



GS 118-7

**THE FABRICATION, ASSEMBLY,
ERECTION AND INSPECTION OF
AUSTENITIC AND DUPLEX STAINLESS
STEEL, CUPRO-NICKEL, NICKEL
BASE ALLOY, TITANIUM AND
ZIRCONIUM PIPEWORK TO
ASME B31.3**

August 1997

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BP GROUP RECOMMENDED PRACTICES AND SPECIFICATIONS FOR ENGINEERING											
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APPLICABILITY Regional Applicability: International											
SCOPE AND PURPOSE This document is a supplement to ASME B31.3. It provides additional detail to the base code and identifies BP's specific requirements for welding procedure qualification, welder skill, workmanship and integrity of process pipe work. The primary objective of this Guidance for Specification is to allow application of ASME B31.1 to BP plant pipework with confidence, fit-for-purpose and with enhanced safety.											
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FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory Volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory Volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Guidance for Specification

This Guidance for specification clarifies and amplifies a number of ASME clauses on the basis of BP's fabrication experience worldwide.

Application

This Guidance for Specification is intended to guide the owner in the use or creation of a fit-for-purpose specification for enquiry or purchasing activity.

It is a transparent supplement to [ASME B31.3](#) 1996 Edition, showing substitutions, qualifications and additions to the ASME text as necessary. As the titles and numbering of the BP text follow those of ASME, gaps in the numbering of the BP document may occur. Where clauses are added, the ASME text numbering has been extended accordingly.

Text in italics is Commentary. Commentary provides background information which supports the requirements of the Specification, and may discuss alternative options.

Throughout this document the term 'owner' is used to imply BP or their nominated representative. Any Specification subsequently prepared for the procurement of fabricated pipework should define the particular party responsible for the stated actions.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.



Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP RPSE's, to assist in the process of their continuous improvement.

For feedback and further information, please contact Standards Group, BP International or the Custodian. See Quarterly Status List for contacts.



1. INTRODUCTION

1.1 Scope

This document specifies general requirements supplementary to [ASME B31.3](#) - 1996 Edition, Chemical Plant and Petroleum Refinery Piping, Chapter V (Fabrication, Assembly and Erection) and Chapter VI (Inspection, Examination and Testing) and is applicable to both onshore and offshore piping systems.

The welding of riser pipework and transmission pipelines is outside the scope of this Specification.

When additional text is to be read as an extension to the text of [ASME B31.3](#), the text numbering of [ASME B31.3](#) has been extended accordingly.

The general requirements for the fabrication of the materials covered by this Specification are detailed in the main body of the document, but specific requirements for duplex stainless steels and titanium/zirconium are detailed in Appendix C and D respectively.

2. QUALITY ASSURANCE

2.1 Initial Documentation

Before commencing fabrication of the pipework the fabricator shall prepare a quality plan and a set of design documents, both of which shall be subject to approval by the owner.

These documents should normally include materials, welding and consumable control procedures, welding and non-destructive testing procedure specifications together with supporting qualification records and an illustration of their proposed areas of application. Mechanical working, heat treatment and leak testing procedures should also be included.

Previously qualified welding procedures may be considered for use where they comply with the requirements of the present document and are appropriate to the proposed scope of work. However, for critical applications, welding procedures shall require re-qualification, as directed by the engineering design.



Simplified welder instruction cards based on the qualified welding procedures should be prepared for each welding process/material combination and issued to each welder.

The quality plan shall include brief details and the sequence of all examinations that will be performed by the fabricator. The names of the individuals responsible for the implementation of all quality assurance and quality control functions shall also be included.

It shall be the responsibility of the fabricator to inspect all materials upon receipt and to ensure that the correct grade of material has been supplied and that identification, dimensions, material quality and end preparation are in accordance with the requisite standards and specifications.

Different materials shall be kept in discrete sections of the storage area and all material shall be marked in a manner that allows it to be related to the original manufacturers certification.

Procedures for the transfer of material identification marks shall be agreed with the owner prior to the commencement of fabrication.

Any material which is not readily identifiable shall be removed from the worksite and quarantined until its material grade and source can be confirmed.

All materials shall be stored above ground and kept free from dirt, grease and other contaminants.

The fabricators procedures for the storage and control of welding consumables shall comply with the requirements of BP [GS 118-4](#).

Positive identification and segregation of materials is an important issue and fabricators involved in the fabrication of alloy piping should submit a Positive Material Identification (PMI) document setting out how they maintain and verify the identity of materials during fabrication. API are currently drafting [RP 578](#) which sets out the requirements for a PMI system.

2.2 Production Documentation

At all stages of the work the fabricator shall maintain all relevant production records using a recording system approved by the owner. The records shall include:-

- (i) Material and welding consumable certificates.
- (ii) Post weld heat treatment records.



- (iii) Visual and dimensional inspection together with NDT and pressure test records.
- (iv) Isometric drawings marked up with weld numbers.
- (v) Welder and welding operator qualification test records.
- (vi) Authenticated copies of NDT operators certificates.
- (vii) Records of any agreed concessions to the fabrication standards.

On completion of the fabrication programme these records shall either be passed to the owner or stored by the fabricator, as directed by the engineering design or the fabrication contract.

2.5

Pipework Marking

All pipework shall be identified by indelible marking, free from sulphur, chloride and other halogens. When spools will be subject to post-weld heat treatment a suitable titanium oxide pigmented heat resisting paint containing less than 250 ppm of lead, zinc, tin or copper shall be used. Vibro-etching techniques may be used for identification transfer but adhesive tapes or hard stamping, other than that with low stress stamps, shall not be used.

All applied marking shall have a life of at least one year in covered, unheated, storage.

The marking applied shall identify the material and the fabricator and include an item number enabling the spool to be traced to the relevant isometric drawing.

Guidance on suitable material identification colours may be obtained by reference to [BS 5383](#).



3. SOUR AND CHLORIDE SERVICE.

Where external chloride attack of austenitic stainless steels is anticipated the requirements of Section 6 of BP [GS 136-1](#) shall apply.

The following additional requirements should be considered for stainless steel piping systems for service conditions which involve either sour environments or those containing chlorides:-

- a) *Appendix B of BP [GS 136-1](#) for austenitic stainless steels*
- b) *[NACE MR 0175](#), paragraph 3.9 for duplex stainless steels.*

4. FABRICATION FACILITIES

The area used for fabrication shall be totally separate from that used for carbon and low alloy steel. Further, each alloy type covered by this specification shall be segregated during fabrication. Adequate precautions shall be taken to prevent surface contamination by contact with jigs and fixtures manufactured in non-compatible materials. Separate sets of clearly identified cleaning and grinding equipment shall also be provided for each material.

The shop layout, equipment and production procedures shall be subject to the approval of the owner, particularly where the fabrication of either titanium or zirconium is involved.

5. FABRICATION, ASSEMBLY AND ERECTION

Supplementary to Chapter V of [ASME B31.3](#) - 1996 Edition.

The text of [ASME B31.3](#) applies, except where amended by the following text or in the engineering design.

328 WELDING

328.2 Welding Qualifications

328.2.1 Qualification Requirements

- (a) Welding procedure specifications and procedure qualification test results shall be submitted to the owner for approval before commencement of fabrication.

Each procedure qualification record shall be certified by a recognised independent inspectorate.



The SMAW, GTAW, PAW and SAW process are frequently employed for pipework fabrication and are considered to be acceptable welding techniques when used in accordance with this specification. The GMAW and FCAW processes are also often applied to piping fabrication. However, there are many variants of these two processes and in addition to ensuring adequate procedure qualification it is important to ensure that the particular welding technique proposed for a given application is well proven and will only be used by qualified and experienced welders.

- (d) Unless otherwise specified by the engineering design, charpy V notch impact testing, as detailed in Appendix C, will be required on all duplex stainless steel piping materials, fittings and weldments for design temperatures below 0°C. The minimum design temperature for duplex stainless steels shall be -50°C.

In the case of austenitic stainless steels charpy V notch impact testing will not generally be required for minimum design temperatures greater than -196°C. However, if the possibility of toughness degradation as a result of post weld heat treatment exists (see 331.1.1) charpy V notch impact testing will be required for austenitic stainless steels. The required impact energy for austenitic stainless steels will be 40J at the minimum design temperature.

When impact testing is required the weld metal, fusion line and HAZ shall be tested. All charpy specimens shall be cut transverse to the weld with the axis of the notch perpendicular to the surface of the test piece. Specimen and notch locations shall be as shown in Figure 1. If only subsize charpy specimens can be taken the standard energy reduction factors of 0.833 for a 10 x 7.5 mm specimen, and 0.667 for a 10 x 5 mm specimen shall be applied.

When a welding procedure requiring impact testing is to be used in all positions, separate 2G and 5G qualifications shall be performed.

- (e) Backing rings are not permitted on pipework fabricated to this Specification.
- (f) P-Numbers (also F-Numbers)
 - (i) The extension of a welding procedure qualification from the material on the procedure qualification record to material of a different specification, even if it has the same P-Number, shall be subject to approval by the owner.



- (ii) A new welding procedure qualification is required if there is a change of consumable classification or consumable brand name, unless agreed otherwise by the owner.
- (iii) A new welder performance test is required if there is a change of SMAW electrode brand name unless the brand characteristics do not differ sufficiently to affect performance. Any such change shall be subject to approval by the owner.
- (g) The welding procedure specification shall require re-qualification if any of the following changes are made:-
 - (i) A change outwith the welding parameter tolerance ranges specified in the qualified welding procedure specification.
 - (ii) Any increase of more than 1 gauge number in the electrode size from that used in the qualified welding procedure.
 - (iii) A change in the type of current, i.e. ac to dc or, in dc welding, a change in electrode polarity, except where these changes are within the electrode manufacturer's recommendations.
- (h) Where any limitation on weldment hardness is specified in the engineering design, macrographic examination and hardness measurements (HV 10) shall also form part of the welding procedure qualification.

Service conditions requiring restrictions to hardness levels are identified in BP [GS 136-1](#).

- (i) In addition to mechanical testing, welding procedure test samples shall be subjected to dye penetrant and radiographic examination. All non-destructive examination shall be completed prior to the machining of test pieces.
- (j) Ideally, welder performance tests for all positional welding should be carried out in both the 2G and 5G positions. However, subject to the agreement of the owner the welder performance test may be undertaken in the 6G position. In that case, each welder shall also demonstrate his ability to deposit



acceptable root runs in both the 2G and 5G positions. With the agreement of the owner this may be achieved by radiography of the welders first production welds in the 2G and 5G positions.

- (k) Welders and welding operators shall be qualified by visual examination and radiography except in the case of either titanium or zirconium where mechanical testing in accordance with Appendix D shall also be required.

Subject to the provision of an authenticated CV and with the agreement of the owner, welders and welding operators may be qualified on their initial production welds for materials other than Titanium and Zirconium.

- (l) Welder and welding operator qualification tests shall be witnessed by the inspector.

The above additions and modifications to the qualification requirements have been made on the basis of fabrication experience and will allow welding to proceed with an improved level of confidence in both procedural qualification and welder skill.

Ultrasonics may be used in lieu of radiography when material thickness restricts the suitability of radiography due to decreased sensitivity or extended exposure time.

328.2.4 Qualification Record. See 2.2.(v) of this document.

328.2.5 **Test Joints**

Welding procedure qualification tests should be carried out using pipe materials. All welder performance tests shall be undertaken on pipe. Performance testing shall utilise pipes of nominally the same chemical analysis as the production material, unless agreed otherwise by the owner. All test shall use filler metal of the same chemical composition and manufacturer as those to be used in production.

A change in the type, or even the manufacturer, of filler metal can alter the fluidity of the weld pool and affect the ability of a welder to successfully complete a weld and this must be recognised in the extent of qualification testing required.

328.3 **Welding Materials**

328.3.1 **Filler Metal**

All GTAW filler wires shall be degreased prior to use and shall subsequently be handled with clean gloves. The degreasant shall leave no chloride or sulphide containing residues on the surface.

Filler metals will be selected with due regard to the need for the weld metal to, as a minimum, match the physical properties and corrosion resistance of the parent material.



In the case of the 300 series austenitic stainless steels the ferrite content of the deposited weld metal should normally lie in the range 3-8%. However, under certain service conditions it may be necessary to further limit the ferrite content. In critical applications it may also be necessary to measure the ferrite content.

Stress relieving heat treatments in the range 900/950°C usually result in a reduction of notch toughness in 300 series austenitic stainless steel weld metals. Where PWHT is specified for pipework in low temperature service or where the piping design code includes notch toughness requirements, welding procedure tests should ensure that the PWHT does not result in unacceptable embrittlement. This is especially relevant for filler metals containing niobium or molybdenum.

Higher alloy austenitic stainless steels such as those containing $\pm 20\%$ Ni and/or $\pm 4\%$ Mo often require the use of nickel base weld metals in order to ensure sound weld metal of adequate corrosion resistance.

Some specific guidance on filler metal selection is provided in the appendices, but final guidance concerning any special requirements including the selection of filler metal composition for dissimilar metal joints or the fabrication of corrosion resistant alloy clad components, should be provided by the engineering design.

328.3.2 Weld Backing Material

As stated in 328.2.1(e) backing rings shall not be used on pipework fabricated to this specification.

328.3.3 Consumable Inserts

Consumable inserts may only be used with the approval of the owner.

328.4 Preparation for Welding

328.4.1 Cleaning

Working practices shall be designed to minimise contamination and, before welding, internal and external surfaces shall be cleaned for a distance of at least 50 mm from the fusion face. The surfaces to be joined by welding shall be stainless steel wire brushed and degreased immediately prior to welding. The degreasant shall leave no chloride or sulphide containing residues on the surface. On small pipes where it is not possible to wire brush the internal surface an approved chemical cleaning material shall be used.



328.4.2 End Preparation

(a) General

- (1) Materials, other than Zirconium and Titanium for which the requirements of Appendix D apply, shall be cut to size and bevelled by plasma arc cutting, cold cutting, machining or an appropriate grinding technique.

Where plasma arc cutting is used, all surfaces adjacent to the cut shall be cleaned prior to cutting by light grinding or wire brushing to bright metal. Immediately prior to cutting, the prepared surfaces are to be further cleaned by a suitable degreasant. Subsequent to plasma arc cutting all surfaces shall be ground smooth and returned to a bright metal finish.

(b) Circumferential Welds

- (4) Weld metal buttering shall not be deposited to assist alignment or provide sufficient material for machining without the approval of the owner.
- (6) Prior to fit up the weld bevels shall be visually inspected, supplemented by dye penetrant or, if appropriate, magnetic particle examination where considered necessary by either the fabricators or owners inspection or welding personnel.

328.4.3 Alignment

(a) Circumferential Welds

Bore misalignment in circumferential butt joints shall not exceed 1.5 mm without the approval of the owner.

(c) Branch Connection Welds

- (3) Weld metal shall not be deposited to correct contour, shape or tolerances without the permission of the owner.

(e) Fabrication Tolerances

Fabrication tolerances shall comply with Figure 2 unless otherwise approved by the owner. Category M tolerances shall



be used for service temperatures above 460°C and class ratings 900 and above or when specified within the engineering design.

Weldments in austenitic steels are prone to distortion due to their high coefficients of thermal expansion and low thermal conductivity. Fabricators should consider this before commencing welding. In some cases, changes to design details will mitigate the risk of distortion and the fabricator shall consult with the owner if, in his opinion, such design changes are necessary to comply with defined tolerances.

328.5 **Welding Requirements**

328.5.1 **General**

- (b) All welds shall be marked with the welders/welding operators identification symbol.
- (c) Preference shall be given to the use of line up clamps, or bridge tacks which do not interfere with the deposition of a continuous root run. Root tack welding, when approved, shall not commence until bore purging has been established. When the tacks are to be incorporated in the final weld, they must be properly cleaned prior to the root pass and the ends feathered by grinding. In addition the delay between tack welding and the deposition of the root pass shall be minimised to reduce contamination. The removal of bridge tacks shall be by mechanical grinding only.

In order to reduce the risk of contamination of the weld zone clamp face and bridge tack materials should be of the same material as, or compatible with, that being welded.

- (d) Peening shall not be permitted on any pass.
- (f) Unless otherwise stated in the manufacturers installation instructions, all welds for the installation of in-line valves shall be performed with the valve in the fully opened position.
- (g) GTAW or PAW shall be used for the root pass of all materials covered by this standard. GTAW or PAW are also the preferred techniques for the second (hot) pass. However, where appropriate, SMAW may be used for the hot pass provided the electrode size does not exceed 2.5 mm. SMAW shall not be used on piping less than NPS 2½ except where the welders have demonstrated their ability to use SMAW on pipe of these diameters.



- (h) Butt welds and pressure containment fillet welds in NPS 1½ and smaller pipes shall use GTAW or PAW for all passes.
- (i) All GTAW and PAW equipment shall use either a high frequency starting unit or an alternative programmed touch starting unit. A current decay device should also be fitted together with a gas lens to improve gas shielding of the weld pool.
- (j) GTAW and PAW shall only be used under enclosed shop conditions unless adequate weather protection is provided at each outdoor location where these techniques are to be used.

Where gas shielded processes are being used moderate air currents can result in the loss of the shielding gas leading to weld defects. Thus, sufficient screening must be used under such circumstances to keep winds and draughts away from the welding area.

- (k) The composition of shielding gas used for welding shall be compatible with the alloy being welded and the weld properties required.
- (l) The bore of all materials covered by this Specification shall be adequately purged during the deposition of the weld to ensure that no oxidation or coking of the root run and internal surface occurs.

In general high purity argon or argon based gas mixtures should be used for bore purging. However, in the case of austenitic stainless steels, nitrogen or nitrogen based gas mixtures may be considered for use. Argon based gas mixtures containing a percentage of nitrogen may be beneficial for use with duplex stainless steels (Appendix C)

When erecting pipe spools, particularly in large diameter pipework, adequate forethought should be given to the installation of internal dams to minimise the usage of purge gas.

When initiating the flow of purge gas a general rule of thumb that may be used is that 'all air may be removed by the admission of a volume of purge gas at least six times the volume of air being displaced.' However, when welding more reactive materials, such as titanium and zirconium, dew point measurements are desirable to establish the quality of the purge and, in general, oxygen meters are valuable for monitoring purposes.

It is often adequate for austenitic steels to ensure a flow of purge gas during the deposition of the root and second pass provided that the bore is subsequently sealed to prevent atmospheric ingress. However, in the case of the more reactive materials such as titanium and zirconium a positive purge flow should be maintained throughout the welding operation.



Guidance on the need for extended purge times is provided in the appendices and will be supplemented as necessary by the engineering design.

- (m) SAW and, where approved, FCAW and GMAW, shall not be used for pipes smaller than NPS 6 unless otherwise agreed by the owner.
- (n) All root welds should be completed without interruption other than to allow the welder to take a new length of filler wire or to reposition himself.
- (o) Vertical down welding is not permitted.
- (p) Temporary attachments to the outside surface of high alloy piping materials shall be minimised and shall not be made without the approval of the owner. Attachments which are permitted shall be made in a controlled manner to avoid oxidation of the internal surface of the pipework. The fabricator shall advise what precautions he proposes to take with regard to fixing and removing temporary attachments to and from such materials.
- (q) Whenever practicable, fillet welded joints used for pressure containment should have a minimum of three weld passes, two of which should be showing for visual inspection.

The above additions and modifications to the welding requirements have been made on the basis of fabrication experience and will allow welding to proceed with an improved level of confidence in workmanship and practice.

328.5.3 Seal Welds

Joints to be seal welded shall be made up clean and without the use of tape or any compound. Welding shall be performed in accordance with a qualified procedure by a qualified welder. The welding shall not cause damage to the threaded fitting and all exposed threads shall be covered by the seal weld.

Threaded joints should be assembled in such a manner that a maximum of three threads are exposed prior to welding.

328.5.4 Welded Branch Connections

When designing angled branch connections, in addition to considering the stress concentration effects care must be taken to ensure sufficient access for welding in the acute angle section.



When set-on integrally reinforced branch connections are used, it should be noted that the wall thickness of the connection may well be in excess of that necessary to provide the required level of reinforcement. Consequently, no reinforcement contribution is necessary from the weld metal and the deposition of a branch weld with an excessive throat thickness may lead to unacceptable distortion of the main run pipe. The engineering design should provide guidance on the sizing of branch welds when using this type of fitting. Controlled weld profiles are required when the branch is on severe cyclic duty.

If set in integrally reinforced branch connections are used particular care should be taken in fit-up, jiggling and in developing an overall welding sequence to minimise the extent of any 'sinking'.

The use of integrally reinforced branch connections on thin wall pipes, typically schedule 10 and below, should be avoided.

328.5.5 Fabricated Laps

Fabricated laps shall not be used without the agreement of the owner.

328.5.6 Welding for Severe Cyclic Conditions

The weld reinforcement shall be smooth and regular. It shall blend smoothly with the external surface of the pipe to minimise possible stress concentration effects.

The engineering design should provide any specific guidance considered necessary for weld profiles in severe cyclic duty.

328.5.7 Proximity of Welds

- (i) The toes of adjacent circumferential butt welds shall be no closer than four times the nominal thickness of the pipe with, in the case of NPS 12 and below, a minimum acceptable separation of 50 mm. For pipe sizes greater than NPS 12 the minimum acceptable separation shall be 100 mm.
- (ii) Branch and non pressure part attachment welds shall not cross longitudinal seams or circumferential butt welds and shall be subject to the toe to toe separation distance specified for circumferential butt welds.

Where such intersections are unavoidable the main weld shall be subject to non-destructive examination prior to making the attachment weld.

- (iii) Joints involving the intersection of more than two welds shall be avoided.



330 PRE-HEATING

330.1 General

The materials covered by this standard do not in general require preheating for welding except to drive off moisture or raise component temperature above 0°C.

330.1.1 Requirements and Recommendations

Cupro-nickel alloys may be preheated to a maximum temperature of 50°C.

Oxy-fuel gas welding or cutting torches may only be used for pre-heating when fitted with proprietary preheating nozzles.

Preheating of cupro-nickel is not normally necessary. However, for high heat sink welds, i.e. tee butt welds, or where one of the members being fabricated is relatively thick, preheats of up to 50°C may be applied to aid fusion.

330.1.3 Temperature Verification

- (b) Thermocouples, to measure pre-heat temperature, shall not be directly attached to pressure parts without the agreement of the owner.

330.1.4 Pre-heat Zone

The pre-heat zone shall extend 75 mm or a distance equal to four times the material thickness, which ever is the greater, beyond each edge of the weld.

330.1.5 Interpass Temperature

The maximum interpass temperature shall not exceed the stated limits for the following materials:

Cupro-nickel,	}	
	}	
high alloy austenitic stainless steels	}	100°C
containing $\geq 20\%$ Ni and/or $\geq 4\%$ Mo,	}	
	}	
Nickel based alloys containing $> 10\%$ Mo,	}	
	}	
Nickel based alloys containing $\leq 10\%$ Mo,		150°C



300 series austenitic stainless steels.

200°C

Guidance concerning interpass temperatures for duplex stainless steels and titanium/zirconium is given in Appendices C and D.

When the 300 series austenitic stainless steels are utilised in critical applications, the interpass temperature may be restricted to 150°C by the engineering design. Particular requirements for special or proprietary alloys shall also be detailed in the engineering design.

331 **HEAT TREATMENT**

331.1 **General**

331.1.1 Heat Treatment Requirements

- (e) Heat treatment is not normally considered necessary for the materials covered by this Specification. However, in the case of austenitic stainless steels it may be necessary to provide some reduction in the residual stress level after welding or cold bending. The engineering design shall identify any specific applications for which heat treatment is required.

When austenitic stainless steels are exposed to environments containing chlorides or polythionic acids the presence of residual stresses generated by either welding or mechanical working may lead to stress corrosion cracking. Stress relief heat treatment may consequently be necessary prior to service

- (f) Where a stress relief heat treatment of austenitic steels is specified by the engineering design the welds shall be heated to a temperature in the range 900-950°C and held for a period of one hour per 25 mm of thickness. The minimum soaking period shall be one hour.
- (g) Low melting point metals such as aluminium, lead, tin, copper, zinc, cadmium and mercury, and their alloys, shall not be permitted to contact any surfaces which will undergo hot forming, welding or post-weld heat treatment.

Possible sources of such contamination include solder, galvanised components, and certain types of paint.



331.1.4 **Heating and Cooling**

- (i) When a furnace heat treatment is applied to austenitic stainless steels, the furnace temperature shall not exceed 300°C when the pipework is loaded.
- (ii) For austenitic stainless steels the maximum heating rate above 300°C shall not exceed 200°C per hour.
- (iii) Following elevated temperature soaking austenitic pipework shall be removed from the furnace and rapidly cooled in air.

Should heat treatment be necessary during the fabrication of any other alloy covered by this Specification, full details of the soaking temperature and time along with of the applicable heating and cooling rates will be provided by the engineering design.

331.1.6 **Temperature Verification**

Where practical, thermocouples shall be attached to spoolpieces at a minimum of six equally spaced locations, adjacent to welds, prior to heat treatment.

Procedures for the attachment of thermocouples by capacitor discharge welding shall be approved by the owner and the use of this technique carefully monitored.

331.1.7 **Hardness Tests**

The requirement for and extent of any hardness testing shall be specified by the engineering design.

331.2.6 **Local Heat Treatment**

When a local heat treatment is applied, the weld shall be sufficiently heated and insulated to ensure that (for a pipe, of NPS 'D' and wall thickness 't'), the specified heat treatment temperature is achieved at the weld and that at a distance of $1.8 \sqrt{Dt}$ on both sides of the weld, a temperature of not less than half of the specified heat treatment temperature is attained.

In the case of branch attachments, the temperature gradient shall be such that the length of material from each crotch heated to a temperature equalling half the heat treatment temperature shall be $1.8\sqrt{Dt}$ where 'D' and 't' are the nominal diameter and thickness of the main pipe and branch as appropriate (Figure 3).



BENDING AND FORMING

The bend manufacturers procedures must be reviewed to confirm that adequate control is being exercised in the heating, cooling and inspection of the bends.

Typical tolerances on completed bends should be:-

- ovality at any cross section of bend should not exceed 5%
- wall thickness after bending should not be less than nominal design thickness
- angle of bend should be within 0.5° of nominal

332.1

General

All bending of stainless steels and nickel alloy pipe should be done cold. However, where the size and schedule of the pipe is such that cold bending becomes impracticable hot bending may be utilised. Unless stated otherwise in the engineering design, factory manufactured piping fittings shall be solution heat treated in the temperature range specified by the alloy manufacturer.

For some highly corrosive applications the use of pulled bends is not permitted. For such applications, the engineering design will define the appropriate bend manufacturing processes.

332.2

Bending

332.2.2

Bending Temperature

- (a) Cold bending of austenitic stainless steel shall be performed at temperatures below 425°C . Cold bending of duplex stainless steels shall be performed at temperatures below 300°C . Cold bends in austenitic or duplex stainless steels shall be heat treated only in applications where there is a likelihood of stress corrosion cracking due to chlorides or polythionic acid in service.

Any heat treatment of duplex stainless steels must produce a microstructure appropriate to the intended service conditions. It is recommended that heat treatment procedure qualification is carried out to demonstrate the adequacy of any heat treatment that is to be applied to duplex stainless steels.

Where cold bending of alloy pipe produces local strain in excess of 10% consideration should be given to the application of a post forming heat treatment and any specific requirements should be stated in the engineering design.

322.2.3 **Corrugated and Other Bends**

Fabricated mitre (segmented) bends are not generally permitted. However, subject to the agreement of the owner, limited use of mitred bends in accordance with Figure 4 may be proposed for applications permitted by BP RP 42-1.

The 'cut and shut' design shall not be used.

Any further guidance or restrictions that may be necessary for bending and forming the materials covered by this Specification will be detailed by the engineering design.

335 **ASSEMBLY AND ERECTION**

335.1 **General**

335.1.1 Alignment

- (a) Piping distortions. The application of heat for the correction of any minor distortions in pipe spools manufactured in the alloys covered by this Specification shall be approved by the owner.

335.1.2 Bolting Procedures

Bolting procedures should be provided for each joint or group of joints to be assembled. These procedures shall contain the following information:-

- (i) Required bolt load or stress.
- (ii) Tightening method.
- (iii) Tightening sequence.
- (iv) Elongation measurement requirements, where considered appropriate.

6. **INSPECTION, EXAMINATION, AND TESTING**

Supplementary to Chapter VI of [ASME B31.3](#) - 1996 Edition.

The text of [ASME B31.3](#) applies except where amended by additional requirements specified in the following text or in the engineering design.



340 **INSPECTION**

340.4 **Qualifications of the Owners Inspector**

BP will appoint a competent and experienced person having relevant practical and theoretical knowledge as the Owners Inspector.

341 **EXAMINATION**

341.3 **Examination Requirements**

341.3.1 General

- (a) For all materials, final examination shall be performed after completion of any heat treatment.

341.3.2. Acceptance Criteria

- (a) Table 341.3.2A as amplified by Table 1 of this document states acceptance criteria for welds.

341.4 **Extent of Required Examination**

The extent of the required examination shall, for all fluid categories, depend on the criticality rating of an individual piping system. The method of determining criticality rating shall be specified by the engineering design and assigned values shall be recorded in the piping line lists

342 **EXAMINATION PERSONNEL**

342.1 **Personnel Qualification and Certification**

Only personnel certified in accordance with PCN, CSWIP or ASNT recommended practice SNT-TC-1A, shall be allowed to undertake the examinations. In the case of ASNT, assessment of operator competence should have been undertaken by an external authority. Other equivalent qualifications may be accepted at the discretion of the owner. All personnel qualifications shall be subject to approval by the owner.



343 **EXAMINATION PROCEDURES**

Only examination procedures approved as required by paragraph 2.1 of this document shall be used.

344 **TYPES OF EXAMINATION**

344.2 **Visual Examination**

344.2.1 Definition

Visual examination shall include an examination of the internal surface of the weld where possible; full use being made of suitable optical instruments.

344.5 **Radiographic Examination**

344.5.1 Method

- (a) X-ray techniques are preferred for all shop radiography of pipework up to 25 mm wall thickness. However, where the use of X-rays is impractical, gamma ray isotopes may be used subject to the approval of the owner.

In each case the technique shall be qualified using a source side image quality indicator of the wire type to [BS 3971](#) or [DIN 54 109 Part 1](#). The single wall, single image technique should be used when ever possible. Lead intensifying screens and fine grain high contrast film shall be used. Film density shall be 2.0 - 3.0 through the thickest portion of the weld and the radiographic sensitivity shall be as shown in Table 2 of this document.

- (b) Radiography of production welds shall use a wire type IQI with each film exposure and this shall be placed on the source side where accessible. When the complete joint circumference is radiographed in a single exposure four IQIs placed at 90 degree intervals shall be used.
- (c) Where set-on branch connections are permitted by the engineering design, they should be subject to intermediate radiography with the film on the bore side of the joint when the weld depth is similar to the wall thickness and before the reinforcing fillet is applied.



344.5.3 Extent of Radiography

- (c) Spot Radiography. Spot radiography shall not be used for circumferential, mitre or branch welds.

344.6 Ultrasonic Examination for Metals

Where ultrasonic examination is required the approval of BP shall be obtained for the procedures for each joint configuration and thickness. It will normally be restricted to wall thickness greater than 10 mm.

When fabricating pipework having a wall thickness in excess of 25 mm, consideration should be given to the examination of the root region when welding is partially complete to a depth of approximately 30% of the wall thickness. This will minimise the need for through wall repairs.

Following any necessary repairs to the root and re-examination, the weld should be completed and subjected to final examination.

345 TESTING

345.4 Hydrostatic Leak Testing

The fabricators hydrostatic test procedure, giving details of test fluid, minimum temperature, test pressure, pressure recording and control method and holding time, shall be reviewed by the owner.

Subsequent to hydrostatic testing, pipe spools that are to be stored prior to installation shall be thoroughly dried have their ends sealed to prevent ingress of dirt, moisture or other contaminants. Flange faces shall be coated with a suitable corrosion preventative.

Hydrotesting should be carried out after the completion of any specified heat treatment.

Current practice is to perform the hydrostatic after the piping has been painted. Where the owner requires hydrotest prior to any painting or, alternatively, only the welds left unpainted until after the hydrotest this requirement should be clearly stated in the engineering design documentation.

Where piping spools are to stored prior to installation, due consideration should be given to the need for the introduction of a suitable vapour phase inhibitor/biocide.

345.4.1 Test Fluid

On all austenitic and duplex stainless steels piping fabricated to this specification, potable water having a chloride content of less than 30 ppm should be used for hydrostatic testing. Water having a chloride content above 100 ppm shall not be used and where it is necessary to



use water within a range of 30 to 100 ppm, lines shall be flushed with water having a chloride content of less than 30 ppm within a short period of testing.

Zirconium, titanium, copper and nickel based alloy pipework may be hydrotested using clean, potable water.

347

Weld Repairs

Prior to the commencement of fabrication the fabricator and the owner shall agree which types of welding defects are to be regarded as notifiable prior to rectification.

The fabricator shall subsequently advise the owner of the need to carry out any such repair and obtain approval prior to commencing any further work on defective welds.

Detailed records of all repairs shall be retained by the fabricator.

Repair welding shall in accordance with approved repair procedures unless the use of the original procedure has been agreed with the owner.

As a minimum, all repair welds shall be inspected to their full extent using the techniques used for the inspection of the initial weld. The owner may require that additional inspection be applied to repairs in certain circumstances.

All weld repairs shall, where practical, be carried out prior to any specified post weld heat treatment. Where a second heat treatment is necessary the details of the procedure qualification requirements shall be agreed with the owner.

Application of a second heat treatment may have adverse effects on the properties of weld metal and some base materials. Thus it may be necessary to consider a qualification test using previously welded and heat treated material for qualification of the repair techniques. In such cases additional testing of the parent material should be carried out.



KIND OF IMPERFECTION	ACCEPTANCE CRITERIA FOR THE SPECIFIED SERVICE CONDITION
Lack of fusion	'A' for all welds.
Incomplete penetration *	'A' shall apply to all welds in severe cyclic or normal fluid service.
Internal porosity	'D' shall apply to all welds in severe cyclic or normal fluid service. 'E' shall be applicable to category D fluid service.
Slag inclusion, tungsten inclusion, or elongated indication *	'F' shall apply to all welds irrespective of service condition.
Undercutting	'H' shall apply to girth and, where approved, mitre groove welds in category D fluid service.
Concave root surface (suck back) *	Not permitted in severe cyclic or normal fluid service unless a specific limit is set by the engineering design. A maximum of 1.6 mm shall apply to welds in category D fluid service.
Reinforcement or internal protrusion	For all welds irrespective of service conditions external weld reinforcement shall be uniform, 1.6 mm to 3 mm in height and shall merge smoothly into the pipe surface. Positive root penetration shall not exceed 1.6 mm for NPS 2 and smaller, or 3 mm for larger pipe.
* When these defects are permitted the total cumulative length of lack of root penetration, slag inclusions or concave root should not exceed 10% of the weld joint circumference.	

TABLE 1

ACCEPTANCE CRITERIA FOR WELDS

To be read in conjunction with Table 341.3.2A. of [ASME B31.3](#)



Maximum Thickness		X-Radiography	Gamma-Radiography
millimetres	inches		
3	$\frac{1}{8}$	2.4%	+
6	$\frac{1}{4}$	1.6%	2.4% *
12	$\frac{1}{2}$	1.4%	2.4%
25	1	1.2%	1.7%
40	$1\frac{1}{2}$	1.1%	1.5%

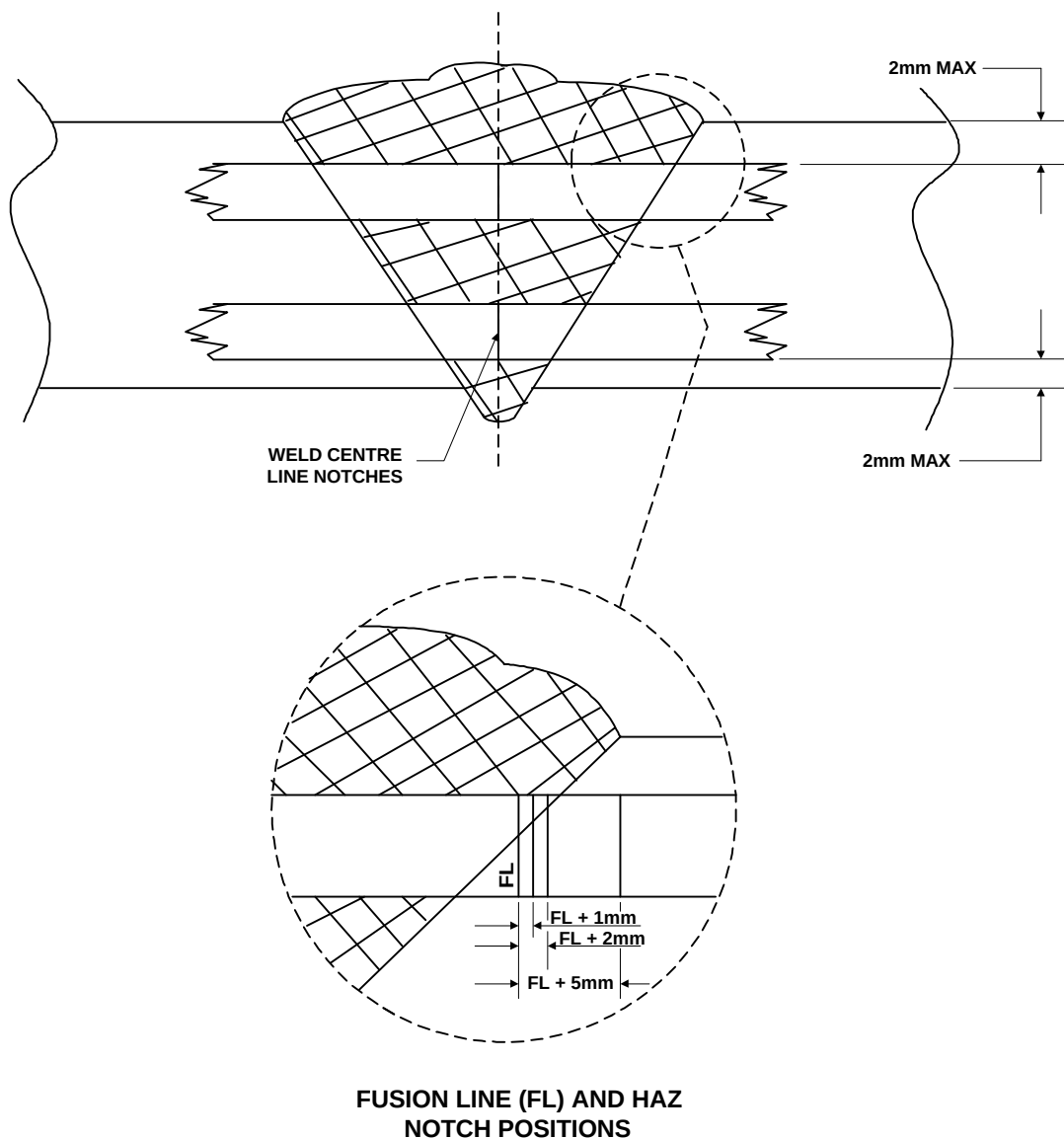
* Based on double wall/single image radiography.

+ To be agreed with the owner following the production of a test radiography.

TABLE 2
ACCEPTABLE RADIOGRAPHIC SENSITIVITY LEVELS

Using a wire type IQI to [BS 3971](#) or [DIN 54 109](#)



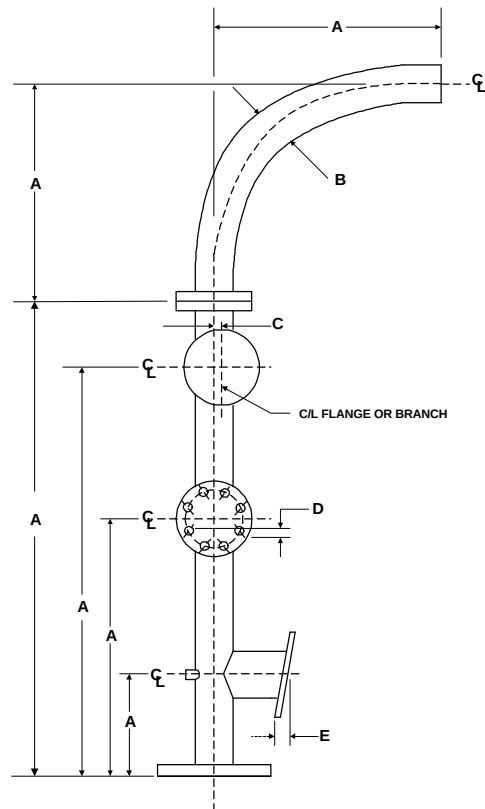


WELD METAL CENTRE LINE, FL AND FL+2mm TESTING IS MANDATORY. THE NEED FOR OTHER NOTCH LOCATIONS TO BE TESTED SHALL BE IDENTIFIED BY THE ENGINEERING DESIGN.

<25mm WALL THICKNESS : CHARPY SPECIMENS TO BE TAKEN FROM WELD CAP

≥25mm WALL THICKNESS : CHARPY SPECIMENS TO BE TAKEN FROM THE ROOT AND CAP REGIONS

FIGURE 1
CHARPY NOTCH LOCATIONS

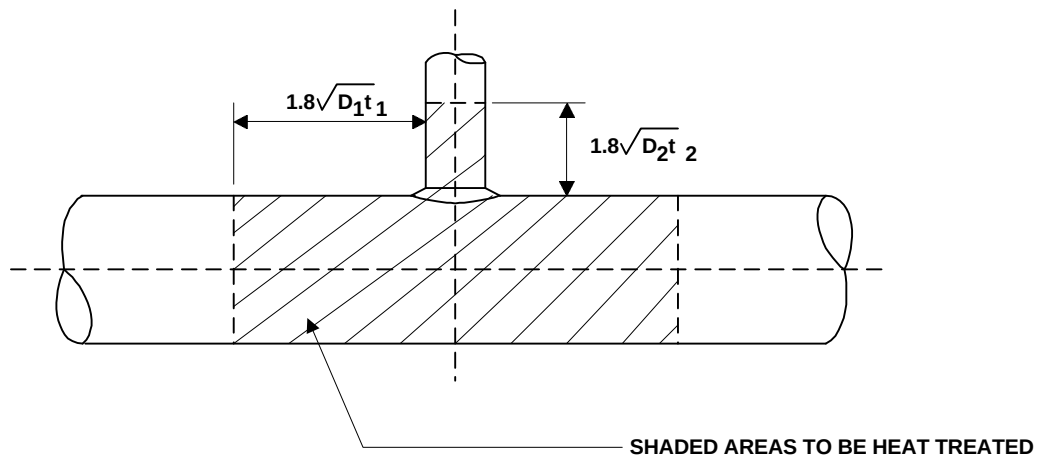


ITEM	CAT. D OR NORMAL SERVICE CONDITIONS	CAT. M. OR SEVERE CYCLIC TEMP > 460° CLASS RATING ≥ 900
A	± 3mm MAX. FROM INDICATED CENTRE TO FACE, LOCATION OF	DIMENSION FROM FACE TO FACE. ATTACHMENTS ETC.
B	8% MAX (FOR INT. PRESS) 3% MAX (FOR EXT PRESS) FLATTENING MEASURED AS AND MIN O.D AT ANY CROSS	2% MAX DIFFERENCE BETWEEN THE MAX SECTION
C	± 3mm MAX LATERAL TRANSLATION OF BRANCHES OR CONNECTIONS	± 1.5 mm MAX. LATERAL TRANSLATION OF BRANCHES OR CONNECTIONS
D	± 1.5mm MAX ROTATION OF FLANGES MEASURED AS SHOWN	FROM THE INDICATED POSITION ,
E	0.75mm MAX OUT OF ALIGNMENT OF FLANGES FROM THE INDICATED POSITION. MEASURED ACROSS ANY DIAMETER	0.4mm MAX OUT OF ALIGNMENT OF FLANGES FROM THE INDICATED POSITION, MEASURED ACROSS ANY DIAMETER

FIGURE 2

DIMENSIONAL TOLERANCES FOR FABRICATED PIPEWORK





D_1 NOMINAL O.D OF MAIN PIPE

D_2 NOMINAL O.D OF BRANCH PIPE

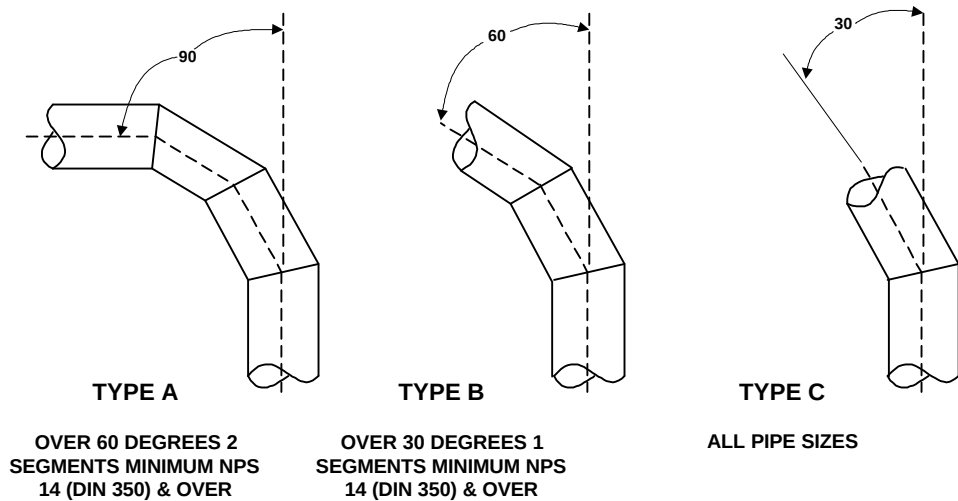
t_1 THICKNESS OF MAIN PIPE

t_2 THICKNESS OF BRANCH PIPE

FIGURE 3

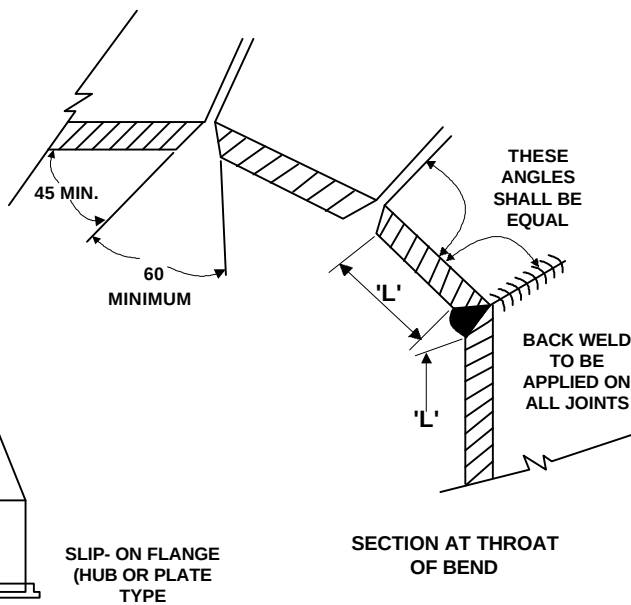
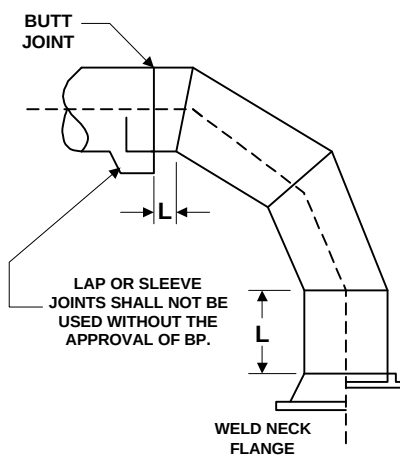
LOCAL HEAT TREATMENT FOR BRANCH CONNECTIONS





NOTE:
LONGITUDINAL SEAMS TO BE
STAGGERED BY 90 DEGREES

**DIMENSION L: REFER
TO PARA 328.5.7**



ALL DIMENSIONS ARE MILLMETRES

FIGURE 4
SEGMENTAL BENDS



DEFINITIONS AND ABBREVIATIONS

Definitions

Standardised definitions may be found in the BP Group RPSEs Introductory Volume.

Abbreviations

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society for Non Destructive Testing
BS	British Standard
CSWIP	Certification Scheme for Welding and Inspection Personnel
CV	Curriculum Vitae
DIN	Deutsche Institut fur Normung
EEMUA	The Engineering Equipment and Materials Users Association
FCAW	Flux Cored Arc Welding
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
IQI	Image Quality Indicators
NACE	National Association of Corrosion Engineers
HAZ	Heat Affected Zone
IQI	Image Quality Indicator
NDT	Non-Destructive Testing
NPS	Nominal Pipe Size
PAW	Plasma Arc Welding
PCN	Personnel Certification in Non-Destruction Testing
PQR	Procedure Qualification Record
PMI	Positive Material Identification
PREn	Pitting Resistance Equivalent Number
PWHT	Post Weld Heat Treatment
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding
TWI	The Welding Institute



LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Referenced standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the owner's professional engineer that they meet or exceed the requirements of the referenced standards.

British Standards

[BS 3971](#) Specification for Image Quality Indicators for Industrial Radiography (Including Guidance on their use)

[BS 5383](#) Material Identification of Steel, Nickel Alloy and Titanium Alloy Tubes by Continuous Character Marking and Colour Coding of Steel Tubes.

American

[ASME VIII Div.1](#) Boiler and Pressure Vessel Code

[ASME B31.3](#) Chemical Plant and Petroleum Refinery Piping
Chapter V - Fabrication, Assembly and Erection
Chapter VI - Inspection, Examination and Testing

[ASNT RP SNT-TC-1A](#) American Society for Non-Destructive Testing Inc. - Recommended Practice Non Destructive Testing

[ASTM B600](#) Recommended Practice for Descaling and Cleaning Titanium and Titanium Alloy Surfaces

[ASTM B614](#) Recommended Practice for Descaling and Cleaning Zirconium and Zirconium Alloy Surfaces

[API RP 578](#) (Drafting 1996) PMI for New and Existing Piping Systems

[AWS A5.16](#) Specification for Titanium and Titanium Alloy Welding Electrodes and Rods

[AWS A5.24](#) Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods



[NACE MR 0175](#)

Sulphide Stress Cracking Resistant Metallic Materials
for Oil Field Equipment

German

[DIN 54 109 Pt 1](#)

Non-Destructive Testing, Image Quality of Radiographs
of Metallic materials, Definitions, Image Quality
Indicators, Determination of Image Quality Index

BP Group Documents

[BP RP 42-1](#)

Piping Systems to [ASME B31.3](#)

[BP GS 118-4](#)

Storage and Control of Welding Consumables

[BP GS 136-1](#)

Materials for Sour Service to [NACE Std MR 0175-90](#)
(replaces BP Std 153)

Others

[TWI Report 5632/18/June 93](#)

Recommended Practice for determining volume fraction
of ferrite in duplex stainless steel weldments by
systematic point counting.



FABRICATION REQUIREMENTS FOR 22%Cr AND 25%Cr DUPLEX STAINLESS STEEL PIPEWORK

C1. INTRODUCTION

This Appendix is intended to be read in conjunction with the main body of this Guidance for Specification and lists any significant differences and additional precautions required for the fabrication of duplex stainless steels.

C2. WELDING

C2.1 Welding Processes

Welding processes shall generally be restricted to GTAW and SMAW. GTAW shall be employed for the root and second (hot) pass which shall both be completed with the addition of filler metal. SMAW shall be restricted to the fill and capping passes in pipe having a wall thickness greater than 5 mm.

Alternative gas shielded welding processes may be employed subject to the approval of the owner and documented evidence of previous successful use.

It should be recognised that duplex stainless steels are potentially susceptible to delayed hydrogen cracking. Consequently all possible steps, such as adequately drying SMAW consumables, the use of a low temperature preheat to remove moisture and the avoidance of hydrogen containing shielding gases should be taken to minimise the hydrogen potential of the welding technique.

C2.2 Filler Metal

Generally, filler metal compositions should be selected from the following list:-

22Cr/9Ni/3Mo.L.,	25Cr/7Ni/2Mo.,
25Cr/9Ni/3Mo.CuL.,	25Cr/9Ni/4Mo.L.

However, other proprietary compositions specifically manufactured for duplex steels **may be appropriate**. Selection shall be made with due regard to meeting a ferrite level of 35-65% in all regions of the weld metal and a minimum PREn value of 34 for 22%Cr duplex and 40 for 25%Cr duplex. Additional guidance on filler metal selection may be provided by the engineering design.

The corrosion resistance of duplex stainless steel weldments is totally dependent on the two criteria above, ferrite level and PREn, and they must not be relaxed without specialist consideration.



C2.3 Shielding Gas

Argon based shielding gases shall be used for welding. Hydrogen containing shielding gases shall not be used.

In the case of GTAW nitrogen may be added to the shield in order to preclude the loss of nitrogen from the weld pool. Nominally 1% and 2% nitrogen additions have been reported to be sufficient to prevent the loss of nitrogen, an important alloying element in the case of duplex steels, from 22% Cr. and 25% Cr. materials, respectively.

Proprietary gas mixtures may be employed when the fabricator can demonstrate their successful use to the satisfaction of the owner.

C2.4 Backing Gas

A positive flow of backing gas shall be maintained during all tacking and welding including the capping passes when the pipe wall thickness is <10 mm. When the pipe wall thickness is <10 mm the positive flow may be terminated and the bore sealed when the weld throat thickness is >10 mm. Argon shall generally be employed for the back purge, but in the case of duplex alloys containing relatively high levels of nitrogen the owner may approve the use of argon/nitrogen mixtures. The oxygen content of the purge gas shall be measured and shall be less than 0.5%.

Hydrogen containing backing gases shall not be used in any application where the possibility of mixing with the shielding gas exists.

C2.5 Joint Geometry

The weld root gap is critically important in achieving root weld metal micro structures containing the specified austenitic ferrite balance. Weld root gaps below 2 mm are not permitted, unless the fabricator can prove that his production method will not adversely effect the microstructural balance of the root bead. The fabricator shall also ensure that the qualified root gap is achieved consistently during production welding.

C2.6 Heat Input

The heat input during welding procedure qualification shall not exceed the range 0.8 - 2.5 kJ/mm. However, in the case of 25%Cr duplex steels the upper limit shall be 1.5kJ/mm. Subject to these limitations the heat input during production welding shall not deviate from that qualified by more than $\pm 10\%$.



C2.7 Preheat and Interpass Temperature

Preheating shall not generally be used except to remove moisture from the joint. The maximum interpass temperature for 22%Cr duplex steels shall be 150°C. A 100°C maximum interpass temperature shall apply to 25%Cr duplex steels.

C3. WELDING PROCEDURE QUALIFICATION

C3.1 P Numbers

P Numbers shall not apply to duplex stainless steels. Each alloy designation shall be separately qualified.

C3.2 All Positional Welding

Unless otherwise specified in the engineering design, qualification for all-positional welding shall require test pieces welded in both the 2G and 5G positions. Sections for hardness and microstructural qualification shall be taken from the 3 o'clock and 6 o'clock position of the 5G test piece.

C3.3 Metallurgical Qualification

This form of qualification is required for all welding procedures. A transverse section taken across the weldment shall be prepared for metallographic examination.

The etchant used shall enable the ferrite, austenitic and any sigma phase present to be clearly identified. The ferrite austenitic balance shall be determined by a systematic point counting procedure as detailed in TWI Report 5632/18/June 93. The phase balance shall, as a minimum, be measured in the root HAZ and root weld metal. The engineering design may call for measurements in other regions of the weldment. Acceptable ferrite levels shall lie in the range 35-65%.

C3.4 Charpy V Notch Impact Testing

For procedures requiring charpy V notch impact testing, impact tests shall be performed at the minimum design temperature. The test locations shall be as detailed in 328.2.1(d) and Figure 1 of this specification. The acceptance criteria shall be 45J minimum average, 35J minimum individual.



C3.5 Hardness Determination

Hardness measurements shall be performed on all duplex stainless steel procedures. Hardness traverses shall sample the HAZ and weld metal in the root and cap regions and the maximum hardness shall comply with [NACE MR 0175](#).

C3.6 Essential Variables

The following additional essential variables shall apply to duplex stainless steels:-

- (i) A tolerance of minus zero, plus 2 mm shall apply to the qualified procedure root gap.
- (ii) Each pipe wall thickness ≤ 5 mm shall be separately qualified. For thicknesses > 5 mm the following qualified thickness range shall apply to each thickness (t) tested:

22% Cr.	0.5t (but not less than 5 mm) - 1.5t (subject to a maximum thickness of 25 mm)
22% Cr. > 25 mm and 25% Cr.	0.75t (but not less than 5 mm) - 1.0t

These thickness limitations reflect the need for careful control over the thermal cycle applied to duplex steels during welding in order to maintain the ferrite/austenitic balance and prevent the formation of intermetallic phases.

- (iii) No change shall be made in the type of groove, or in the basic groove design from that used in the qualified welding procedure specification. Where welding in the pipe bore is to be applied an appropriate welding procedure shall be qualified.
- (iv) The electrode size used in the qualified welding procedure may be reduced by no more than one size. No increase in the maximum size of electrode is allowed.

C3.7 Corrosion Testing

The engineering design shall define the need for any corrosion testing and the acceptance criteria.

[ASTM G48](#) corrosion testing may be required as an integral part of the welding procedure qualification. In many instances this requirement will be imposed solely as an additional means of quality control depending on the grade of duplex stainless steel and the specific application.



C4. WELDER QUALIFICATION

Welders shall be qualified on duplex stainless steel. Unless otherwise required by the engineering design, both 2G and 5G qualification is required at the maximum root gap specified by the relevant welding procedure.

The engineering design shall specify where additional testing, typically metallography and/or corrosion tests, is required for welder qualification.

Qualification on initial production welds shall not be allowed.

C5. PRODUCTION WELDING

C5.1 General

The welding instruction card shall include details of the root gap and heat inputs to be used.

Bridge tacking shall be used for all butt welds.

Each temporary attachment is subject to BP approval.

C5.2 Repair Welding

The fabricator shall qualify procedures for both deep penetration and shallow repairs. The extent of testing shall be subject to BP approval.

No local through the wall repairs are permitted. Joints shall be cut out and re-welded.



FABRICATION REQUIREMENTS FOR TITANIUM AND ZIRCONIUM

D1. INTRODUCTION

This appendix is intended to be read in conjunction with the main body of this Guidance for Specification and lists any significant differences and additional precautions required for the fabrication of titanium and zirconium.

D2. CLEANING AND PREPARATION FOR WELDING

Weld preparation shall be carried out by machining, sawing or manually using a metal burr followed by draw filing or wire brushing with a stainless steel brush. Thermal cutting techniques are unacceptable.

Working practices shall be designed to minimise contamination and, before welding, internal and external surfaces shall be cleaned for a distance of at least 75 mm from the fusion face. The surfaces to be joined by welding shall be stainless steel wire brushed and degreased immediately prior to welding. The degreasant shall leave no chloride or sulphide containing residues on the surface. On small pipes where it is not possible to wire brush the internal surface an approved chemical cleaning material shall be used.

New files and stainless steel brushes strictly reserved for use on only titanium or zirconium shall be used.

The need for cleanliness during the fabrication of titanium and zirconium cannot be overemphasised. Strict segregation from all other materials must be implemented and this may be assisted by the construction of a restricted access tented area or a clean room facility. Guidance on cleaning of titanium and zirconium is given in [ASTM B 600](#) and [B 614](#) respectively.

D3. WELDING

D3.1 Welding Process

Welding shall be performed by a gas shielded welding process, GTAW or PAW may be used.

D3.2 Filler Metal

Filler metals shall have the same nominal composition as the base material and shall comply with the requirements of [AWS A5.16](#) (titanium) and [A5.24](#) (zirconium).



All filler wires shall be thoroughly cleaned and degreased. The degreasant shall leave no chloride and sulphide residues on the surface. After cleaning, the wires shall be handled with clean gloves specifically issued for either titanium or zirconium fabrication.

The welder shall ensure that the end of the filler wire is kept within the gas shield at all times during welding by restricting weaving of welding wire to a minimum. Prior to each weld pass the end of the filler wire shall be cut to expose clean wire employing chromium plated wire cutters.

D3.3 Shielding Gases

Only high purity (99.998%) argon, helium or argon helium mixtures shall be used as shielding gases. Particular care shall be taken in selecting welding torch nozzle size and the associated gas lens to ensure adequate primary shielding.

A trailing secondary shield shall be used to protect the weld and HAZs while they are cooling to temperatures less than 180°C.

The dew point of the shielding gas shall be less than -50°C and shall be measured at the torch immediately prior to welding and at each cylinder change. For bulk supply systems the dew point shall be measured at the beginning of each shift.

As an alternative, but less preferable option to dew point measurement, a test weld meeting the silver coloration requirements of D6.2 shall be produced at the above frequency.

D3.4 Backing Gas

A positive flow of high purity (99.998%) argon backing gas shall be maintained throughout the welding operation and during cooling to 180°C. The system shall be purged prior to the commencement of welding. The effectiveness of the purge system shall be assessed as directed, and at the frequency detailed, for the gas shield.

Titanium and zirconium readily absorb carbon, oxygen, nitrogen and hydrogen at high temperatures with the consequence that weldments can become embrittled. Thus the importance of preweld cleaning and degreasing of the joint area and filler metal cannot be over emphasised. The efficiency of the primary and secondary shielding together with the purge is of paramount importance. The gas shielding and purging methods used during the successful qualification of welding procedures must be strictly enforced during production welding.

Where relatively small components are being fabricated, welding within a controlled atmosphere chamber may be a cost effective production technique.



D3.5 Preheat and Interpass Temperature

Although preheating is not required the minimum temperature for welding shall be 15°C. Interpass temperatures shall be restricted to 100°C and shall be measured by a contact thermometer.

D3.6 Interpass Cleaning

No interpass cleaning shall take place until the colour test detailed in D6.2 has been completed.

All craters shall be lightly ground using a metal burr and each pass shall be cleaned with a stainless steel wire brush.

D4. WELDING PROCEDURE QUALIFICATION

D4.1 Hardness Determination

Hardness measurements (HV5) shall be performed on all titanium welding procedure qualifications. Hardness traverses shall sample all regions of the weldment and the acceptance limit shall be 200 HV5. Hardness measurements are not required for zirconium unless specified by the owner.

Where hardness testing is required for zirconium piping testing will be carried out using Brinell hardness testing. The maximum difference in hardness value across the weldment should not exceed 30 points on the Brinell hardness scale.

D5. WELDER QUALIFICATION

Unless welders or welding operators have been welding titanium or zirconium immediately prior to contract they shall be re-qualified prior to the start of production welding.

Qualification shall be by radiography and by root and face bend testing.

Additionally, welders/welding operators shall weld an agreed quality control test piece at a frequency specified by the owner. Bend test coupons shall be taken from the test piece and shall pass transverse root bend and face bend tests (bend radius 5T) meeting the procedure qualification acceptance criteria.

Normal practice is for welders working on zirconium to produce a separate testpiece for every tenth weld produced.



D6. PRODUCTION WELDING

D6.1 General

The Welding Instruction card shall emphasise the need to strictly adhere to all cleaning and gas shielding/purging procedures.

Preference shall be given to the use of line-up clamps, but bridge tacks may be used with the agreement of the owner.

Temporary welded attachments are not allowed.

D6.2 Weld Bead Discolouration

Each weld bead, including every pass in multi-pass weldments shall be examined for any discoloration. Colours shall be judged against the table below.

The quality plan and the welder instruction card shall clearly define the procedure and individual responsibilities associated with this examination.



Weld Colour	Significance	Shielding	Action
Silver	Generally a good weld	Good	Clean with stainless steel wire brush, proceed to NDT or next weld pass
Pale straw	Acceptable weld	Fair	Discoloration should be removed with stainless steel brush before next pass
Light blue/purple	Poor weld	Poor	Remove weld bead and adjacent metal completely; improve shielding before re-welding.
Grey or yellow powder	Very poor weld	Extremely poor	Remove weld bead and heat-affected zone completely. Examine shielding equipment for leaks, gas supply etc. Make test welds before re-welding.

