



Document No.	GP 18-03
Applicability	Group
Date	Draft 25 October 2005

Guidance on Practice for Heat Exchanger Tube End Fixing

GP 18-03

BP GROUP
ENGINEERING TECHNICAL PRACTICES

Foreword

This is the first issue of Engineering Technical Practice (ETP) BP GP 18-03. This Guidance on Practice (GP) is based on parts of heritage documents from the merged BP companies as follows:

British Petroleum

GS 118-8

Heat Exchanger Tube End Fixing.

Uncontrolled Copy

Copyright © 2005, BP Group. All rights reserved. The information contained in this document is subject to the terms and conditions of the agreement or contract under which the document was supplied to the recipient's organization. None of the information contained in this document shall be disclosed outside the recipient's own organization without the prior written permission of Director of Engineering, BP Group, unless the terms of such agreement or contract expressly allow.



Table of Contents

	Page
1. Scope	6
2. Normative references.....	6
3. Symbols and abbreviations	7
4. General	7
4.1. Types of tube end joint.....	7
4.2. Quality assurance	8
5. Preparation of tubes and tubesheets	8
6. Tube end welding	9
6.1. Welding processes.....	9
6.2. Joint details.....	9
6.3. Metallurgical considerations.....	9
6.4. Welding procedure specification (WPS)	10
6.5. Welding procedure qualification test.....	11
6.6. Welder qualifications	11
6.7. Tube location for welding	12
6.8. Preheat	12
6.9. Post weld heat treatment (PWHT).....	13
6.10. Welding.....	13
6.11. Quality control during welding	13
6.12. Production control test blocks	14
6.13. Cleaning and inspection.....	14
7. Tube expansion	14
7.1. General.....	14
7.2. Roller expansion	15
7.3. Hydroswaging	15
7.4. Wall thinning	15
7.5. Expansion after welding	15
7.6. Expansion procedure test block	16
7.7. Expansion check.....	16
8. Leak detection	16
8.1. Leak detection of welded or welded and expanded tube ends	16
8.2. Leak detection of expanded only tube ends	17
9. Repairs	17
10. Pressure testing.....	17
11. Draining and dewatering	17
12. Inspection	18
Annex A (Normative) Typical joint details.....	19



A.1. Plain fillet weld	19
A.2. Recessed tube.....	19
A.3. Groove welds.....	20
A.3.1. General.....	20
A.3.2 Groove plus fillet	20
A.3.3. Groove only	20
A.4. Castellated weld preparation.....	21
A.5. Back face tube sheet welding	22
A.6. Design to avoid hot hydrogen sulphide corrosion.....	23

List of Tables

Table 1 – Welding procedure qualification testing requirements.....	11
Table 2 – Pre-heat temperatures	12
Table 3 – Tube wall thinning	15
Table 4 – Summary of inspection activities	18
Table 5 – Required radius of tube end weld preparation for a given tube thickness and welding process.....	21

List of Figures

Figure A.1 – Plain fillet weld	19
Figure A.2 – Recessed tube.....	20
Figure A.3 – Groove welds.....	21
Figure A.3.1 – Groove plus fillet.....	21
Figure A.3.2 – Groove.....	21
Figure A.4 – Castellated weld preparation	22
Figure A.5 – Back face tube end welds	23
Figure A.6 – Design to avoid hot hydrogen sulphide corrosion.....	24



Introduction

This GP details BP's requirements for heat exchanger tube end fixing. Reliable, leak tight, tube end joints are essential in shell and tube heat exchanges and air coolers for efficient operation. A controlled process of design together with careful fabrication and inspection are prerequisites for satisfactory service. Consequently, it is BP's requirement that tube end fixing procedures shall be qualified by test and that each tube end joint shall be subject to a combination of non destructive testing, leak testing, and pressure testing before dispatch from the manufacturer's works.



1. Scope

This GP details BP's general requirements for the tube end welding and / or expansion of ferrous and non-ferrous tubes. The requirements apply to both shell and tube exchangers and air coolers having tube and tube sheet dimensions within the following size ranges:

- a. Nominal tube diameter 15 mm (0,5 in) to 40 mm (1,5 in).
- b. Tube wall thickness 1,6 mm (0,064 in) to 4 mm (0,160 in).
- c. Tubesheet thickness 15 mm (0,5 in) and above.

The use of tube dimensions outside the above range shall require the specific approval of BP

Wall thicknesses down to 1,25 mm are sometimes used with zirconium and nickel alloy tubes; in these cases, weld joint details shall be approved by BP. While this GP is independent of any particular design code, it should be noted that BSI PD 5500, Appendix T provides useful information on the design, fabrication, and testing of tube to tubesheet welds.

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical practice are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

BP

GP 18-01	Guidance on Practice for Welded Fabrication and Construction.
GP 18-02	Guidance on Practice for The Storage and Control of Welding Consumables.
GIS 42-102	Guidance on Industry Standard for Fabrication, Assembly, Erection, and Inspection of Austenitic and Duplex Stainless Steel, Cupro-Nickel, Nickel Base Alloy, Titanium, and Zirconium Pipework (ASME B31.3).

American Society of Mechanical Engineers (ASME)

ASME Sec IX	ASME Boiler and Pressure Vessel Code – Section IX Welding and Brazing qualifications.
-------------	--

British Standards Institute (BSI)

PD 5500	Unfired fusion welded pressure vessels.
BS 4871-3	Approval testing of welders working to approved welding procedures, Part 3: Arc welding of tube to tube-plate joints in metallic materials.

International Organisation for Standardization (ISO)

ISO 3834-1	Quality requirements for welding. Fusion welding of metallic materials. Part 1. Guidelines for selection and use.
ISO 3834-2	Quality requirements for welding. Fusion welding of metallic materials. Part 2. Comprehensive quality requirements.
ISO 9001	Quality systems - Model for quality assurance in design/development, production, installation and servicing.



ISO 15614-8 Specification and qualification of welding procedures for metallic materials - Welding procedure test -
Part 8: Welding of tubes to tube-plate joints.

Tubular Exchanger Manufacturer's Association (TEMA)

TEMA Standards of Tubular Exchanger Manufacturers Association.

3. Symbols and abbreviations

For the purpose of this GP, the following symbols and abbreviations apply:

GMAW	Gas metal arc welding
GTAW	Gas tungsten arc welding
HAZ	Heat affected zone
NDT	Non-destructive testing
PWHT	Post weld heat treatment
SMAW	Shielded metal arc welding
WPS	Welding procedure specification

4. General

4.1. Types of tube end joint

- a. The following combinations of tube expansion and tube end welding may be adopted depending on service conditions:
 1. Expanded only.
 2. Strength welded only.
 3. Expanded and seal welded.
 4. Strength welded and lightly expanded.
 5. Strength welded and expanded.
 6. Back face welded.

- b. A strength weld is defined as a weld in which the minimum throat thickness is not less than the tube wall thickness (t). A weld having a smaller throat thickness than this is considered to be a seal weld and its function is solely to seal between the tube and the tubesheet.

In BSI PD 5500 Para. 3.9.6 and ASME Sec VIII, Div 1 Appendix A, strength factors are assigned to the above types of tube end joint. This is to check, during design, the strength of the joint for the axial loads which may be applied in service.

- c. The combination of welding and expansion required on each exchanger shall be as specified by, or approved by, BP. An adequate tubesheet ligament shall be provided for the specified fabrication technique.

For many applications, tube expansion into grooves in the tubesheet without welding is satisfactory and economic. In deciding whether tube end welding is necessary, an assessment is required of the likelihood of leakage and the possible consequences.



With properly applied strength welds, tube expansion is frequently unnecessary as it does not significantly contribute to the mechanical strength of the tube end joints.

However, for certain service duties, it is necessary to provide intimate contact between the outside diameter of the tubes and the bore of the tubesheet holes. This contact may be accomplished by light expansion of the tubes after both welding and successful leak testing, but before final pressure testing. A light expansion avoids the build-up of corrosion products in the annular gap, but does not guarantee that crevice corrosion will not occur.

If service conditions preclude any crevice between the tubes and the tubesheet, back face welding must be used. (Annex A, Figure A.5). It is used if there is a high heat flux as the tubes enter the tubesheet and therefore concern that the tubes might crack. It is also used if the shell side fluid is corrosive such that no crevice may be permitted.

If the additional security provided by strength welds in combination with tube expansion into grooves is considered necessary, the sequence of operations and the technique employed for tube location is important. Weld cracking may occur with expansion after welding. Porosity can occur in the welds if the tubes are fully expanded before welding because, if the tubes and tubesheet are not thoroughly cleaned, the expanding operation may increase the amount of dirt at the root of the weld.

In air coolers, access for tube end welding can only be through the header plug plate and it is very limited. Tube end welding is usually GTAW with the torch and wire coming through separate holes in the plug-plate, and the operator controlling through a third. It may be done manually or automatically. The principles on which the tube end preparation is selected are very similar to those for a shell and tube exchangers, but the lack of access for welding and inspection greatly increases the complexity of the work.

Failure of tube to tubesheet attachments can be extremely costly. Selection of the optimum materials for tubes and tubesheet and specification of the correct combination of expansion and welding are both essential to ensure maximum integrity and service reliability.

4.2. Quality assurance

- a. Tube bundle fabrication should take place in a controlled environment employing manufacturing procedures administered by a Quality Assurance programme based on ISO 9001 or an agreed equivalent standard. Additionally, welding quality requirements and systems should comply with the principles of ISO 3834-1 & 2.
- b. The quality plan or inspection and test plan, together with the associated procedures for cleaning, welding, expansion, NDT, leak testing, and pressure testing shall be submitted for BP approval before the commencement of fabrication.

5. Preparation of tubes and tubesheets

- a. Tube holes shall be normal to the tubesheet surface, parallel, circular, and free from burrs and shall have a smooth internal surface. The periphery of the holes on the tube bundle side shall be chamfered or radiused to approximately 1,5 mm (0,06 in). The diametral limits of the tube holes shall not exceed those defined by TEMA.
- b. For light tube expansion, no grooves are required. For full expansion, grooves shall be machined to suit the intended expansion technique (see clause 7).
- c. Immediately before assembly, the tubes and tubesheet shall be cleaned with a chloride and sulphur free, non-residue forming solvent.

