TECHNICAL SPECIFICATION

WELDED AND SEAMLESS DUPLEX AND SUPER DUPLEX STAINLESS STEEL LINE PIPE
(AMENDMENTS/SUPPLEMENTS TO API SPEC 5LC)

DEP 31.40.20.34-Gen.

December 1998

DESIGN AND ENGINEERING PRACTICE

PREFACE

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TABLE OF CONTENTS

APPENDICES

PART I INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the manufacture and supply of seamless and longitudinally welded duplex and super duplex stainless steel line pipe for use in oil and gas operations under both sour and non-sour service conditions.

NOTE: Sour service is defined in DEP 31.22.20.31-Gen.

Part II of this DEP gives amendments and supplements to API Spec 5LC Second Edition August 1991 (plus Supplement 1, December 1992) which are considered necessary to ensure pipeline integrity in accordance with Shell Group requirements. The clause numbering in Part II of this DEP follows that of API Spec 5LC. Where clauses of API Spec 5LC are not amended or supplemented by this DEP, they shall apply in their entirety.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIEP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers nominated by them (i.e. the distribution code is “F”, as described in DEP 00.00.05.05-Gen.).

This DEP is primarily intended to be used for oil and/or gas pipelines, flowlines and related facilities. It is intended for use by Exploration and Production, Manufacturing, Chemicals or Supply/Marketing companies which require the use of line pipe.

If national and/or local regulations exist in which some of the requirements may be more stringent than this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Defect (in NDT)	An imperfection or group of imperfections whose indication(s) do not meet specified acceptance limits.
Electric-welded	Term used in API Spec 5LC which shall be understood to mean HFW.
Finished pipe	Pipe passed through all stages of production and inspection.
Imperfection (in NDT)	An interruption, which may be either intentional or unintentional, in the physical structure or configuration of a pipe.
Indication (in NDT)	Evidence of an imperfection that requires interpretation to determine its significance.
Lot	A unit of pipes from the same heat and, for batch heat treatment, heat treatment batch, having the same dimensions. For pipes with OD < 508 mm, a lot shall be a maximum of 100 pipes. For other sizes, a lot shall be a maximum of 50 pipes.
Pipe end	Complete pipe segment of 100 mm length measured from the end face of the finished pipe.
Plate or Coil	The flat starting material for welded pipe before forming into the shape of a pipe.
Purchaser	Term used in API Spec 5LC which shall be understood to mean Principal.
Radiological	Term used in API Spec 5LC which has the same meaning as radiographic. The term radiographic is used in this DEP.

1.4 ABBREVIATIONS

CRA	Corrosion Resistant Alloy
FL	Fusion Line
HAZ	Heat Affected Zone
HFW	High Frequency Welded
ID	Inside Diameter
LBW	Laser Beam Welded
NDT	Non-Destructive Testing
OD	Outside Diameter
PREN	Pitting Resistance Equivalent Number
PT	Liquid-Penetrant Testing
RT	Radiographic Testing
SSRT	Slow Strain Rate Test
t	Wall thickness
T	Minimum design temperature
UNS	Unified Numbering System
UT	Ultrasonic Testing
WCL	Weld Centre Line

1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced in this DEP are listed in (Part III).

1.6 INFORMATION TO BE SUPPLIED BY THE PRINCIPAL

The information shown in the section of API Spec 5LC entitled “Suggestions For Ordering API CRA Line Pipe”, with the following additional information, should be provided by the Principal at the enquiry stage of the order.

- Nominal ID (and whether constant ID is required).
- Minimum design temperature.
- Maximum design temperature.
- Design pressure.
- Service environment (gas, oil, water, multiphase, sour, non-sour).
- End preparation required if different from the standard API bevel.
- Whether pipe is to be used as mother pipe for induction bends.
- Whether mechanical property restrictions for reeling are to be applied.
- Whether elevated temperature tensile testing is required and the acceptance criteria.
- Length requirements if different from Part II - 7.5 of this DEP.
- Whether supply of jointers is acceptable and the welding requirements if different from this DEP.
- Surface roughness requirements where the pipe is to be coated under a separate contract Part II - 2.5 of this DEP.
- Which of the Manufacturer/Supplier’s quality control procedures are to be submitted for agreement.
- Level of inspection to be deployed by the Principal.
- Whether inspection reports in accordance with ISO 10474 type 3.2 are required instead of inspection certificates in accordance with ISO 10474 type 3.1.B.
- Specific marking requirements.
- Specific packaging requirements.
- Other specific requirements amending or supplementing this DEP.

PART II AMENDMENTS/SUPPLEMENTS TO API SPEC 5LC

SECTION 1 SCOPE

1.1 COVERAGE

Delete the first two paragraphs and replace with:

See Part I - 1.1 of this DEP.

1.3 REFERENCED STANDARDS

a. General

Add the following:

Other standards and publications referenced in this DEP are listed in (Part III).

c. Equivalent standards.

Delete this item.

1.4 RETENTION OF RECORDS

Delete this section and replace with the following:

Contract records, and any other records requiring retention by the Manufacturer/Supplier's quality assurance system, shall be retained by the Manufacturer/Supplier and made available to the Principal on request for a period of five years after completion of the order.

1.5 MEASURING DEVICES

Add the following:

The Manufacturer/Supplier shall control measuring devices within the requirements of ISO 10012-1.

1.7 CERTIFICATION

Delete this section and replace with the following:

Inspection certificates in accordance with ISO 10474 type 3.1.B shall be supplied unless the Principal specifies inspection reports in accordance with ISO 10474 type 3.2., in which case the Manufacturer/Supplier shall issue and validate the inspection reports and they shall be counter-validated by the Principal's authorised representative. The Manufacturer/Supplier shall provide a listing of all pipes supplied detailing for each pipe the unique pipe number, heat number, test number, certificate number, length and weight. These data shall also be supplied to the Principal on a computer disc in an agreed format.

Add the following new section:

1.8 QUALITY SYSTEM

The Manufacturer/Supplier should maintain and operate a quality assurance system in accordance with ISO 9001 or ISO 9002. The Manufacturer/Supplier may maintain and operate a quality assurance system based on an alternative standard which may be considered for agreement by the Principal.

SECTION 2 PROCESS OF MANUFACTURE AND MATERIAL

2.1 PROCESS OF MANUFACTURE

Add the following:

Plates or coil shall be formed into pipe when at ambient temperature.

b. Welded processes

1. Welding without filler metal

Add the following:

The HFW welding process shall employ a minimum frequency of 150 kHz.

2. With filler metal

Add the following:

The longitudinal seam welds shall be full penetration welds using a welding procedure specification which is in accordance with the requirements of this DEP.

3. With or without filler metal

Add the following:

b.1 Laser beam welding

A welding process that produces coalescence with the heat from a laser beam impinging on the joint.

c. Pipe making processes

Delete the fourth column of Table 2.1.

6. Combination welding

Delete “or double”.

7. Double seam

Delete this section.

d. Tack welding

Add the following:

Tack welding shall be continuous.

2.2 COLD EXPANSION

Add the following:

Where appropriate to the manufacturing process, seam-welded pipe shall be subjected to cold expansion. Expansion shall be by a mechanical process.

The % expansion is defined as follows:

$$\% \text{ expansion} = \frac{D_a - D_b}{Db} \times 100$$

D_a OD (ID) after expansion

D_b OD (ID) before expansion

Alternative sizing methods may be considered by the Principal.

2.3 HEAT TREATMENT

Add the following:

All pipes shall be full body solution annealed and water quenched.

The temperatures and times during the heat treatment operation shall be permanently recorded.

Add the following new section:

2.5 SURFACE FINISH

All internal and external surfaces shall be supplied free of scale, oxide film, oil, grease, and lacquers (except for paint marking characters).

Where the pipe is to be coated under a separate contract, the Principal may specify additional surface finish and roughness requirements.

SECTION 3 CHEMICAL PROPERTIES AND TESTS

3.1 COMPOSITION

Delete this section and replace with the following:

The chemical composition of duplex and super duplex stainless steel shall be in accordance with a relevant UNS number with the following minimum nitrogen content and PREN:

Alloy	Nitrogen Content% (min)	PREN (min)
22% Cr duplex	0.14	34
25% Cr super duplex	0.20	40

PREN shall be calculated as follows:

PREN = %Cr + 3.3 x %Mo + 16 x %N.

The Manufacturer/Supplier shall supply the aim analysis and manufacturing tolerances for each element when required by Part II – 12 of this DEP.

Delete Table 3.1.

3.2 HEAT ANALYSES

In the first sentence delete ”When requested by the Purchaser”.

In the second sentence, replace "in Par 3.1" with "in (3.1).”

Delete the second paragraph and replace with the following:

The inspection documents shall report the analysis for the elements shown in Table 3.0 plus any deliberately added additional elements.

3.3 PRODUCT ANALYSES

Delete this section, including Table 3.0, and replace with the following:

Product analyses shall be provided to the Principal in the inspection documents. The frequency shall be two pipes per heat. Samples shall be taken from formed pipe.

3.6 CHEMICAL ANALYSES PROCEDURES

Delete this section and replace with the following:

Chemical analyses shall be determined in accordance with ASTM E 353 or ASTM A 751.

SECTION 4 MECHANICAL PROPERTIES AND TESTS

4.1 MECHANICAL PROPERTIES

Delete this section, including Table 4.1, and replace with the following:

Tensile properties shall meet the minimum requirements given in (Table 4.1).

Table 4.1 Tensile requirements

Specimen condition and orientation (parent material)	Minimum Proof Strength $R_{t0.5}$ MPa	Minimum Tensile Strength R_m MPa	Minimum Elongation A (%)	Maximum $R_{t0.5}/R_m$
22% Cr duplex stainless steel				
Room temperature longitudinal and transverse	448	620	25	0.9
25% Cr super duplex stainless steel				
Room temperature longitudinal and transverse	550	750	25	0.9

4.2 TENSILE TESTS - GENERAL

Delete the first sentence and replace with the following:

Tensile test orientation shall be in both the transverse and longitudinal direction at ambient temperature and in the transverse direction at elevated temperatures.

Add the following:

Elevated temperature tensile tests shall be performed in accordance with ISO 783.

4.3 TENSILE TESTING

a. Frequency

Delete this section and replace with the following:

One transverse and one longitudinal tensile test from each first-day-production test pipe and one pipe per lot shall be performed at room temperature.

If elevated temperature testing is specifed by the Principal, one elevated temperature transverse tensile test from each first-day-production test pipe and one pipe per lot shall also be performed.

4.4 LONGITUDINAL TENSILE TESTS

Delete this section and replace with the following:

Longitudinal tensile properties shall be determined on strip specimens without flattening.

4.5 TRANSVERSE TENSILE TESTS

Delete the first paragraph and items a and b and replace with the following:

Transverse tensile properties shall be determined by flattened strip specimen. Where pipe dimensions preclude the use of a strip specimen, round bar specimens may be used with the agreement of the Principal.

4.15 GUIDED BEND TEST

Add the following:

The test frequency shall be once per lot of pipes.

4.17 WELD DUCTILITY TEST FOR ELECTRIC-WELDED PIPE

Delete formula **(a)**.

4.20 HARDNESS TESTS (LC52-1200)

Change heading as follows:

4.20 HARDNESS TESTS

Delete the existing section and replace with the following:

4.20.1 Seamless pipe

A full circumferential section shall be taken as a sample from each first-day-production test pipe and from one pipe representing each lot.

A series of Rockwell C hardness impressions shall be made in accordance with ASTM E 18 at three locations 120 degrees apart around the circumference of the sample as shown in Figure 4.6 of API Spec 5LC. A minimum of 3 impressions shall be made at 2.5 mm intervals along each circumferential traverse. The centre of the traverses at the outer and inner pipe surfaces shall be 2.5 mm from the relevant surface. The test may be performed on individual test pieces removed from the sample.

The maximum allowable individual hardness value shall not exceed the following:

22% Cr duplex stainless steel	28 HRC
25% Cr super duplex stainless steel	32 HRC

4.20.2 Longitudinally welded pipe

a. Macrographic examination

Two full thickness transverse samples from the longitudinal weld from each first-day-production test pipe and from one pipe representing each lot shall be extracted. Test pieces from the samples shall be polished and etched for macro-examination in accordance with ASTM E 340 using double electrolytic etching in oxalic acid and then potassium hydroxide. The examination shall be performed at a minimum magnification of x5. The acceptance criteria shall be no defects as defined by this DEP. Photomacrographs shall be included in the inspection documents.

b. Hardness testing

A series of Vickers HV10 hardness indentations shall be made in accordance with EN 1043 - 1 on one of the test pieces prepared for macro-examination from each of the first-day-production test pipes and from one pipe representing each lot. The hardness indentation locations shall be agreed by the Principal. The indentations shall be visible in the photomacrographs.

The maximum allowable individual hardness value shall not exceed the following:

22% Cr duplex stainless steel	300 HV10
25% Cr super duplex stainless steel	325 HV10

Add the following new section:

4.21 FRACTURE TOUGHNESS TESTING

4.21.1 Charpy impact testing

The tests shall be performed in accordance with ASTM A 370.

For seamless line pipe, one set of three transverse Charpy test pieces shall be taken from the base material of each first-day-production test pipe and one pipe representing each lot. Test pieces shall be located at the mid thickness.

For welded pipe, in addition to a parent material test, sets of three transverse Charpy test pieces shall be taken from each of the weld centre line, FL and FL + 5 mm, as shown in (Figure 4.8). If the pipe wall thickness exceeds 20 mm, additional sets of three Charpy test pieces shall be taken from all corresponding locations within 3 mm of the outside surface of the pipe. For HFW and LBW pipe, notch locations shall be weld centre line, WCL + 2 mm, and WCL + 5 mm.

For parent material tests, the descending hierarchy of test piece size and orientation shall be as follows:

Choice	Orientation	Size mm
1	Transverse	10 x 10
2	Transverse	10 x 7.5
3	Transverse	10 x 5
4	Longitudinal	10 x 10
5	Longitudinal	10 x 7.5
6	Longitudinal	10 x 5

Lower choice test pieces shall only be used when the higher choice is impractical. For pipe of wall thickness less than 5 mm, Charpy testing may be omitted.

For all test pieces, the notch shall be perpendicular to the pipe surface.

The test temperature shall be as follows:

Nominal t mm	Test temperature °C	Max test temperature °C
$t \leq 16$	T	0
$16 < t \leq 25$	T - 10	0
$25 < t \leq 32$	T - 20	0
$t > 32$	T - 30	0

The acceptance criteria fof 10 x 10 transverse test pieces shall be as follows:

Material	Minimum Average J	Minimum single test piece from the set J	Individual Shear Area % minimum
22 Cr DSS	70	53	50
25 Cr SDSS	100	75	50

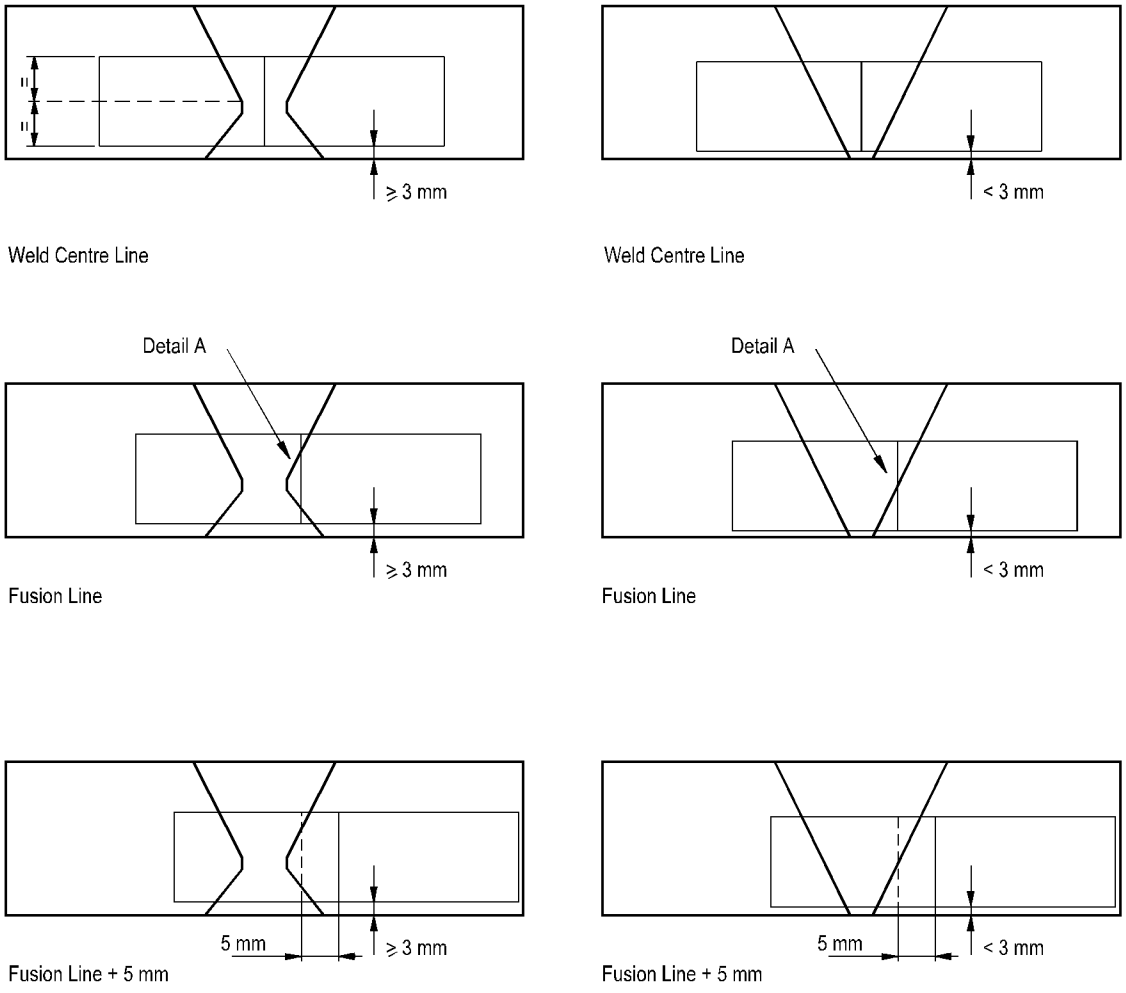
For other specimens, the following factors shall be applied to the acceptance criteria:

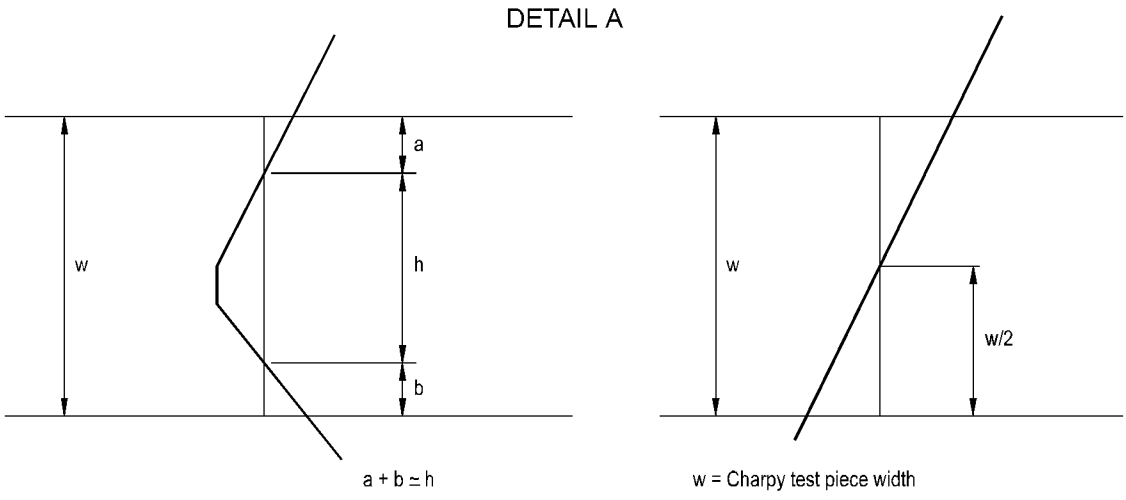
Size mm	Orientation	Factor
10 x 10	Longitudinal	1.5
10 x 7.5	Transverse	0.8
10 x 7.5	Longitudinal	1.2
10 x 5	Transverse	0.5
10 x 5	Longitudinal	0.8

4.21.2 Charpy retests

Where tests fail to meet the specified requirements, the sampled pipe shall be rejected. Two further pipes from the lot shall then be tested. The results for both of these further tests shall be satisfactory without recourse to retesting. Should one or both pipes be unsatisfactory, the lot of pipes shall be rejected.

Figure 4.9 Location of Charpy V-notch for different weld configurations in pipe of wall thickness ≤ 20 mm





SECTION 5 SPECIAL TESTS

5.1 FERRITE/AUSTENITE RATIO FOR DUPLEX STAINLESS STEEL

Delete this section and replace with the following:

The percentage of ferrite phase shall be determined on one test piece from each end of each of the first-day-production test pipes and one test piece from one pipe representing each lot. The test pieces shall be extracted from the sample(s) removed for mechanical acceptance tests at a location around the pipe circumference agreed with the Principal. For longitudinally welded pipe, the test piece shall contain the full cross-section of the longitudinal weld.

The ferrite content shall be measured 1 mm from both the internal and external surfaces and be reported for the parent material, weld metal and the parent material within 0.2 mm of the FL, as relevant to the method of manufacture.

Measurement of ferrite content shall be in accordance with (Appendix 1). Original photomicrographs shall be included in the inspection documents.

The ferrite content shall be in the range 40 - 60% for parent material and HAZ and 30-60% for weld metal.

The microstructure shall be considered acceptable if it displays a uniform ferrite and austenite phase distribution and freedom from third phase precipitates.

5.2 INTERGRANULAR CORROSION TEST (STRAUSS TEST)

Delete this section including items **a)**, **b)**, **c)**, **d)**, **e)**, and **f)**.

SECTION 6 HYDROSTATIC TESTS

6.1 INSPECTION HYDROSTATIC TEST

Delete the second sentence and replace with the following:

The test pressure shall be held for a minimum of 15 seconds for all pipes.

Add the following:

Hydrostatic testing of welded pipe shall be performed before non-destructive testing.

6.3 TEST PRESSURES

Delete this section and replace with the following:

The test pressure for all sizes of pipe shall be such that the hoop stress calculated on the basis of the minimum allowable wall thickness and including stresses from end loading is at least 95% of the specified minimum proof strength at room temperature.

The Manufacturer /Supplier shall define the end load compensation factor in the hydrotest procedure.

6.4 SUPPLEMENTARY HYDROSTATIC TESTS

Delete this section.

SECTION 7 DIMENSIONS, WEIGHTS AND LENGTHS

7.1 DIMENSIONS AND WEIGHTS

Add the following:

Dimensional and weight inspection shall be performed on finished pipes.

7.2 DIAMETER

Table 7.1 Tolerances on dimensions and weights

Outside diameter

Delete this section of Table 7.1 and replace with the following:

The outside diameter of the pipe body, as measured by a circumference tape, shall not deviate by more than $\pm$ 0.5% of the nominal diameter.

Pipe ends

Delete this section of Table 7.1 and replace with the following:

The inside diameter shall be checked over a distance of 100 mm from each end face. The maximum permitted variation from the nominal internal diameter shall be as follows:

Designation	Tolerance on nominal ID
All offshore pipe	± 1 mm
Onshore pipe $\leq$ 219.1 mm OD	± 1 mm
Onshore pipe > 219.1 mm OD	± 1.5 mm

NOTE: The nominal internal diameter is defined as follows: $ID_{nom} = OD_{nom} - 2\ t_{nom}$

For seamless pipe, machining and/or grinding may be carried out to achieve these tolerances, provided that the minimum wall thickness is maintained. The transition in thickness on the internal surface between the machined ends and the pipe body shall not be greater than 1:4.

Conformance with the minimum ID requirement shall be verified by inserting a circular template with a diameter equal to the specified minimum ID into each pipe end to a distance of 100 mm. The plane of the template shall be maintained perpendicular to the pipe axis. For welded pipe, the template may contain a local notch to provide clearance of the internal weld profile.

Out-of-roundness

Add the following to this section of Table 7.1:

The pipe out-of-roundness shall be determined at three locations equidistant along the pipe body.

The out-of-roundness (i.e. the difference between the major and minor outside diameters) measured at the same plane over four axes at 45° intervals shall not exceed 1% of the nominal outside diameter .

Wall thickness

Delete this section of Table 7.1 and replace with the following:

See Part II - 7.3 of this DEP.

Add the following new section to Table 7.1:

Local irregularities of seam welds

The pipe ends and three positions equidistant along the length shall be checked for non-circularity at the position of the longitudinal weld using a template gauge agreed with the Principal. The chord length of the template shall be a minimum of 25% of the OD or ID as applicable up to a maximum of 200 mm.

At the pipe ends, the guage shall be located internally. The local irregularity in profile shall not exceed 1.5 mm measured between the guage and the pipe.

7.3 WALL THICKNESS

Delete the second sentence and replace with the following:

The tolerance on the nominal wall thickness shall be :

Seamless pipe	-10% +15%
Longitudinally welded pipe	-5% +10%

7.5 LENGTH

Delete this section and replace with the following:

Unless otherwise indicated in the purchase order, pipe shall be supplied in the following lengths:

Onshore lines: A minimum of 95% of pipes shall be between 11 and 12.2 m in length.

No pipe shall be less than 8 m in length.

No pipe shall be greater than 12.5 m in length.

Offshore lines: The length of pipes in any one order shall average 12.2 m with a minimum of 95% of pipes between 11.9 and 12.5 m in length.

No pipe shall be less than 11.6 m in length .

No pipe shall be greater than 12.8 m in length.

7.6 STRAIGHTNESS

Delete the first two sentences of this section and replace with the following:

All pipe shall be checked for straightness. Deviations from a straight line shall not exceed 1.5 mm/m or 12 mm total over the full length whichever is smaller.

7.7 JOINTERS

Add the following:

Jointers shall only be supplied when specified by the Principal.

The girth welds of jointers shall meet the requirements of DEP 61.40.20.31-Gen.

7.8 PIPE ENDS

Add the following:

The pipe ends shall be cut square to the pipe axis.

The out-of-squareness shall not exceed the following values:

- 1 mm for OD = 220 mm;
- 0.005 x OD with a maximum of 1.6 mm for OD > 220 mm.

SECTION 8 NON-DESTRUCTIVE INSPECTION

8.1 INSPECTION METHODS FOR WELDED PIPE

Add the following to the first paragraph:

NDT for acceptance purposes shall take place after hydrostatic testing of the pipe.

a.

Delete this section and replace with the following:

Welded pipe, except HFW pipe, shall be subjected to the NDT operations shown in (Table A).

Table A

NDT Operation	Specification	Cross-reference	Notes
Ultrasonic testing for longitudinal and transverse imperfections in the weld seam	ISO 9765	Part II - 8.15	1
Ultrasonic testing for laminar imperfections in the pipe body	ISO 12094	Part II - 8.15	2
Ultrasonic testing for laminar imperfections in the plate/strip edges adjacent to the weld	ISO 13663	Part II - 8.15	3
Testing of the weld seam at pipe ends not covered by automatic testing: manual UT or RT	ISO 9765 or ISO 12096	Part II - 8.15 or Part II - 8.4	
Ultrasonic testing for laminar imperfections at pipe ends	ISO 11496	Part II - 8.15	
Liquid penetrant testing of bevel faces	ISO 12095	Part II - 8.18	

NOTES
1. Full length RT of the weld seam in accordance with this DEP may be substituted.
2. The test may be performed on the plate/strip body prior to forming into pipe with a minimum coverage of 25%.
3. The test may be performed on the plate/strip edges in accordance with ISO 12094 prior to forming into pipe.

HFW pipe shall be subjected to the NDT operations shown in (Table B).

Table B

NDT Operation	Specification	Cross-reference	Notes
Ultrasonic testing for longitudinal imperfections in the weld seam	ISO 9303 or ISO 9764	Part II - 8.15	
Ultrasonic testing for laminar imperfections in the pipe body	ISO 12094	Part II - 8.15	1
Ultrasonic testing for laminar imperfections in the plate/strip edges adjacent to the weld	ISO 13663	Part II - 8.15	2
Ultrasonic testing for longitudinal imperfections in the pipe body	ISO 9303	Part II - 8.15	
Ultrasonic testing for laminar imperfections at pipe ends	ISO 11496	Part II - 8.15	
Liquid penetrant testing of bevel faces	ISO 12095	Part II - 8.18	

NOTES:
1. The test may be performed on the strip prior to forming into pipe with a minimum coverage of 25%.
2. The test may be performed on the strip edges in accordance with ISO 12094 prior to forming into pipe.

8.2 INSPECTION METHODS FOR SEAMLESS PIPE

Delete this section and replace with the following:

Seamless pipe shall be subjected to the NDT operations shown in (Table C).

Table C

NDT Operation	Specification	Cross-reference
Ultrasonic testing for longitudinal imperfections	ISO 9303	Part II – 8.15 and 8.16
Ultrasonic testing for transverse imperfections	ISO 9305	Part II – 8.15 and 8.16
Ultrasonic testing for laminar imperfections	ISO 10124	Part II – 8.15 and 8.16
Ultrasonic testing of wall thickness	ISO 10543	Part II – 8.15 and 8.16
Ultrasonic testing for laminar imperfections at pipe ends	ISO 11496	Part II – 8.15 and 8.16
Liquid penetrant testing of bevel faces	ISO 12095	Part II – 8.18

8.4 RADIOLOGICAL INSPECTION

Add the following:

The radiographic technique shall be in accordance with ISO 12096. The image quality class shall be R1 using a wire type image quality indicator.

a. Equipment

Delete this section and replace with the following:

Radiographic testing of welds shall be executed with X-ray equipment using fine-grain type film and lead intensifying screens.

8.5 FLUOROSCOPIC OPERATOR QUALIFICATION

Delete this section.

8.6 OPERATOR CERTIFICATION

Delete this section and replace with the following:

See Part II - 8.19 of this DEP.

8.7 REFERENCE STANDARDS

Delete this section.

8.9 FREQUENCY

Delete this section.

8.10 PROCEDURE FOR EVALUATING IN-MOTION OPERATION OF THE FLUOROSCOPE

Delete this section.

8.11 ACCEPTANCE LIMITS

Delete this section and replace with the following:

Acceptance criteria shall be as specified in ISO 12096. The test report shall contain the details specified in ISO 12096. Where the Principal specifies that the radiographic test procedure is to be agreed, items a to i of clause 9 of ISO 12096 may be stated in the procedure and only items j to l included in the test report. Item k in the test report shall include the actual sensitivity and density achieved.

8.12 IMPERFECTIONS

Delete this section including Tables 8.2 and 8.3 and Figures 8.1 and 8.2.

8.13 DEFECTS

Delete this section.

8.15 ULTRASONIC AND ELECTROMAGNETIC INSPECTION OF WELDED PIPE

a. Equipment

Add the following:

Automatic ultrasonic equipment shall incorporate:

i. A device which monitors the effectiveness of the coupling.
In the case where a zero degrees compression wave probe is used to monitor coupling, or where a through transmission technique is used, loss of coupling shall be deemed to occur if the sensitivity (echo height) decreases by more than 6 dB relative to the static calibration.
ii. An audible warning/paint spray system which operates when the coupling is unsatisfactory.
iii. An automatic paint-marking device or other automatic 'hard copy' recording device which activates when the ultrasonic echo received exceeds the trigger/ alarm level.

From each pipe under test, an automatic "on-line" record shall be made without operator intervention. For every pipe, a summary record shall be made showing pipe identification number, time, examination results (including re-examinations) and effectiveness of acoustic coupling.

b. Reference standards

Delete this item, including Figure 8.3, and replace with the following:

Reference standards and calibration shall be as specified in the appropriate ISO specification and this DEP. For automatic UT, calibration shall be performed using a reference standard and shall also be checked dynamically.

Specific requirements for each NDT standard shall be as follows:

ISO Standard	Specific requirements
ISO 9764	Notch shall be on both internal and external surface
ISO 10124	Reference standard shall be a flat-bottomed round recess
ISO 11496	Tested band shall be a minimum of 50 mm and shall overlap automatic tested pipe body area by a minimum of 25 mm. Reference standard shall be a flat-bottomed round recess
ISO 12094	Minimum coverage shall be 25%. Edge band shall be 25 mm from final plate/strip edge. Reference standard shall be a flat-bottomed round recess
ISO 13663	Reference standard shall be a flat-bottomed round recess

c. Acceptance limits

Delete this item, including Table 8.4, and replace with the following:

ISO Standard	Acceptance limit
ISO 9303	L2C
ISO 9764	L3
ISO 10124	ISO/FDIS 3183-3, Table D.2, sour
ISO 11496	No trigger/alarm
ISO 12094	B1 (body). E1 (edge)
ISO 13663	ISO/FDIS 3183-3, Table D.2

8.16 ULTRASONIC AND ELECTROMAGNETIC INSPECTION OF SEAMLESS PIPE

a. Equipment

Delete this item and replace with the following: See Part II - 8.15**a** of this DEP.

b. Reference standards

Delete this item and replace with the following:

See Part II - 8.15**b** of this DEP and the following:

ISO Standard	Specific requirements
ISO 9305	Notch shall be on both internal and external surface

c. Acceptance limits

Delete this item and replace with the following:

See Part II - 8.15**c.** of this DEP and the following:

ISO Standard	Acceptance limit
ISO 9305	L2C
ISO 10543	As per ISO 10543

Add new item:

d. Repair

See Part II - 9 of this DEP.

8.17 ULTRASONIC INSPECTION OF CENTRIFUGALLY CAST PIPE

Delete this section including items **a.**, **b.** and **c.**, and replace with the following:

Inspection methods and ultrasonic testing shall be as specified for seamless pipe in Part II - 8.2 and 8.16 of this DEP.

Add the following new sections:

8.18 LIQUID PENETRANT TESTING OF BEVEL FACES

The acceptance criterion shall be no linear indications.

8.19 PERSONNEL QUALIFICATION

All personnel undertaking NDT activities shall be certificated in accordance with ISO 11484.

For UT at least one NDT Level 3 certificated individual with UT main method shall be available to the mill for overall supervision. An NDT Level 2 individual is required for shift supervision, manual weld inspection, and calibration of all systems (both manual and automatic).

For RT and PT, the individuals shall be certificated to a level appropriate for the task content and responsibilities as defined in ISO 11484.

SECTION 9 WORKMANSHIP, VISUAL INSPECTION AND REPAIR OF DEFECTS

9.3 WORKMANSHIP

a. Dents

Delete the third sentence and replace with the following:

All cold-formed dents with a sharp bottom gouge and all sharp gouges (without dents) deeper than 1.0 mm shall be considered to be defects.

b. Offset of plate edges

Delete this item and replace with the following:

For HFW pipe, the maximum radial offset shall be as follows:

Wall thickness mm	Maximum radial offset mm
≤10	0.5
>10	0.05t

For other welded pipe, the maximum radial offset shall be as follows:

Wall thickness mm	Maximum radial offset mm
≤10	1
10 < t ≤ 20	0.1t
> 20	2.0

d. Height of outside and inside weld beads - except ERW

Delete tabulation after first paragraph and replace with the following:

The bead height shall not lie outside the ranges specified below:

Outside - 0, + 3 mm

Inside - 0, + 2.5 mm

The inside weld bead shall be ground flush with the parent material over the full length of the pipe end.

9.5 DEFECTS

b. Laminations and inclusions

Delete this item and replace with the following:

The bevel face shall be free of laminations and inclusions.

f. Disposition

Add the following to item **1.**:

In all cases where repair by grinding has been carried out, the length of pipe containing each grinding repair shall be re-inspected after the grinding operation. This re-inspection shall use the same inspection methods as the original inspection and shall confirm freedom from defects and that the wall thickness is not less than the minimum specified. Where manual ultrasonic testing for wall thickness is performed it shall be in accordance with ASTM E 797.

9.6 REPAIR OF DEFECTS

b. Weld seam of welded pipe

Delete the last sentence and add the following:

Repair welding is not acceptable within 200 mm of the ends of the seam weld. Repair welds shall be subjected to radiographic testing in accordance with Part II – 8 of this DEP.

Repairs to the welded seam shall be limited to three per pipe. The length of repair welding shall not exceed 5% of the total weld length on each pipe.

No weld-repaired area shall be subjected to a further repair.

Repair welding of HFW pipe weld seams shall not be performed.

c. Heat treated pipe

Delete the section and replace with the following:

Heat treated pipe which has been repaired by welding shall be re-heat treated.

9.8 PROCEDURE FOR REPAIR OF WELD SEAMS OF ELECTRIC WELD AND INDUCTION WELDED PIPE

Delete this section.

9.9 PROCEDURE FOR REPAIR OF WELD SEAM OF GAS METAL-ARC WELDED PIPE

Add the following to item **b.**:

The requirements of Part II - 9.6**b.** of this DEP shall also apply.

Add the following new section:

9.10 GAUGE PIG

A gauge pig shall be passed through the following pipes in their supply conditions:

i. All first-day-production test pipes.
ii. Two pipes from each working shift, one at the beginning and one at the end.
iii. First two pipes immediately after any adjustment or maintenance is carried out on the mechanical expander.

The gauge shall consist of two parallel, 6 mm thick circular plates each at least 98% of minimum pipe ID separated by a rigid bar of which the length is twice the pipe ID. In order to pass the test, the gauge shall be passed through the pipe without damaging the gauge plates. The material of the gauge plates shall be 316L or duplex stainless steel or other material agreed by the Principal.

SECTION 10 MARKING AND SURFACE TREATMENT

10.1 MARKING - GENERAL

b.

Delete this item and replace with the following:

Marking of test pressure, sizes and weights shall be in metric units.

Add the following new item:

c. The paint used for stencilling shall be free of halogens, metal ions and other elements which may be detrimental to the pipe surface.

Paint markings shall be executed in black, block capitals with a minimum height of 25 mm. In the case of jointers, both ends of the pipes shall be marked.

10.2 LOCATION OF MARKINGS

b. Seamless pipe in all other sizes and welded up to 16 in. OD

Delete this item and replace with the following:

Pipes shall be marked in the sequence defined in Part II - 10.3 of this DEP on the outer surface at approximately 450 mm from the end of the pipe.

Continuous stencilling may be performed along the entire length of the pipe.

c. Welded pipe 16 in. OD and larger

Delete this item and replace with the following:

The marking location and format shall be as specified in Part II - 10.2**b.** of this DEP.

10.3 SEQUENCE OF MARKINGS

i. Supplementary requirements

Delete this item.

Add the following new items:

j. DEP 31.40.20.34-Gen.

k. Principal-specified markings

Additional marking requirements may be specified by the Principal.

10.5 DIE STAMPING

Delete this section.

10.6 SURFACE TREATMENT

Add the following:

Abrasive for blast cleaning shall be fused aluminium oxide in accordance with ISO 11126-7, or garnet in accordance with ISO/DIS 11126-10. Abrasive shall not be recycled.

Add the following new section:

SECTION 11 HANDLING, STORAGE, PACKAGING, AND DELIVERY

11.1 HANDLING

During manufacture, storage, and transportation, the pipes shall not contact with loose carbon steel (e.g. swarf, filings etc.). Nylon slings or rubber-coated hooks/supports etc. shall be used for all handling operations.

11.2 STORAGE

The pipe shall be segregated from other materials during storage.

11.3 PACKAGING

Packaging shall be as specified by, or agreed with, the Principal.

11.4 DELIVERY

The transportation of pipe shall be as specified in the following:

i. API RP 5LW for marine transportation;
ii. API RP 5L1 for railroad transportation.

Pipe shall not travel as deck cargo.

Add the following new section:

SECTION 12 DOCUMENTATION

12.1 LANGUAGE

All documentation submissions required by this DEP shall be in the English language unless another language is specified by the Principal.

12.2 PRE-MANUFACTURING DOCUMENTATION

The Manufacturer's quality plan specific to the purchase order shall be submitted to the Principal within the time period specified in the contract document.

NOTE: Review of a draft quality plan at the enquiry stage may assist this process.

12.2.1 Content of the quality plan

The format and issue of the quality plan shall be consistent with the documented control element of the Manufacturer's quality system.

The quality plan shall be prepared in accordance with ISO 10005 and shall include the following:

1. Identification of the product and contract to which the plan is to be applied.
2. Reference to API Spec 5LC and this DEP.
3. Location of steel making and pipe production.
4. Identification of the individuals responsible for controlling the activities defined in the plan.
5. Identification of the individuals with the authority to interface directly with the Principal.
6. Identification of all subcontractors.
7. The quality plans of all subcontractors.
8. All sequenced activities for the product required and references to the quality system procedures and work instructions which will be applied to these activities.
9. Copies of all the quality system procedures and work instructions covering production, test and inspection, special processes, control of non-conforming product, handling, storage, packing, preservation, and delivery as requested for agreement by the Principal.
10. Test and inspection frequency and acceptance criteria including the upper and lower process control limits where statistical process control is employed.

    NOTE: Process control of chemical composition and dimensional parameters is generally based on upper and lower control levels.

11. The location of each inspection and test point in the process sequence.
12. Points where the Principal has established witnessing or verification requirements.

Add new section:

SECTION 13 FIRST-DAY-PRODUCTION TESTS

13.1 GENERAL

At the commencement of production, three completely finished pipes of the first day's production shall be selected at random for testing to verify that the proposed manufacturing procedure results in fully acceptable pipe.

In the event that more than one cast is used or pipes of more than one dimension are produced then the 3 pipes shall be taken from different heats or size range. The selection shall be made by the Principal when a representative is deployed.

The selected pipes shall be considered to be the production test pipes per lot as required in this DEP.

These tests shall be repeated upon any change in manufacturing procedure or significant interruption to the production programme.

13.2 NON-DESTRUCTIVE TESTING

a. Visual examination

All test pipes shall be examined visually for dimensional tolerances, and for surface defects, in accordance with Part II - 7, 8 and 9 of this DEP respectively.

b. Liquid Penetrant Testing

Each test pipe shall be submitted to liquid penetrant testing over the entire pipe body in accordance with ISO 12095. Acceptance of indications shall be in accordance with test category P1 of ISO 12095 with the exception that linear indications, other than acceptable undercut in welded pipe, shall be considered as defects.

c. Ultrasonic Testing

The body of each pipe used for first-day production shall be examined by ultrasonic testing in accordance with Part II - 8 of this DEP.

d. Radiographic Testing

For welded pipe, except HFW, the entire weld seam shall be inspected in accordance with section Part II - 8 of this DEP.

13.3 CHEMICAL COMPOSITION

The chemical composition of each test pipe and weld (if applicable) shall be determined in accordance with Part II - 3 of this DEP.

13.4 MECHANICAL TESTING

Mechanical tests shall be carried out on each test pipe as required by section Part II - 4 of this DEP.

13.5 SPECIAL TESTS

a. Ferrite/Austenite Ratio for duplex stainless steel.

Ferrite/Austenite ratio shall be determined according to section Part II - 5.1 and (Appendix 1) of this DEP. For first-day production, the microstructure shall be checked at each end on each test pipe in 3 locations 120° apart around the pipe. For seam-welded pipe one of these locations shall be taken across the weld seam.

APPENDIX A SPECIFICATION FOR WELDED JOINTERS

A1. METHOD

Delete this section and replace with the following:

Where the supply of jointers has been agreed with the Principal, the girth welds shall be welded and inspected and tested in accordance with DEP 61.40.20.31-Gen.

A2. WORKMANSHIP

Delete this section.

A3. MARKING

Delete this section.

A4. NON-DESTRUCTIVE TESTING

Delete this section.

APPENDIX B REPAIR WELDING PROCEDURE

B.2. REPAIR WELDING PROCEDURE QUALIFICATION

Delete this section and replace with the following:

A repair welding procedure specification shall be prepared in accordance with ISO 9956-2. A fully simulated repair weld shall be made on a pipe piece of sufficient length to accommmodate extraction of all the required test specimens. Qualification shall be by the visual, non-destructive, and destructive testing of the test weld seam as specified in this DEP for the original seam weld.

Repair weld metal shall not be exposed on the inner surface of the pipe unless it has been heat-treated.

B.2.2 Mechanical testing

Delete this section and replace with the following:

The repair welding procedure shall be subject to the same testing required for the original weld by sections Part II - 4 and 5 of this DEP.

PART III REFERENCES

In this DEP, reference is made to the following publications:

Note: Unless specifically designated by date, the latest edition of each publication shall be used together with any amendments.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Pressure vessels (amendments/supplements to ASME Section VIII, Division 1 and Division 2)	DEP 31.22.20.31-Gen.
Field welding of duplex and super duplex stainless steel pipelines	DEP 61.40.20.31-Gen.

AMERICAN STANDARDS

Specification for Corrosion Resistant Alloy (CRA) Line Pipe	API 5LC, Second Edition, August 1991 (plus Supplement 1, December 1992)
Recommended Practice for Railroad Transportation of Line Pipe	API RP 5L1
Recommended Practice for Marine Transportation of Line Pipe	API Spec. RP 5LW

Issued by:
American Petroleum Institute
Publications and Distribution Section
1220 L Street Northwest
Washington DC 20005
USA

Mechanical testing of steel products	ASTM A 370
Methods, practices and definitions for chemical analysis of steel products	ASTM A 751
Methods of preparation of metallographic specimens	ASTM E 3
Standard test method for Rockwell hardness and Rockwell superficial hardness of metallic materials	ASTM E 18
Macroetching metals and alloys	ASTM E 340
Chemical analysis of stainless, heat resisting, maraging and other similar chromium – nickel – iron alloys.	ASTM E 353
Determining volume fraction by systematic manual point count	ASTM E 562
Measuring thickness by manual ultrasonic pulse-echo contact method	ASTM E 797

Issued by:
American Society for Testing and Materials
1916 Race Street
Philadelphia19103
USA

EUROPEAN STANDARDS

Destructive tests on welds in metallic materials. Hardness testing – Part 1: Hardness test on arc welded joints.	EN 1043-1

Issued by:
Comité Européen de Normalisation
rue de Stassart 36
B-1050 Brussels
Belgium

INTERNATIONAL STANDARDS

Metallic materials – Tensile testing at elevated temperature	ISO 783
Petroleum and natural gas industries - Steel pipe for pipelines – Technical delivery conditions - Part 3: Pipes of requirement class C.	ISO/FDIS 3183-3
Quality systems - Model for quality assurance in design, development, production, installation and servicing.	ISO 9001
Quality systems - Model for quality assurance in, production, installation and servicing.	ISO 9002
Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes - Full peripheral ultrasonic testing for the detection of longitudinal imperfections	ISO 9303
Seamless steel tubes for pressure purposes - Full peripheral ultrasonic testing for the detection of transverse imperfections	ISO 9305
Electric resistance and induction welded steel tubes for pressure purposes - Ultrasonic testing of the weld seam for the detection of longitudinal imperfections	ISO 9764
Submerged arc-welded steel tubes for pressure purposes - Ultrasonic testing of the weld seam for the detection of longitudinal and/or transverse imprefections	ISO 9765
Specification and approval of welding procedures for metallic materials - Part 2: Welding procedure specification for arc welding	ISO 9956-2
Quality management - Guidelines for quality plans	ISO 10005
Quality assurance requirements for measuring equipment - Part 1: Metrological confirmation system for measuring equipment	ISO 10012-1
Seamless and welded (except submerged arc-welded) steel tubes for pressure purposes - Ultrasonic testing for the detection of laminar imperfections	ISO 10124
Steel and Steel Products, Inspection documents	ISO 10474
Seamless and hot-stretch-reduced welded steel tubes for pressure purposes - Full peripheral ultrasonic thickness testing	ISO 10543
Preparation of steel substrates before application of paints and related products – Specifications for non-	ISO 11126-7

metallic blast-cleaning abrasives – Part 7: Fused aluminium oxide	
Preparation of steel substrates before application of paints and related products – Specifications for non-metallic blast-cleaning abrasives – Part 10: Garnet	ISO/DIS 11126-10
Steel tubes for pressure purposes - Qualification and certification of non-destructive testing (NDT) personnel	ISO 11484
Seamless and welded steel tubes for pressure purposes – Ultrasonic testing of tube ends for the detection of laminar imperfections	ISO 11496
Welded steel tubes for pressure purposes - Ultrasonic testing for the detection of laminar imperfections in strips/plates used in the manufacture of welded tubes	ISO 12094
Seamless and welded steel tubes for pressure purposes - liquid penetrant testing	ISO 12095
Submerged arc-welded steel tubes for pressure purposes - Radiographic testing of the weld seam for the detection of imperfections	ISO 12096
Welded steel tubes for pressure purposes – Ultrasonic testing of the area adjacent to the weld seam for the detection of laminar imperfections	ISO 13663

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APPENDIX 1 DETERMINATION OF THE VOLUME FRACTION OF FERRITE IN DUPLEX STAINLESS STEEL BY SYSTEMATIC POINT COUNT

1. SCOPE

This Appendix specifies the requirements for estimating the volume fraction of delta ferrite in duplex stainless steel by systematic point counting on transverse metallographic sections. This procedure is a specific interpretation of ASTM E 562 which should be referenced for additional background and definition of detail as noted.

2. BASIS OF METHOD

The method involves the superimposition of a test grid over an image, produced by an optical light microscope, of the appropriate microstructural area. The number of grid points falling within delta ferrite are counted and divided by the total number of grid points, to yield a point fraction which represents an estimate of the volume fraction of delta ferrite present within the field of view. The average point fraction taken over a number of appropriately selected fields gives an estimate of the volume fraction within the region sampled.

3. TERMINOLOGY

i. Point count - the number of grid points which lie within areas of a specific phase (in this case delta ferrite).

ii. Point fraction (P_p) - the point count divided by the total number of points in the test grid.

iii. Volume fraction (V_v) - the volume of a specific phase per unit volume, expressed as a fraction.

4. TEST PIECE PREPARATION

Planar sections shall be taken through the parent material or the weldment, as relevant. Sections shall be perpendicular to the material surface and transverse to the welding direction, when relevant, from the locations specified in Part II - 5.1 of this DEP. Each weld sample shall section the whole of the weldment and HAZ and an area of parent material on either side of the weld. Preparation of the test pieces shall be in accordance with standard metallographic techniques, such as described in ASTM E3. It is recommended that the last grinding stage should be with 600 grit, or finer, abrasive and the final polish should be with 1μm, or finer, abrasive, e.g. diamond paste.

The test piece shall be etched electrolytically in 40% KOH solution, i.e. 400 g KOH in 1000 ml of solution made with distilled water. Etching shall be carried out in a container of sufficient size to allow immersion of the test piece in the etch at a distance of $\leq$100 mm from the platinum cathode. Electrical contact between the test piece and power source may be made by means of a suitably shaped conducting probe.

Acceptable contrast may be obtained at an anode/cathode voltage that generates a current density of 1 amp/cm^2 for a period of 2-5 seconds, but trials may be necessary to determine the most appropriate conditions for a particular test piece. It may be noted that the contrast between the delta ferrite and austenite phases will probably vary through the weldment.

5. AREA SELECTION

The areas in which measurements have been made shall be specified precisely, as should the exact measurement locations. The weld pass shall be stated, e.g. root, cap, fill - preferably with a number, as shall the area which has been measured, i.e. weld metal, HAZ or parent material. Where possible it should be indicated whether the area has been re-heated or is as-deposited. Any uncertainty shall be noted. The location of measurements shall be recorded on a sketch or photograph of the section.

6. APPARATUS

An optical light microscope which projects an image of the magnified micro-structure onto a viewing screen shall be used, preferably with graduated x and y translation controls. The magnification shall be selected such that the ferrite particles have an average dimension approximately one half of the grid point spacing. This should be judged visually in more than one field of view, before measurements are made.

NOTE: For many weldment microstructures, particularly in re-heated areas, a magnification in the range x 500 - x 1000 is suitable.

The test grid shall be marked on a transparent sheet which shall be superimposed on the magnified image of the microstructure. The grid shall consist of a square array of equally spaced points, produced by the intersection of fine parallel lines (maximum width 0.3 mm), and shall have 16 or 25 points. It is recommended that the spacing of the points should be 10 mm along both directions parallel to the edges of the square grid, e.g. as in Figure. A2.1. At a magnification of x 1000 this corresponds to a point spacing on the actual microstructure of 10 µm.

7. PROCEDURE

Superimpose the test grid on the magnified image of the microstructure in the chosen area of the parent material or weldment.

Count the number of points which lie within the delta ferrite phase; any points which cannot be assigned positively to either phase shall be counted as one half. Delta ferrite is the phase which is stained dark by the etch, although its colour may vary significantly throughout the weldment. The austenite phase remains light coloured in all areas after etching.

The test piece shall then be moved by a small amount in x and/or y so that another field is chosen. A second point count shall be performed in the new field, provided that this field of view still falls within the specified region of the parent material or weldment. If the field of view falls outside the area of interest the specimen shall be moved back, without rotating, to an appropriate position within the specified area. Where possible the test piece should be moved without looking at the micro-structure in order to avoid bias in the choice of fields. It is recommended that the use of overlapping fields be avoided. This process shall be continued until a minimum of 400 points have been counted.

When measurements are being made within the coarse grained HAZ, the operator shall first assess whether the test grid can be superimposed over an area which is entirely within the coarse grained HAZ. This can be done simply by attempting to fit the grid within a single coarse grain. If the grid size is less than the grain size, then the technique described above shall be used. If the whole grid is too large, a smaller area of the grid shall be used, by ignoring one or more whole rows of grid points. The area chosen may be either square or rectangular. If a rectangular grid is used, the specimen shall be rotated so that the long axis of the rectangle is kept parallel to the fusion boundary.

Measurements in the coarse grained HAZ shall be made within 0.2 mm of the fusion line.

The volume fraction, as defined by ASTM E 562, of delta ferrite shall be estimated by taking an average of the point fractions counted in each of the *n* fields as follows:

$$V_V = P_p = \frac{1}{n} \sum P_p(i) \qquad \text{(equation 1)}$$

where (i) is the field number.

The 95% confidence interval (CI), as defined by ASTM E 562, shall be calculated as follows:

$$95\%CI = \frac{2.0s}{\sqrt{n-1}} \qquad \text{(equation 2)}$$

where

$$s = \left(\frac{1}{n-1}\sum[P_p(i) - P_p]^2\right)^{0.5} \qquad \text{(equation 3)}$$

The accuracy of the technique shall comply with the allowable errors specified in (Table A2.1) where the *error* is as defined in ASTM E 562.

8. REPORTING

The following details shall be included in the point counting report:

i. The number of sections taken from the weld.
ii. The locations of sections taken along the weld.
iii. The polishing procedure and etching conditions.
iv. The magnification used.
v. The number of points and shape of the grid.
vi. Whether the fields were chosen randomly or at regular intervals. If regular intervals were employed, report the spacings used.
vii. The location of the areas in which measurements were made, preferably on sketch or photograph and in words, specifying parent metal or the weld pass, the region of the weld pass (i.e. weld metal or HAZ) and, where practical, whether the area was re-heated or not. Any uncertainty should be indicated.
viii. A list of the point fractions of delta ferrite in each field.
ix. An estimate of the volume fraction of delta ferrite, calculated as the average of the point fractions.
x. The calculated value of the 95% CI.
xi. Stage of manufacture, i.e. procedure qualification, production test, etc.
xii. Location of sample and heat number.
xiii. Statement of conformance with specified ferrite content.
xiv. Signature of operator responsible for ferrite determination.

Figure A2.1 Two grid types suitable for systematic manual point counting of delta ferrite in duplex stainless steel

Table A2.1 Allowable error in ferrite/austenite determination

Volume %	Error
45-50	± 10%
40-45	± 11%
35-40	± 12%
0-35	± 14%