

Recommendations for tube end welding

PUBLICATION 143

Edition 2

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Registered and Trading Address:
EEMUA, Second Floor, 16 Black Friars Lane, London EC4V 6EB
Telephone: +44 (0)20 7488 0801
Email: sales@eemua.org
Website: www.eemua.org



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Preface

Publication 143 was first published under the EEMUA banner in 1985 following the merger of the Engineering Equipment Users Association (EEUA) and the Oil Companies Materials Association (OCMA). The Publication was originally *OCMA Specification No. TEW-1: Recommendations for tube end welding: tubular heat transfer equipment, Part 1 – Ferrous materials*. It was written by OCMA's Welding Panel with assistance from the Heat Transfer Society.

A joint meeting was convened in October 1966 of members of OCMA welding panel and representatives of the Heat Transfer Society to exchange information on experience gained in making welded joints between heat exchanger tubes and tube-plates. It was the opinion of that meeting that an urgent need existed for standardised procedures to be established for the design, fabrication, inspection and testing of these and similar components. At that time, there was no national or international standard in existence that adequately covered this important subject. Members pooled their knowledge and experience, and co-operated in preparing a recommended practice for tube end welding and testing. Such a recommendation could then be used as a basis for specifying requirements for the oil, chemical and other industries.

In the interim, codes such as ASME BPVC VIII, ASME IX and particularly EN ISO 15614-8:2002 have covered much of the same ground. This new Second Edition of EEMUA 143 takes ISO 15614-8:2016 *Specification and qualification of welding procedures for metallic materials - Welding procedure test – Part 8: Welding of tubes to tube-plate joints* as the primary source material with some additions where it was felt that the standard required further clarification, or does not address the topic sufficiently.



1. Scope

This Publication supplements the requirements of ISO 15614-8:2016 for all tube to tube-plate welding. However, it does not cover joints made purely by mechanical means, e.g. expansion.

1.1 Acronyms and definitions

The following list of acronyms used in this Publication are defined below:

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BPVC	Boiler and Pressure Vessels Code
EN	European Standards
GTAW	Gas Tungsten Arc Welding
HAZ	Heat Affected Zone
ID	Inside Diameter
IEC	International Electro-technical Commission
IIS	Italian Institute of Welding
IIW	International Institute of Welding
ISO	International Organization for Standardization
ITP	Inspection and Test Plan
NDT	Non Destructive Testing
OD	Outside Diameter
TEMA	Tubular Exchanger Manufacturers Association
UTS	Ultimate Tensile Strength

1.2 Convention

This Publication refers to parts of other specifications as 'section' and to its own contents as 'clause'.

2. Welding process and joint detail

2.1 Manual processes

Earlier editions of this Publication included detailed design criteria based on IIS/IIW recommendations that represented welding practice at that time, including details of suitable joint sizes relative to individual, mostly manual, welding processes. This level of detail is not included in this edition as the majority of welding will be automated.

2.2 Automatic and semi-automatic processes

Modern welding techniques for tube-to-tube-plate welding predominantly use automatic welding machines that are capable of consistent results and can accurately reproduce the weld joints performed during qualification testing. However, it is still sometimes necessary to use manual or semi-automatic processes, particularly in the case of large diameter tubes.

2.3 Acceptable welding processes

All welding processes are permissible, provided that acceptable results and appropriate metallurgical properties can be achieved during procedure qualification and reproduced consistently in production. This Publication does not prohibit the use of any suitable welding process.

2.4 Joint types

No joint types are prohibited but the main joint types can be summarised as follows:

2.4.1 Expansion only (no welding)

Expansion-only joints are outwith this Publication and not usually permitted for process service due to the risk of crevice corrosion at the tube-to-tube-plate edge.

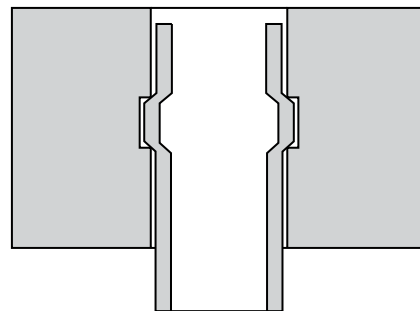


Figure 1 Expansion only

2.4.2 Expansion and seal-welding

For certain applications, and where specified in the Purchase Order, expansion into ring groove(s), coupled with seal-welding may be utilised. This method introduces risks if the tube is fully expanded prior to welding as gases evolved/released during welding will not be able to escape from the root side of the joint. Therefore, partial expansion to secure the tube, followed by welding and final expansion is recommended.

When this method is applied, all criteria of this Publication and ISO 15614-8 apply with the exception of the $0.9t$ weld throat requirement.

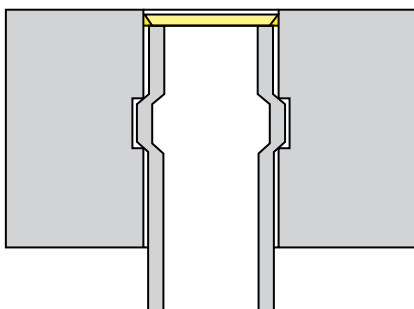


Figure 2 Expansion and seal-welding

2.4.3 External fillet weld

The tube passes completely through and extends beyond the tube-plate, allowing a fillet weld to be performed on the outside diameter of the tube. The fillet leg size can exceed the tube wall thickness and is normally specified as $1.4t$ minimum to provide a weld throat thickness at least equal to the tube wall thickness.

This method is recommended for manual and semi-automatic welding processes.

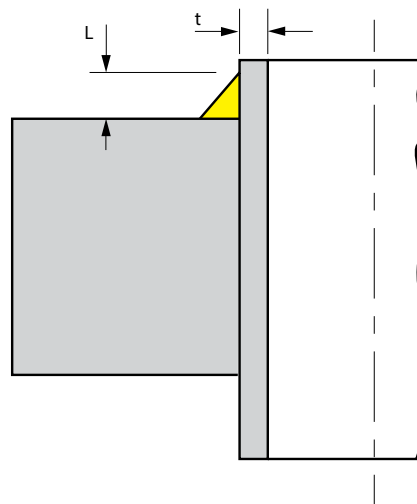


Figure 3 External fillet weld

2.4.4 External butt and fillet weld

This configuration is similar to the external fillet weld, but a bevel is cut into the tube-plate allowing the resulting butt weld throat to be supplemented by the fillet weld. The advantage of this design is that the overall weld volume is reduced and there is less chance of burning through the tube wall.

There is a risk of lack of fusion at the weld root on the tube-plate due to the larger wall thickness, particularly for manual and semi-automatic welding.

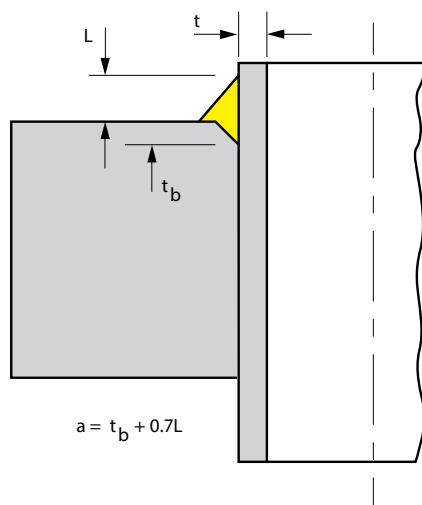


Figure 4 External butt and fillet weld

2.4.5 Internal fillet weld

Internal fillet welds are commonly applied using manual, semi-automatic, or automatic welding processes. There is a risk of inadequate weld throat thickness as the fillet leg length cannot exceed the tube wall thickness. As a result of this ISO 15614-8 table 4 item 16 has a weld throat acceptance criterion for the macrosections of $0.9t$ instead of the $1t$ that would be expected for a full strength joint.

Push-through tensile tests are more likely to fail in the weld as a result of this reduced throat thickness (see clause 3.4 Weld Strength Tests).

There is an additional risk of excessive weld penetration into the tube ID when using this joint configuration and trying to obtain sufficient weld throat thickness.

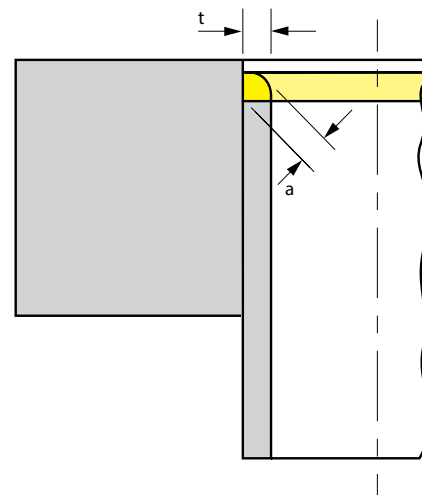


Figure 5 Internal fillet weld

2.4.6 Castellated

A U-Groove is machined into the tube-plate to provide a joint that appears to be a concentric tube outside the tube. The advantage of this configuration is that the heat sink on the tube-plate side is reduced to be comparable with the tube. Furthermore, welding distortion of the tube-plate is minimised.

A disadvantage of this joint configuration is that the weld bead profile becomes critical to achieving sufficient weld throat.

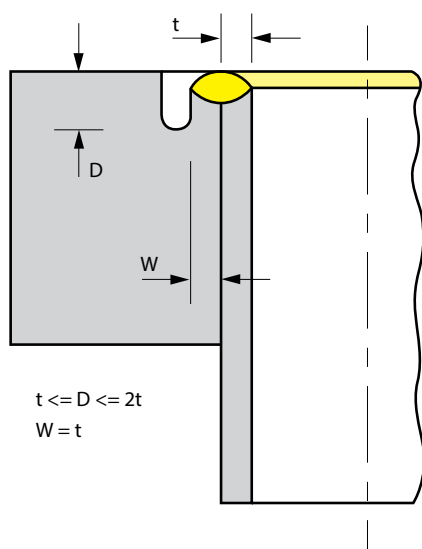


Figure 6 Castellated

2.4.7 Full penetration internal butt weld

A U-Groove is machined into the tube-plate to provide a joint that appears to be a matching tube on the tube side of the tube-plate. This allows a full penetration weld to be performed from the inside of the tube and will normally require an additional shielding gas to be applied from the outside of the tube. The preferred geometry on the right includes a recess that centres the tube and provides additional weld metal for autogenous welds (though see clause 8.4 of this Publication).

Although this configuration is shown without a root gap, a gap can be incorporated to allow filler metal addition by fed wire or consumable insert ring.

This specialist geometry is employed to eliminate crevices on both side of the tube-plate, particularly for liquid/liquid heat exchangers. It is also the only joint type that permits full volumetric NDT.

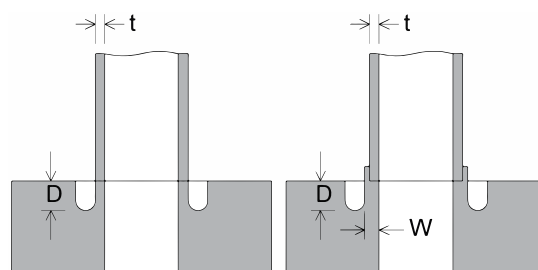


Figure 7 Full penetration internal butt weld

3. Qualification of welding procedure

3.1 Introduction

Qualification of weld procedures should be in accordance with ISO 15614-8 as modified by this Publication.

The Purchaser shall be given sufficient notice to enable them or their representative to witness all weld procedure qualification tests.

At the discretion of the Purchaser, the results of previously 3rd party-authenticated procedure tests may be acceptable.

3.2 Test samples

All tubes used for procedure testing shall be of the same diameter, wall thickness and nominal chemical composition as those proposed for production. Tube-plate material to be used for the procedure test shall also be of the same nominal composition and supply condition (including product form and heat treatment) as that to be used in manufacture.

Qualification range shall be in accordance with ISO 15614-8 Table 5 (section 9.3.2), except as follows:

- When the thickness of the tube-plate (t_2) is less than 35mm, the qualified thickness range is $0.75t_2 - 1.5t_2$;
- The tube nominal diameter and wall thickness for mechanised / automatic welding shall be the size used for qualification;

If tube expansion after welding is specified, it may be necessary for a sample of full plate thickness to be employed (see clause 14 of this Publication).

3.3 Non-destructive testing

3.3.1 Visual examination

A visual examination of the welds shall show uniform contour without excessive reinforcement with the bores of the tubes free from any spatter, obstruction, weld spillage or overfill, which is considered to be detrimental.

3.3.2 Radiographic examination

Refer to ISO 15614-8 Section 8.1.4.

3.4 Destructive testing

3.4.1 Weld strength tests

Unless otherwise specified by the Purchaser, three tensile tests shall be carried out in accordance with ISO 15614-8, Section 8.1.7, as amended below.

Note that for larger diameter tubes (over 40mm) this means that the minimum number of tubes to be welded is eight.

The purpose of the tensile test is to apply a tension load to the tube and weld. This can be carried out by direct tension test on the tube end or by pushing a plunger through the welded end of the tube against the closed end, as shown in the following figures. The breaking load should then be recorded.

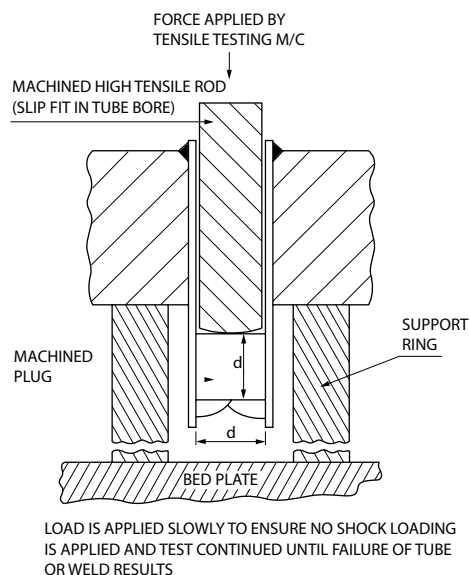
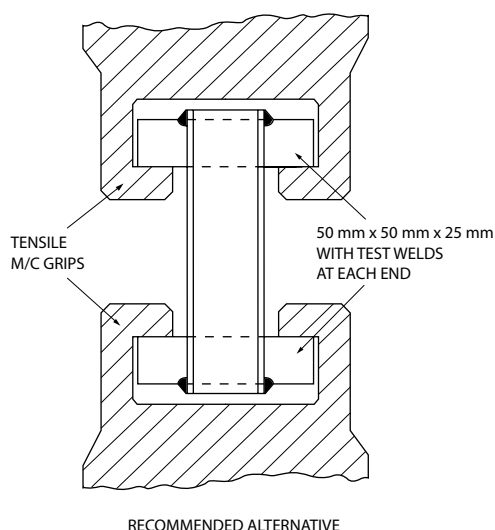


Figure 8 Weld strength tests

Alternative Testing Arrangements

The results of the tension test shall comply with one of the following:

- Failure in the tube is acceptable.
- Failure in the weld or heat affected zone at or above 100% of specified minimum UTS of the tube material is acceptable.
- Another criterion as agreed between Purchaser and Manufacturer, e.g. for a partial strength weld.

3.4.2 Macroexamination and hardness tests

Sections shall be cut, polished, and etched according to ISO 15614-8 section 8.1.5

The transverse sections of welds, including weld craters, shall be free from cracks, fissures and lack of fusion. Slag inclusions and gross porosity shall not exceed the limits of ISO 15614-8 Tables 2 and 3.

After polishing and etching the sections, the minimum throat thickness or leak path of each weld shall be not less than $0.9t_1$, where t_1 is the nominal wall thickness of the tube. The size of any visible imperfections shall be taken into account in assessing the dimensions of the minimum leak path.

Hardness tests shall be carried out in accordance with ISO 15614-8 section 8.1.6 for all materials. Acceptance criteria for metals that do not have a specified maximum in EN ISO 15614-1 shall be as-specified for the base material specification or as agreed between the Purchaser and Manufacturer. The Purchaser may specify additional limits based on application requirements.

3.4.3 Ferrite test

For duplex and super duplex austenitic / ferritic stainless steels two faces 90° apart shall be polished to a one micron finish and suitably etched. The specimen shall be examined for any deleterious third phases and ferrite content shall be determined using point counting to ASTM E562. The acceptance criterion shall be 35% - 65% ferrite in the weld and HAZ.

Note: For tube-plates in the vertical position, the ferrite determination shall be carried out at 3 and 12 o'clock positions. For tube-plates in the flat position, two diametrically opposed tests are required.

3.4.4 Corrosion test

For duplex austenitic / ferritic and superaustenitic stainless steels, a corrosion test shall be carried out in accordance with ASTM G48. Care should be taken to grind away or seal crevices on the root side, depending on weld geometry. The minimum test parameters and acceptance criteria shall be as follows:

22% Cr duplex	24hrs @ 22°C minimum
25% Cr duplex	24hrs @ 35°C minimum
27% Cr duplex	24hrs @ 40°C minimum
6% Mo	24hrs @ 35°C minimum

The acceptance criteria shall be a weight loss < 4g/m² and no pitting on the test face. If the weight loss is >4g/m² and it can be positively identified that this is only due to corrosion at the cut faces, the test shall be invalid. In this case re-testing shall be carried out on replacement specimens.

For other corrosion-resistant alloys, test requirements will be defined by the Purchaser.