Braze Sleeves, Connectors, Caps, and Connectors with SAE J1926-2 Inch Stud Ends

SAE J1475 Hydraulic Hose Fittings for Marine Applications

SAE J2044 Quick Connect Coupling Specification for Liquid Fuel and Vapor/Emissions Systems

SAE J2551-1 Recommended Practices for Fluid Conductor Carbon, Alloy and High Strength Low Alloy Steel Tubing Applications-Part 1: Design and Fabrication

SAE J2552-3 Recommended Practices for Fluid Conductor Carbon, Alloy and High Strength Low Alloy Steel Tubing Applications-Part 3: Procurement

SAE J2593 Information Report for the Installation of Fluid Conductors and Connectors

SAE J2613 Welded Flash Controlled, High Strength Low Alloy Steel Hydraulic Tubing, Sub-Critically Annealed for Bending, Double Flaring, and Bending

SAE J2614 Welded and Cold-Drawn, High Strength Low Alloy Steel Hydraulic Tubing, Sub-Critically Annealed for Bending and Flaring

SAE J2832 Welded Flash Controlled, High Strength (690 MPa Tensile Strength) Low Alloy Steel Hydraulic Tubing, Stress Relieved Annealed for Bending and Double Flaring

SAE J2833 Welded and Cold-Drawn, High Strength (690 MPa Tensile Strength) Low Alloy Steel Hydraulic Tubing, Stress Relieved Annealed for Bending and Flaring

2.1.2 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

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 4406 Hydraulic fluid power - Fluids - Method for coding the level of contamination by solid particles

ISO 6162-1 Hydraulic fluid power - Flange connectors with split or one-piece flange clamps and metric or inch screws - Part 1: Flange connectors for use at pressures of 3.5 MPa (35 Bar) to 35 MPa (350 Bar), DN 13 to DN127

ISO 6162-2 Hydraulic fluid power - Flange connectors with split or one-piece flange clamps and metric or inch screws - Part 2: Flange connectors for use at pressures of 35 MPa (350 Bar) to 40 MPA (400 Bar), DN 13 to DN 51

ISO 8434-1 Metallic tube connections for fluid power and general use - Part 1: 24° Compression connectors

ISO 8434-2 Metallic tube connections for fluid power and general use - Part 2: 37° Flared connectors

ISO 8434-3 Metallic tube connections for fluid power and general use - Part 3: O-ring face seal connectors

ISO 8434-4 Metallic tube connections for fluid power and general use - Part 4: 24° Cone connectors with o-ring weld-on nipples

ISO 9227 Corrosion tests in artificial atmospheres - Salt spray testing

ISO 10763 Plain-end, seamless and welded steel tubes - Dimensions and nominal working pressures

ISO 17635 Non-destructive testing of welds - General rules for metallic materials

ISO 19879 Metallic tube connections for fluid power and general use - Test methods for hydraulic fluid power connections

2.1.3 EN Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

EN 10305-2 Steel tubes for precision applications - Technical delivery conditions - Part 2: Welded cold drawn tubes

EN 10305-4 Steel tubes for precision applications - Technical delivery conditions - Part 4: Seamless cold drawn tubes for hydraulic and pneumatic power systems

2.1.4 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org

ASTM B117 Standard Practice for Operating Salt Spray (Fog) Apparatus

ASTM D2247 Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity

2.1.5 American Welding Society Publications

Available from American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126, Tel: 800-443-9353, www.asw.org.

AWS D1.1/D1.1M Structural Welding Code - Steel

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J246 Spherical and Flanged Sleeve (Compression) Tube Fittings

SAE J343 Tests 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 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 J524 Seamless Low-Carbon Steel Tubing Annealed for Bending and Flaring

SAE J525 Welded and Cold Drawn 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 J1273 Recommended Practices for Hydraulic Hose Assemblies

SAE J1290 Automotive Hydraulic Brake System - Metric Tube Connections

SAE J1677 Tests and Procedures for Steel and Copper Nickel Tubing

SAE J1926-1 Connections for General Use and Fluid Power - Ports and Stud Ends with ASME B1.1 Threads and O-Ring Sealing - Part 1: Threaded Port with O-Ring Seal in Truncated Housing

SAE J1926-2 Connections for General Use and Fluid Power - Ports and Stud Ends with ASME B1.1 Threads and O-Ring Sealing - Part 2: Heavy-Duty (S Series) Stud Ends

SAE J1926-3 Connections for General Use and Fluid Power - Ports and Stud Ends with ASME B1.1 Threads and O-Ring Sealing - Part 3: Light-Duty (L Series) Stud Ends

SAE J2094 Vehicle and Control Modifications for Drivers with Physical Disabilities Terminology

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 J2592 Carbon Steel Tubing for General Use - Understanding Nondestructive Testing for Carbon Steel Tubing

2.2.2 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 272 Fasteners - Hexagon products - Widths across flats

ISO 273 Fasteners - Clearance holes for bolts and screws

ISO 2944 Fluid power systems and components - Nominal pressures

ISO 3448 Industrial liquid lubricants - ISO viscosity classification

ISO 3457 Earth-moving machinery - Guards and shields - Definitions and specifications

ISO 3601 O-ring sealing devices for fluid carrier systems

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 6072 Hydraulic fluid power - Compatibility between elastomeric materials and fluid

ISO 6149 Ports and stud ends with ISO 261 Metric threads and O-ring sealing

ISO 6150 Pneumatic fluid power - Cylindrical quick-action couplings

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 6743-4 Lubricants, industrial oils and related products (Class L) - Part 4: Family H (Hydraulic Systems)

ISO 7241 Quick action couplings

ISO 9974 Metric threaded ports and stud ends

ISO 10583 Test methods for tube connections

ISO 11926 Ports and stud ends with ISO 725 Inch threads and O-ring sealing

ISO 15171 Hydraulic couplings for diagnostic purposes

ISO 16028 Hydraulic flush face quick-action couplings

2.2.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM A 213/A 213M Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

ASTM A 268/A 268M Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing

ASTM 269-96 Seamless and Welded Austenitic Stainless Steel Tubing for General Service

ASTM 312A/A312M Seamless and Welded Austentic Stainless Steel Pipes

ASTM A 450/A 450M-96a General Requirements for Carbon, Ferritic Alloy and Austenitic Alloy Steel Tubing

ASTM A 513 Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Tubing

ASTM A 519 Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing

ASTM A 554 Welded Stainless Steel Mechanical Tubing

3. DEFINITIONS

Reference SAE J2551-1 for definitions related to specific terms used throughout this document.

4. GENERAL SPECIFICATIONS

4.1 Tube Construction

Tube assemblies should be produced from carbon, alloy or high strength low alloy steel tubing and designed and fabricated per the recommendations of SAE J2551-1 Recommended Practices for Fluid Conductor Carbon, Alloy and High Strength Low Alloy Steel Tubing Applications-Part 1: Design and Fabrication. The tube material used to produce tube assemblies should be tested and certified for hydraulic applications and conform to the applicable tubing standard. Connectors and tube end configurations should conform to the applicable end connection standard and associated performance requirements. Non-standard tubing and end connections should be performance tested as described in section 4.5.2 to ensure the capabilities of the finished tube assembly are compliant with the application's performance expectation.

4.2 Dimensional Requirements

The tube assembly configuration should conform to the dimensional requirements indicated on the tube assembly print. Tubing and end connections should conform to the dimensional requirements of the applicable tube and end connection standard or non-standard design requirements. Reference SAE J2551-1 for guidance associated with standard industry tube assembly dimensional tolerances, inspection methods and acceptable tube material deformation caused by bending and forming processes.

4.3 Workmanship

Workmanship should be of the quality necessary to produce tube assemblies free of all defects that could affect proper form, fit and function in service. Attached hydraulic components should have clean and defect free sealing surfaces while threads should be free of scratches or contamination that may affect torques values during assembly. All surfaces other than the tube/fitting interface should be free of weld and/or braze materials. Finished tube assemblies should be visibly clean and rust free both internally and externally with a surface finish free of excessive tool marks and imperfections that are inconsistent with the appearance of the specified tube material and coating.

4.4 Quality Conformance and Assurance

Quality conformance assurance tests should be sufficient to qualify that the tube assembly meets all design requirements and the general specifications and performance requirements in this specification.

4.4.1 Initial Quality Conformance Assurance

Initial quality conformance assurance, sometimes referred to as Initial Sample Inspection Report (ISIR) activity, is defined as the qualification and testing required to ensure the tube assembly complies with the general specifications and performance requirements specified on the print and other relevant specifications prior to the first shipment of production parts. Recommended test lot should consist of a minimum 3 pieces and include the following documented verification and test activities.

a. Tube material compliance with applicable tube standard provided by the tube supplier in the form of a material certification.

b. Visual workmanship inspection.

c. Performance qualification or testing as defined by this document and ISO19879.

d. Dimensional testing of assembly as defined by SAE J2551-1.

e. Dimensional testing of end connections and components as defined by the related SAE and ISO standard.

f. Inspection and test of braze and/or weld joints.

g. Cleanliness test of assembly to minimum levels per print or user specification.

h. Corrosion resistance testing per ASTM test procedures to comply with the minimum level per coating type shown in SAE J2551-1 or as specified by the user.

Additional test requirements and the number of initial sample inspection assemblies to be tested should be agreed upon between the supplier and the user.

4.4.2 Lot Testing

Testing of identified key characteristics of the tube assembly should be conducted on each production batch. Recommended frequency of inspection associated with specific key characteristics are as follows:

a. Dimensional contours of the finished assembly per recommended minimum test frequency shown in Table A.

b. Integrity of braze and/or weld joints: 100% visual inspection or other non-destructive testing of samples per Table A if specified by the user.

c. Form and appearance of end connections per minimum test frequency shown in Table A.

d. Additional tests may be required by the supplier for inspection of materials during specific process steps that are not defined in this document or user engineering prints and specifications.

TABLE A

MINIMUM SAMPLING PLAN

LOT SIZE	**SAMPLE SIZE**
1-15	First & last pieces
Next 16-100	1 piece every 15 pieces
Next 100+	1 piece every 50 pieces

INSPECTION SAMPLES ARE TO BE EVENLY SPACED THROUGHOUT THE PRODUCTION RUN. 100+ REQUIRES RANDOM CHECKS.

Compliance with cleanliness and pressure ratings is typically verified through process controls, testing of related factory processes and material certifications. Additional test requirements or frequency should be agreed upon between the supplier and user prior to the start of production operations.

4.4.3 Responsibility for Tests

Unless otherwise specified in the contract or purchase order, the supplier of the tube assembly is typically responsible for the verification of material certifications and performance of all test requirements. The supplier of the tube may use his own or any other facilities suitable for the performance of test requirements unless disapproved by the user. Records of test results and data should be retained for a minimum of one year after shipment or for the user's specified document retention period, whichever is greater. The user reserves the right to perform any of the tests specified to assure supplies and services conform to the standard requirements.

WARNING: Some of the tests described in this document are considered hazardous; it is therefore essential that, in conducting these tests, all appropriate safety precautions are strictly adhered to. Attention is drawn to the danger of fine jets of high-pressure hydraulic fluid which can penetrate the skin. To reduce the hazard to energy release, bleed air out of test specimens prior to pressure testing. Tests should be set-up and performed by properly trained personnel. Also personal protective equipment such as safety glasses, hearing protection and metatarsal safety shoes, should be used when working around and on hydraulic test laboratories and equipment.

4.5 Storage and Identification

4.5.1 Marking

Identification labels on individual tube assemblies are recommended to maintain traceability of processes and materials. Identification markings may be printed on the surface of the tube, printed on an adhesive label or embossed on a metal tag that is attached to the assembly. Information provided on the label should identify the supplier, part number, lot control number (if available) and month/date of manufacture. The method of the identification of tube assemblies should be specified by the user, or agreed upon between the supplier and user. Marking requirements should be specified on the engineering drawing or otherwise documented as a part specification.

4.5.2 Examination of Product

Prior to packaging each tube assembly should be visually examined by the supplier to verify conformance to this document and the appropriate customer print requirements with respect to the following:

a. Workmanship

b. Number of bends

c. Coating type

d. End connections type

e. Tube material

f. Marking

4.5.3 Packaging

Unless otherwise specified by the user, parts are to be bulk packaged in a closed container to protect the items from dust or other foreign debris and damage during normal shipment and handling. The use of returnable containers for shipment is encouraged to reduce waste and dunnage. Tube assemblies with coating appearance requirements should be packaged to protect the coating from scuffing, scratching or chipping during shipment.

4.5.4 Shelf Life

Individual tube assemblies should be coated to prevent rust during storage in a closed container and capped on both ends to protect inside surfaces from contamination. Storage areas should be indoors and protected from environmental contamination. The type of coating and its expected corrosion resistance should be specified on the engineering drawing or agreed upon between the supplier and the user and documented as a part specification.

5. PRODUCT TYPES AND PERFORMANCE REQUIREMENTS

5.1 Product Types

Tube assemblies produced using this recommended practice should be classified by product type and meet the minimum performance requirements described herein.

5.1.1 Pressure Tubes

Used in pressure applications with the potential for high pressure impulse cycles.

5.1.2 Return Tubes

Hydraulic return lines that operate at pressures less than 6.6 MPa.

5.1.3 Suction Tubes

Suction lines that operate with an internal vacuum or pressures less than 1.0 MPa.

5.2 Hydraulic Connections

Hydraulic connections should meet the requirements of user specifications and the performance requirements of the applicable connection standard. Connections that have been tested by the supplier are not required to be retested as an integral part of the tube assembly. Typical attachment methods for hydraulic components are brazing, welding and forming. These attachment methods should be qualified as a production process and inspected during production operations.

5.2.1 Braze Joints

Braze joints are often used to attach hydraulic connections, fuse multiple tubes together, or attach brackets or other holding devices to tube assemblies. Minimum recommend inspection for braze joints during production operations is 100% visual inspection. Minimum recommended testing for the qualification of a brazing process is 100% visual inspection and destructive peel testing. Braze joints should meet or exceed the strength requirements specified for the finished tube assembly.

5.2.1.1 Non-destructive Testing

Non-destructive testing of braze joints are methods used to examine braze joints while maintaining the functionality of the tube assembly.

5.2.1.1.1 Visual Inspection

Visual inspection is performed as an examination to determine conformance to this document and the appropriate customer print requirements with respect to the following:

a. Lumps of filler metal around the braze joint are indicators of an insufficiently heated braze joint and are cause for rejection.

b. Any visible voids, cracks or pinholes are cause for rejection.

c. Filler material should not be visible on sealing surface area.

5.2.1.1.2 Ultrasonic Inspection

Ultrasonic testing uses short ultrasonic pulse-waves to detect braze flaws. When performed by trained and experienced personnel ultrasonic testing can provide improved inspection results versus visual examination.

5.2.1.1.3 Underwater Leak Test

The underwater leak test is performed by pressurizing a tube assembly with air, then submersing the assembly in water to detect bubbles that are indicators of air leaking through braze joints.

5.2.1.2 Destructive Testing

Destructive testing of braze joints are methods that subject a braze joint to extreme stress, or physically deconstructs the joint, as a way of determining the effectiveness of a brazing process.

5.2.1.2.1 Peel Testing

Peel testing of braze joints is performed by cutting the joint into sections that are then physically peeled apart to expose the tube to joint interface for the purpose of examining the ratio of wetted surface versus the number of voids which is usually expressed as a percentage of defects resulting from the brazing process. For detailed information about performing a braze peel test and acceptance criteria refer to the pertinent section of SAE J1475.

5.2.1.2.2 Burst Pressure Testing

Pressure testing the tube and braze joint at or above the maximum design strength of the tube assembly is intended to induce leaks or failure under extreme hydraulic loads. For detailed information about burst pressure testing and acceptance criteria refer to ISO 19879.

The use and evaluation of destructive testing is to be determined by agreement between the supplier and the user. All tube assemblies that have been subjected to destructive braze connection tests should be destroyed.

5.2.2 Welding

Weld joints are often used to attach hydraulic connections, fuse multiple tubes together, or attach brackets or other holding devices to tube assemblies. Minimum recommend inspection for weld joints during production operations is 100% visual inspection. Weld joints should meet or exceed the strength requirements specified for the finished tube assembly.

5.2.2.1 Non-destructive Testing

Non-destructive testing of weld joints are methods used to examine weld joints while maintaining the functionality of the tube assembly.

5.2.2.1.1 Visual Inspection

Visual inspection is an examination to determine conformance to this document and the appropriate customer print requirements with respect to the following:

a. Weld should exhibit no visible cracks, surface porosity and entrapped slag.

For detailed information about performing the visual inspection of weld joints and acceptance criteria refer to the pertinent section of SAE J1475.

5.2.2.1.2 Liquid Penetrant

Liquid penetrant inspection is used to evaluate welds and detect surface discontinuities, such as cracks, fractures, porosity and incomplete fusion. For additional information about liquid penetrant test methods refer to SAE J426 Liquid Penetrant Test Methods.

For additional information and guidelines for the non-destructive testing of welds refer to ISO 17635 Non-destructive testing of welds - General rules for metallic materials.