Base Load Power Hub (BLPH)

Radiographic Examination Procedure – Piping

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Table of contents

1	INTRODUCTION	5
1.1	PROJECT OVERVIEW	5
1.1.1	Project Location	5
1.1.2	Project Concept	6
2	DOCUMENT SCOPE	8
2.1	REFERENCES documents (Applicable edition)	8
2.2	DEFINITIONS AND ABBREVIATIONS	8
3	PERSONNEL QUALIFICATION	9
4	SURFACE PREPARATION	9
5	RADIATION SOURCE	9
6	CALIBRATIONS	10
7	FILM SYSTEM AND METAL SCREEN	11
8	BACKSCATTERED RADIATION	12
9	PENETRAMETERS (IQI)	12
10	EXAMINATION	13
11	IDENTIFICATION SYSTEM	14
12	FILM PROCESSING	15
13	STORAGE FILM	15
14	QUALITY OF RADIOGRAPHS	15
15	FILM DENSITY	16
16	ACCEPTANCE CRITERIA	16
17	WELD REPAIR	26
18	EXAMINATION REPORT	26
19	ATTACHMENT	27

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List of Figures

Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map 5
Figure 2 - Wind Park Details 6
Figure 3 – BLPH Concept 6

List of tables

Table 1 - Reference Documents 8
Table 2 - Definitions and Abbreviations 8

List of Attachments

Attachment 1 – Maximum permissible voltage

Attachment 2 – Radiographic techniques

Attachment 3 – Image quality indicators

Attachment 4 – Examination Report

1 INTRODUCTION

1.1 PROJECT OVERVIEW

Crosswind, a Shell and Eneco joint venture, was awarded the tender to develop the offshore Hollandse Kust Noord (HKN) wind farm, located 18.5km off the coast of Netherlands near the town of Egmond aan Zee. The consortium plans to have HKN operational in 2023 with an installed capacity of 759MW generating at least 3.3TWh per year. This is sufficient renewable power to supply more than 1 million Dutch households with green electricity.

Offshore wind farms produce intermittent electricity and balancing these dips and peaks and integrating this electricity into the national energy system requires new technologies. For this reason, the offshore wind farm will include several new technologies that could be implemented at full-scale in the future. The new technologies being explored include a floating solar park, a short-duration battery storage as well as long-term storage via green hydrogen produced by water electrolysis and subsequently consumed in a fuel cell. The combination of these individual measures, herein referred to as the Base Load Power Hub (BLPH) will ensure a continuous power supply regardless of the wind situation.

1.1.1 Project Location

The Hollandse Kust Noord (HKN) wind farm is located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

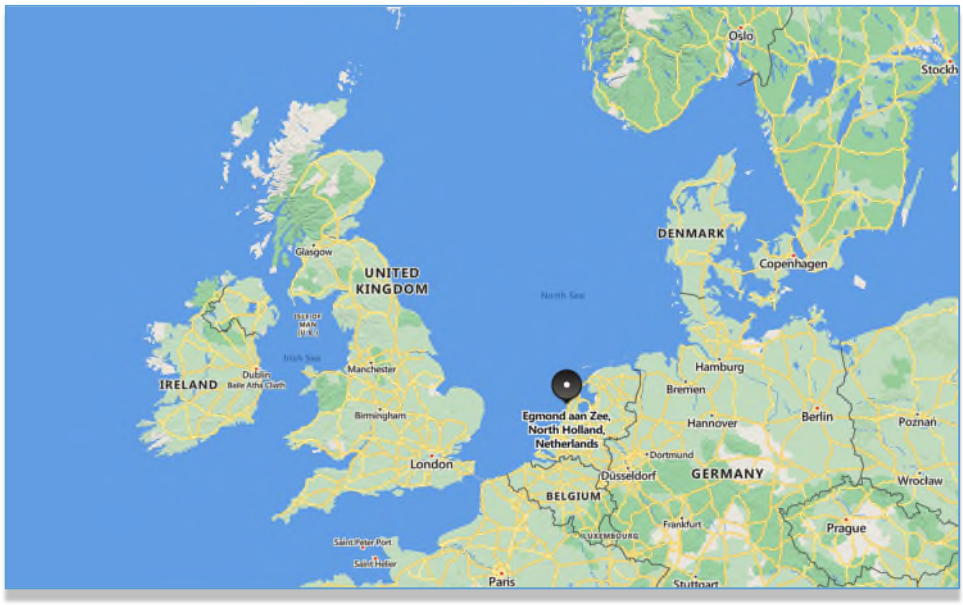


Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map

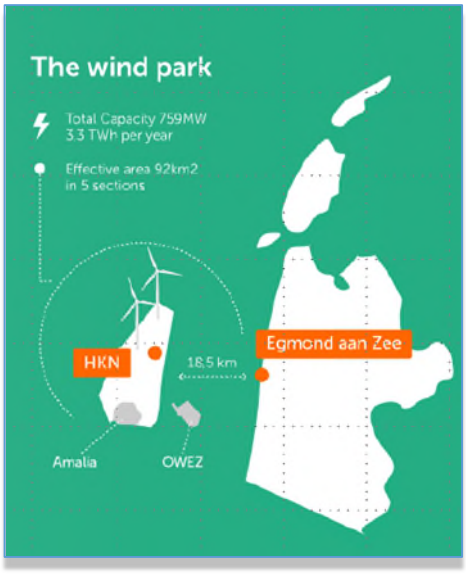


Figure 2 - Wind Park Details

The wind farm will consist of No. 69 x 11.5MW wind turbine generators each to be installed on a dedicated monopile structure. A 70th monopile located on coordinates E 590719.1, N 5841602.3 is reserved for installing the platform accommodating the BLPH. The monopile structure was designed and installed by Van Oord Offshore Wind (VooW) and therefore not part of the BLPH scope.

1.1.2 Project Concept

All components included in the BLPH will be integrated onshore on a topsides and installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating solar PV farm) and release it during periods of low generation. In practice. It is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability.

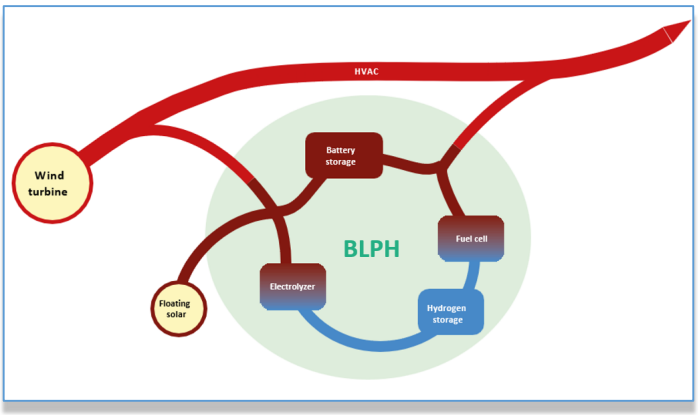


Figure 3 – BLPH Concept

Electricity in the BLPH will be stored in the form of electrons in a battery energy storage system (BESS) as well as converted into green hydrogen via water electrolysis. When the power output from the connecting wind turbine drops to below 1 MWe, the BLPH will return its stored energy to supplement the remaining power output. This will be by discharging the BESS, while stored hydrogen will be converted back into electricity using a fuel cell to extend the discharge duration.

The purpose of the BLPH s to function as a testbed for the integration of energy storage technologies with renewable generation. It is expected that equipment installed on the BLPH will operate as Normally Unmanned Installation for at least two (2) years with no or minimal maintenance and it will have its own independent control room with the ability to communicate with Crosswind's control room.

2 DOCUMENT SCOPE

This procedure specifies the requirements for the execution, examination and evaluation of radiographic films obtained by x-rays or γ-rays on welded joint in carbon steel, low and medium alloy stainless steel and non ferrous materials on piping .

All welds shall be 100% visually examined and accepted in accordance with the Project requirements before testing.

This procedure applies also to qualification of welders and welding procedures.

2.1 REFERENCES documents (Applicable edition)

Doc. No.	Description
123A90-DDL-PP-SP-70029_2	TSS-Piping materials narrative
ASME V Art.2	Asme Boiler and Pressure Vessel Code – Nondestructive Examination
ASME B31.3	Process Piping
ASME B31.12	
ISO 19232-1	Non-destructive testing of welds – Acceptance levels for radiographic testing – Part 1: Steel,nickel,titatium and their alloys
ISO 11699-1	Non-destructive testing – Industrial radiographic film – Part . Classification of film systems for industrial radiography
ISO 9712	Non-destructive testing — Qualification and certification of NDT personnel

Table 1 - Reference Documents

2.2 DEFINITIONS AND ABBREVIATIONS

COMPANY or Client (CPY):	Crosswind
CONTRACTOR (CTR):	ROSETTI MARINO S.p.A.
PROJECT:	HOLLANDSE KUST NOORD WIND PARK Project
RT	Radiographic test
NDT:	Non Destructive test

Table 2 - Definitions and Abbreviations

3 PERSONNEL QUALIFICATION

Personnel performing and evaluating Radiographic examinations shall be qualified and certified minimum as Level II in accordance with ISO 9712.

The personnel shall have an annual near vision acuity test, with correction if necessary, and shall be able to read the 1st line of a JAEGER STANDARD chart at a distance of not less than 300 mm. For colour contrast differentiation and shades of grey, the test may be conducted upon initial certification and at one-year intervals.

Operators/Interpreters shall have passed an eyesight acuity test within the previous 12 months.

4 SURFACE PREPARATION

All welds shall be 100% visually examined and accepted in accordance with the Project requirements before testing.

Excessive surface irregularities, nicks, slag and weld ripples, etc. that could mask or be confused with discontinuities shall be removed by grinding or other suitable means in according with manufacturing specifications.

5 RADIATION SOURCE

The X Ray generating set available and relevant focal spot is:

Type / Model	Max. X-ray Volt.	Source Size (mm)
Seifert Eresco Model 60 MF	Kv 275	3,0
Seifert Eresco Model 65 MF3	Kv 300	3,0
Seifert Eresco Model 42 MF2	Kv 200	3,0

Or equivalent X-ray.

The following radioactive isotopes may be used :

- Selenium 75 maximum Source Size 3 x 3 mm.
- Iridium 192 maximum Source Size 2 x 2 mm.

Gamma radiation sources shall be used as Se 75 or Ir 192 isotope for penetrated thickness ranges as following indicated:

- Se 75 for minimum thickness 2.5 mm. to 30 mm.
- Ir 192 for minimum thickness 12 mm. to 70 mm.

The selection of equipment to be used depends on the technique of exposure chosen, which

Is directly connected to the accessibility of the part to be radiographed as well as the diameter of pipes or parts.

6 CALIBRATIONS

Manufacturer's publications of x-ray source documenting actual source size and decay curves shall be available.

X-Ray equipment shall be calibrated by the Equipment Manufacturer for the verification of the focal spot size.

When manufacturer's or supplier's publications are not available, source size may be determined as follows:

- X-Ray Machines. For X-ray machines operating at 1,000 kV and less, the focal spot size may be determined in accordance with SE-1165, Standard Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging.
- Iridium-192 Sources. For Iridium-192, the source size may be determined in accordance with SE-1114, Standard Test Method for Determining the Focal Size of Iridium-192 Industrial Radiographic Sources.
- A certified densitometer shall be always available on site during film evaluation. The Densitometers shall be calibrated at least every 90 days as follow:

(a) A national standard step tablet or a step wedge calibration film, traceable to a national standard step tablet and having at least five steps with neutral densities from at least 1.0 through 4.0, shall be used.

The step wedge calibration film shall have been verified within the last year by comparison with a national standard step tablet unless, prior to first use, it was maintained in the original lighttight and waterproof sealed package as supplied by the manufacturer. Step wedge calibration films may be used without verification for one year upon opening, provided it is within the manufacturer's stated shelf life.

(b) The densitometer manufacturer's step-by-step instructions for the operation of the densitometer shall be followed.

c) The density steps closest to 1.0, 2.0, 3.0, and 4.0 on the national standard step tablet or step wedge calibration film shall be read.

(d) The densitometer is acceptable if the density reading do not vary by more than ±0.05 den-sity units from the actual density stated on the national standard step tablet or step wedge cali-bration film.

The step wedge calibration film shall have been verified within the last year by comparison with a national standard step tablet unless, prior to first use, it was maintained in the original light-tight and waterproof sealed package as supplied by the manufacturer.

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one year upon opening, provided it is within the manufacturer's stated shelf life. Step wedge comparison films shall be verified prior to first use, unless performed by the manufacturer.

Recommended maximum values for geometric unsharpness are as follow: (ASME V art.2)

Material Thickness, in.(mm)	Ug Maximum, in.(mm)
Under 2 (50)	0.020 (0.51)
2 through 3 (50-75)	0.030 (0.76)
2 through 3 (50-75)	0.030 (0.76)

Note: Material thickness is the thickness on which the IQI is based.

Geometric unsharpness of the radiograph shall be determined in accordance with:

$$Ug = Fd / D$$

Where:

D = distance from source of radiation to weld or object being radiographed

d = distance from source side of weld or object being radiographed to the film

F = source size: the maximum projected dimension of the radiating source (or effective focal spot) in the plane perpendicular to the distance D from the weld or object being radiographed.

Ug = geometric unsharpness

D and d shall be determined at the approximate center of the area of interest.

7 FILM SYSTEM AND METAL SCREEN

The following film shall be used if sensitivity requirements are met during qualification process:

Class II film Fine grain (e.g. AGFA D7, Kodak A400 or equivalent) for X-rays.

Class I film very fine grain for Gamma rays, (e.g. AGFA D5 or Kodak T200 or equivalent) can be used.

8 BACKSCATTERED RADIATION

A lead symbol "B," with minimum dimensions of 13 mm in height and 1.5 mm in thickness, shall be attached to the back of each film holder during each exposure to determine if backscatter radiation is exposing the film.

The lead symbol "B" shall be placed in a location so that it would appear within an area on the radiograph that meets the requirements of T-282.

If a light image of the "B" letter, appears on a darker background of the radiograph, protection from backscatter is insufficient and the radiograph shall be considered unacceptable.

A dark image of the "B" on a lighter background is not cause for rejection.

9 PENETRAMETERS (IQI)

IQI shall be of the wire type, in accordance with Table T-276 (show below).

Table T-276
IQI Selection

Nominal Single-Wall Material Thickness Range, in. (mm)	IQI					
	Source Side			Film Side		
	Hole-Type Designation	Essential Hole	Wire-Type Essential Wire	Hole-Type Designation	Essential Hole	Wire-Type Essential Wire
Up to 0.25, incl. (6.4)	12	2T	5	10	2T	4
Over 0.25 through 0.375 (6.4 through 9.5)	15	2T	6	12	2T	5
Over 0.375 through 0.50 (9.5 through 12.7)	17	2T	7	15	2T	6
Over 0.50 through 0.75 (12.7 through 19.0)	20	2T	8	17	2T	7
Over 0.75 through 1.00 (19.0 through 25.4)	25	2T	9	20	2T	8
Over 1.00 through 1.50 (25.4 through 38.1)	30	2T	10	25	2T	9
Over 1.50 through 2.00 (38.1 through 50.8)	35	2T	11	30	2T	10
Over 2.00 through 2.50 (50.8 through 63.5)	40	2T	12	35	2T	11
Over 2.50 through 4.00 (63.5 through 101.6)	50	2T	13	40	2T	12
Over 4.00 through 6.00 (101.6 through 152.4)	60	2T	14	50	2T	13
Over 6.00 through 8.00 (152.4 through 203.2)	80	2T	16	60	2T	14
Over 8.00 through 10.00 (203.2 through 254.0)	100	2T	17	80	2T	16
Over 10.00 through 12.00 (254.0 through 304.8)	120	2T	18	100	2T	17
Over 12.00 through 16.00 (304.8 through 406.4)	160	2T	20	120	2T	18
Over 16.00 through 20.00 (406.4 through 508.0)	200	2T	21	160	2T	20

The designated essential wire shall be as specified in Attachment 3 and can be used the IQI in accordance with EN-19232-1.

IQI shall be selected from either the same alloy material group/grade or from an alloy material group or grade with less radiation absorption than the material being radiographed.

The thickness on which the IQI is based is the nominal single-wall material thickness plus the actual weld reinforcement thickness estimated to be present on both sides of the weld.

IQI shall be placed on the source side of the part being examined, except here inaccessibility prevents hand placing the IQI on the source side, the IQI shall be placed on the film side in contact with the part being examined.

A lead letter "F" shall be placed adjacent or on the IQI, but shall not mask the essential.

IQI shall be placed on the weld so that the length of the wires is across the length of the weld. The IQI identification and when used, the lead letter "F" shall not be in the area of interest.

Radiography shall be performed with a technique of sufficient sensitivity to display the essential wire as per T-276.

The radiograph shall also display the IQI identifying numbers and letters.

10 EXAMINATION

RT shall be performed in accordance with ASME V Art.2.

For welds that require cap to be ground flush final RT examination shall be performed after cap flushing, weld status at the time of examination shall be noted in inspection report (ie. as welded, cap flushed etc).

A single-wall exposure technique shall be used for radiography whenever practical.

When it is not practical to use a single-wall technique, a double-wall technique shall be used.

An adequate number of exposures shall be made to demonstrate that the required coverage has been obtained.

For materials and for welds in components 3" in. (89 mm) or less in nominal outside diameter, also the technique in which the radiation passes through two walls and the weld (material) in both walls is viewed for acceptance on the same radiograph (DWDI) may be used.

The full circumference of each production weld shall be radiographed in accordance with this procedure.

The elliptical technique (double wall and double image should not be used for

external diameter De> 100 mm or wall thickness t > 8 mm or weld width >De/4. Two 90 ° displaced images are sufficient if t/De < 0, 12; otherwise three images are needed.

The distance between the two projected weld images shall be about one weld width.

When it is difficult to carry out an elliptical examination at De≤100 mm, the perpendicular technique may be used.

In this case, three exposures 120° or 60° apart are required.

When complete coverage is required, a minimum of two exposures taken 90 deg. to each other shall be made for each joint.

Where :

OD = outside diameter

ID = inside diameter

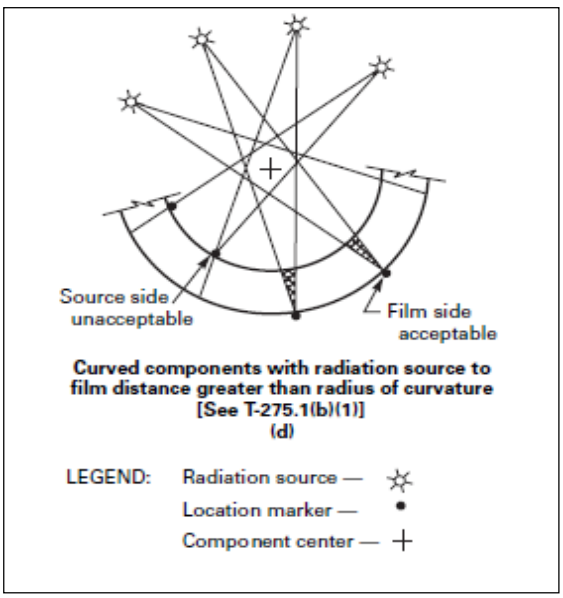
As an alternative, the weld may be radiographed with the radiation beam positioned so that the image of both walls are superimposed.

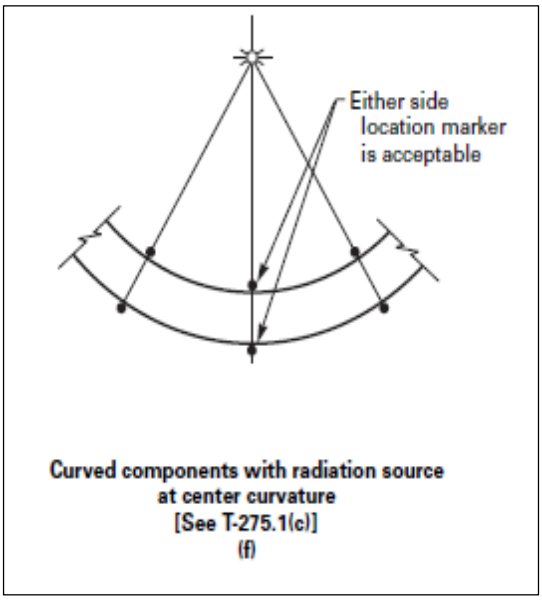
When complete coverage is required, a minimum of three exposures taken at either 60 deg. or 120 deg. to each other shall be made for each joint.

11 IDENTIFICATION SYSTEM

Location markers shall be used to identify the useful portion of film.Markings shall be stencilled near the joint (at 25 mm distance or more) for all the duration of manufacture.

The entire coverage of circumference welds for diameter greater than 3 inch shall be based on the Figures shown below:





Location markers shall be permanently stencilled on the part radiographed and/or reported on a radiographic map. When metric markers strip is used, the start point and progression direction shall be identified and applied directly on the part when 100% coverage is required.

Where the radiograph doesn't show the weld (smooth grinding), markers shall be placed on either side of the weld.

When radiographing an area with two or more separate films, the films shall overlap sufficiently to ensure the complete coverage.

This shall be verified by markers on the surface of the object which will appear on each film.
Location marks shall be placed on the object being inspected not on film holder/cassette. On each film shall be permanently marked the following information:

- Project Nr
- Item Nr
- Weld Nr
- Date of radiograph execution

Remarks:

- Flash marking on film can be perform only if approved by Company.
- Films carried out after "repair" shall have a marking "R" and the eventual repair number
- Films carried out after "repeat confirmation defect "shall have a marking "RXX"
- Films carried out after "repeat" shall have a marking symbol "RR"
- Films carried out after reweld after cutting shall have marking "C"
- Markers and symbols shall not be placed out on area of the interest of examination

12 FILM PROCESSING

Film can be processed by automatic develop process or manual develop process AGFA / KODAC or equivalent.
Processing shall ensure at least ten year of conservation.
The processed film shall not exhibit a degree of fogging greater than a density of 0.3.
Periodic testing of non-processed films shall be performed.

13 STORAGE FILM

Exposed and unexposed films shall be stored in places where they cannot be damaged by humidity, secondary radiation, high temperatures, fumes or gases as per ASTM E1254.

14 QUALITY OF RADIOGRAPHS

The films shall be free of mechanical defects such as: scratches, finger marks, dirtyness, lines, false indications to the extent that they do not mask and are not confused with the image of any discontinuity in the area of interest of the object being radiographed.
Films shall be handled with care to avoid damages due to excessive pressure or electrostatic charges.

15 FILM DENSITY

The check of density shall be done using an electronic calibrated densitometer at least 90 days.

The transmitted film density through the radiographic image of the body of the designated IQI adjacent to the essential wire of a wire-type IQI and the area of interest shall be 1.8 minimum for single film viewing for radiographs made with an X-ray source and 2.0 minimum for radiographs made with a gamma ray source.

For composite viewing of multiple film exposures, each film of the composite set shall be a minimum density of 1.3, the maximum density shall be 4.0 for either single or composite viewing.

The maximum density shall be 4.0 for either single or composite viewing.

16 ACCEPTANCE CRITERIA

The acceptance criteria shall be in accordance with ASME B31.3 Table 341.3.2 normal fluid.

Table 341.3.2 Acceptance Criteria for Welds — Visual and Radiographic Examination

Criteria (A to M) for Types of Welds and for Service Conditions [Note (1)]											Examination Methods	
Normal and Category M Fluid Service			Severe Cyclic Conditions			Category D Fluid Service						
Girth, Miter Groove, and Branch Connection Welds [Note (2)]	Longitudinal Groove Weld [Note (3)]	Fillet Weld [Note (4)]	Girth, Miter Groove, and Branch Connection Welds [Note (2)]	Longitudinal Groove Weld [Note (3)]	Fillet Weld [Note (4)]	Girth and Miter Groove Welds	Longitudinal Groove Weld [Note (3)]	Fillet Weld [Note (4)]	Branch Connection Weld [Note (2)]	Weld Imperfection	Visual	Radiography
A	A	A	A	A	A	A	A	A	A	Crack	✓	✓
A	A	A	A	A	A	C	A	N/A	A	Lack of fusion	✓	✓
B	A	N/A	A	A	N/A	C	A	N/A	B	Incomplete penetration	✓	✓
E	E	N/A	D	D	N/A	N/A	N/A	N/A	N/A	Rounded Indications	...	✓
G	G	N/A	F	F	N/A	N/A	N/A	N/A	N/A	Linear indications	...	✓
H	A	H	A	A	A	I	A	H	H	Undercutting	✓	✓
A	A	A	A	A	A	A	A	A	A	Surface porosity or exposed slag inclusion [Note (5)]	✓	...
N/A	N/A	N/A	J	J	J	N/A	N/A	N/A	N/A	Surface finish	✓	...
K	K	N/A	K	K	N/A	K	K	N/A	K	Concave surface, concave root, or burn-through	✓	✓
L	L	L	L	L	L	M	M	M	M	Weld reinforcement or internal protrusion	✓	...

GENERAL NOTES:
(a) Weld imperfections are evaluated by one or more of the types of examination methods given, as specified in paras. 341.4.1, 341.4.2, 341.4.3, and M341.4, or by the engineering design.
(b) "N/A" indicates the Code does not establish acceptance criteria or does not require evaluation of this kind of imperfection for this type of weld.
(c) Check (✓) indicates examination method generally used for evaluating this kind of weld imperfection.
(d) Ellipsis (...) indicates examination method not generally used for evaluating this kind of weld imperfection.

NOTES:
(1) Criteria given are for required examination. More-stringent criteria may be specified in the engineering design. See also paras. 341.5 and 341.5.3.
(2) Branch connection weld includes pressure containing welds in branches and fabricated laps.
(3) Longitudinal groove weld includes straight and spiral (helical) seam. Criteria are not intended to apply to welds made in accordance with a standard listed in Table A-1, Table A-1M, or Table 326.1. Alternative Leak Test requires examination of these welds; see para. 345.9.
(4) Fillet weld includes socket and seal welds, and attachment welds for slip-on flanges, branch reinforcement, and supports.
(5) These imperfections are evaluated only for welds ≤5 mm ($^{5}/_{16}$ in.) in nominal thickness.

Criterion		
Symbol	Measure	Acceptable Value Limits [Note (1)]
A	Extent of imperfection	Zero (no evident imperfection)
B	Cumulative length of incomplete penetration	≤38 mm (1.5 in.) in any 150 mm (6 in.) weld length or 25% of total weld length, whichever is less
C	Cumulative length of lack of fusion and incomplete penetration	≤38 mm (1.5 in.) in any 150 mm (6 in.) weld length or 25% of total weld length, whichever is less
D	Size and distribution of rounded indications	See ASME BPVC, Section VIII, Division 1, Appendix 4 [Note (2)]
E	Size and distribution of rounded indications	For $\overline{T}_w \leq 6$ mm (¼ in.), limit is same as D [Note (2)] For $\overline{T}_w > 6$ mm (¼ in.), limit is 1.5 × D [Note (2)]
F	Linear indications	
	Individual length	$\leq \overline{T}_w/3$
	Individual width	≤2.5 mm (3/32 in.) and $\leq \overline{T}_w/3$
	Cumulative length	$\leq \overline{T}_w$ in any 12 $\overline{T}_w$ weld length [Note (2)]
G	Linear indications	
	Individual length	$\leq 2\overline{T}_w$
	Individual width	≤3 mm (⅛ in.) and $\leq \overline{T}_w/2$
	Cumulative length	$\leq 4\overline{T}_w$ in any 150 mm (6 in.) weld length [Note (2)]
H	Depth of undercut	≤1 mm (1/32 in.) and $\leq \overline{T}_w/4$
	Cumulative length of internal and external undercut	≤38 mm (1.5 in.) in any 150 mm (6 in.) weld length or 25% of total weld length, whichever is less
I	Depth of undercut	≤1.5 mm (1/16 in.) and $\leq [\overline{T}_w/4$ or 1 mm (1/32 in.)]
	Cumulative length of internal and external undercut	≤38 mm (1.5 in.) in any 150 mm (6 in.) weld length or 25% of total weld length, whichever is less
J	Surface roughness	≤12.5 µm (500 µin.) R_a in accordance with ASME B46.1
K	Depth of surface concavity, root concavity, or burn-through	Total joint thickness, including weld reinforcement, $\geq \overline{T}_w$ [Notes (3) and (4)]
L	Height of reinforcement or internal protrusion [Note (5)] in any plane through the weld shall be within limits of the applicable height value in the tabulation at right, except as provided in Note (6). Weld metal shall merge smoothly into the component surfaces.	For $\overline{T}_w$, mm (in.) / Height, mm (in.) ≤6 (¼) / ≤1.5 (1/16) >6 (¼), ≤13 (½) / ≤3 (⅛) >13 (½), ≤25 (1) / ≤4 (5/32) >25 (1) / ≤5 (3/16)
M	Height of reinforcement or internal protrusion [Note (5)] as described in L. Note (6) does not apply.	Limit is twice the value applicable for L above

NOTES:
(1) Where two limiting values are separated by "and," the lesser of the values determines acceptance. Where two sets of values are separated by "or," the larger value is acceptable. $\overline{T}_w$ is the nominal wall thickness of the thinner of two components joined by a butt weld.

Criterion Value Notes for Table 341.3.2 (Cont'd)

NOTES: (Cont'd)
(2) Porosity and inclusions such as slag or tungsten are defined as rounded indications where the maximum length is three times the width or less. These indications may be circular, elliptical, or irregular in shape; may have tails; and may vary in density. Indications where the length is greater than three times the width are defined as linear indications and may also be slag, porosity, or tungsten.
(3) For circumferential groove welded joints in pipe, tube, and headers made entirely without the addition of filler metal, external concavity shall not exceed the lesser of 1 mm (1/32 in.) or 10% of the joint nominal thickness. The contour of the concavity shall blend smoothly with the base metal. The total joint thickness, including any reinforcement, shall not be less than the minimum wall thickness, t_m.
(4) For radiography, acceptability may be determined by comparing the density of the image through the affected area to the density through the adjacent base metal ($\overline{T}_w$). If digital radiography is used, brightness comparison may be utilized. A density or brightness darker than the adjacent base metal is cause for rejection.
(5) For groove welds, height is the lesser of the measurements made from the surfaces of the adjacent components; both face reinforcement and root reinforcement are permitted in a weld. For fillet welds, height is measured from the theoretical throat, Figure 328.5.2A; root reinforcement does not apply.
(6) For welds in aluminum alloy only, root reinforcement shall not exceed the following values:
(a) 1.5 mm (1/16 in.) for thickness ≤2 mm (≤5/64 in.)
(b) 2.5 mm (3/32 in.) for thickness >2 mm and ≤6 mm (≤¼ in.)
For face reinforcement and for greater thicknesses, see the tabulation for symbol L.

Acceptance criteria for hydrogen line shall be in accordance with ASME B31.12 Table IP-10.4.3-1

Table IP-10.4.3-1 Acceptance Criteria for Weldments and Methods for Evaluating Weld Imperfections

Piping Design											
Design Conditions up to Class 150 in a Ventilated Location			Design Conditions up to Class 150 Not in a Ventilated Location			Design Conditions Above Class 150					
Type of Weld			Type of Weld			Type of Weld					
Girth and Miter Groove	Longitudinal Groove	Fillet	Girth and Miter Groove	Longitudinal Groove	Fillet	Girth and Miter Groove	Longitudinal Groove	Fillet	Weld Imperfection [Note (1)]	Examination Method: Visual	Radiography and Ultrasonic	Magnetic Particle and Liquid Penetrant
A	A	A	A	A	A	A	A	A	Cracks	✓	✓	✓
B	B	B	B	B	B	B	B	B	Lack of fusion and incomplete penetration	✓	✓	✓
C	C	C	C	C	C	C	C	C	Surface porosity; inclusions, tungsten	✓	✓	✓
D	D	N/A	D	D	N/A	D	D	N/A	Internal porosity	...	✓	...
F	F	N/A	F	F	N/A	E	E	N/A	Internal inclusions, slag or tungsten; elongated indications	...	✓	...
H	H	H	H	H	H	G	G	G	Depth of undercut	✓	✓	...
J	J	N/A	J	J	N/A	I	I	N/A	Depth of surface concavity	✓	✓	...
K	K	K	K	K	K	K	K	K	Weld surface finish O.D. and I.D.	✓	✓	...
L	L	L	L	L	L	L	L	L	Weld reinforcement O.D. and I.D.	✓	✓	...

GENERAL NOTES:
(a) Girth and miter groove welds include other complete joint penetration weldments such as for branch connections and fabricated laps.
(b) Fillet welds include socket and seal welds, and attachment welds for slip-on flanges, branch reinforcement, and supports.
(c) Weld imperfections are evaluated by one or more of the types of examination methods given, as specified in para. IP-10.4, or by the engineering design.
(d) "N/A" indicates the Code does not establish acceptance criteria or does not require evaluation of this kind of imperfection for this type of weld. See Table IP-10.4.3-3 for letter symbols.
(e) Check (✓) indicates examination method generally used for evaluating this kind of weld imperfection.
(f) Ellipsis (...) indicates examination method not generally used for evaluating this kind of weld imperfection.
(g) Criteria given are for required examination method(s). More stringent criteria may be specified in the engineering design.
(h) Longitudinal groove welds (single or double) include straight seam only. Criteria are not intended to apply to welds made in accordance with a standard listed in Table IP-8.1.1-1 or Mandatory Appendix IX, Table IX-1A.

NOTE: (1) The criteria value for the type of weld and design pressure is identified by the letter symbol for the measure and acceptable value limits of each NDE method.

ASME B31.12-2019

Table IP-10.4.3-3 Criterion Value Notes for Table IP-10.4.3-1

Criterion Symbol	Criterion Measure	Acceptable Value Limits [Note (1)]
A	Cracks	None of weld deposit, HAZ and BM
B	Lack of fusion and incomplete penetration	None of weld deposit or weld deposit to BM
C	Surface porosity; inclusions, slag or tungsten	None of weld deposit
D	Size and distribution of internal porosity	See ASME BPVC, Section VIII, Division 1, Mandatory Appendix 4
E	Internal inclusions, slag or tungsten; elongated indications Individual length Individual width Cumulative length	 $\leq \overline{T}_w/4$ and ≤4 mm ($^5/_{32}$ in.) $\leq \overline{T}_w/4$ and ≤2.5 mm ($^3/_{32}$ in.) $\leq \overline{T}_w$ in any $12\overline{T}_w$ weld length
F	Internal inclusions, slag or tungsten; elongated indications Individual length Individual width Cumulative length	 $\leq \overline{T}_w/3$ ≤2.5 mm ($^3/_{32}$ in.) and $\leq \overline{T}_w/3$ $\leq \overline{T}_w$ in any $\overline{T}_w$ weld length
G	Depth of undercut	None allowed
H	Depth of undercut [Note (2)]	≤1 mm ($^1/_{32}$ in.) and $\leq \overline{T}_w/4$
I	Depth of root surface concavity	None below pipe component I.D.
J	Depth of root surface concavity [Note (3)]	Total joint thickness, including weld reinforcement, $\geq \overline{T}_w$
K	Weld surface of O.D. finish [Note (4)]	Roughness average ≤ 12.5 μm R_a (500 μin. R_a) per ASME B46.1
L	Weld reinforcement O.D. and I.D. [Note (5)]	See Table GR-3.4.6-1

NOTES:

(1) Where two limiting values are separated by "and," the lesser of the values determines acceptance. $\overline{T}_w$ is the nominal wall thickness of the thinner of two components joined by a butt weld.

(2) Depth of undercut shall be applied to the O.D. and I.D. surfaces.

(3) Concavity on the root side of a single groove weld is permitted when the resulting thickness of the weld is at least equal to the thickness of the thinner member of the two sections being joined and the contour of the concavity is smooth without sharp edges.

(4) Weld metal reinforcement, O.D. and I.D., shall merge smoothly into the weld surfaces.

(5) For all butt groove welds (single and double), height is the lesser of the measurements made from the surfaces of the adjacent components. For single groove welds, I.D. reinforcement (internal protrusion) is included in a weld (see Figure GR-3.4.4-1). Weld reinforcement, O.D. or I.D., may be flush to the adjoining surfaces. For fillet welds and added reinforcement to nonbutt groove welds, height is measured from the theoretical throat (see Figure GR-3.4.7-1). Internal protrusion does not apply.

For all line: size and distribution of internal porosity see below:

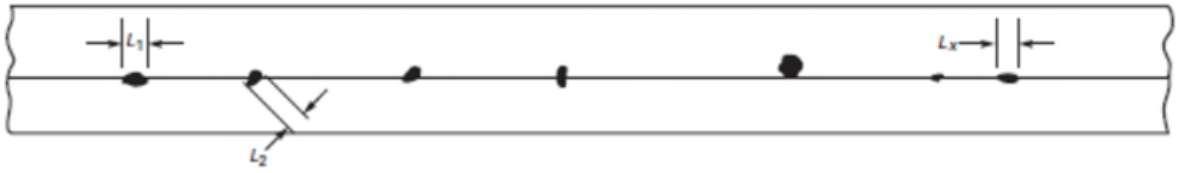
- No more than three isolated indications in any 150 mm weld length, with a minimum distance of 30 mm between two indications.

TBLE 4-1

SI Units			
	Maximum Size of Acceptable Rounded Indication, mm		Maximum Size of Nonrelevant
Thickness, t, mm	Random	Isolated	Indication, mm
Less than 3	$\frac{1}{4}t$	$\frac{1}{3}t$	$\frac{1}{10}t$
3	0.79	1.07	0.38
5	1.19	1.60	0.38
6	1.60	2.11	0.38
8	1.98	2.64	0.79
10	2.31	3.18	0.79
11	2.77	3.71	0.79
13	3.18	4.27	0.79
14	3.61	4.78	0.79
16	3.96	5.33	0.79
17	3.96	5.84	0.79
19.0 to 50, incl.	3.96	6.35	0.79
Over 50	3.96	9.53	1.60
GENERAL NOTE: This Table contains examples only.			

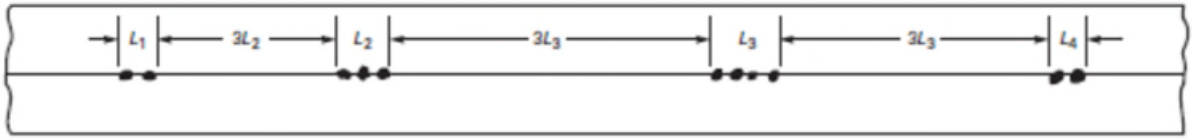
- (b) Relevant Indications. (See Table 4-1 for examples.)
  - Only those rounded indications which exceed the following dimensions shall be considered relevant.
  -
  - (1) 1/10t for t less than 1/8 in. (3mm)
  - (2) 1/64 in. for t from 1/8 in. to 1/4 in. (3mmto6mm), incl.
  - (3) 1/32 in. for t greater than 1/4 in. to2in.(6mm to 50mm),incl.
  - (4) 1/16 in. for t greater than2in.(50mm)
  -
- Maximum Size of Rounded Indication. (See Table 4-1 for examples.)
  - The maximum permissible size of any indication shall be 1/4t, or 5/32 in. (4mm), whichever is smaller; except that an isolated indication separated from anadjacentindicationby1in.(25mm) or more may be 1/3t, or 1/4 in.(6mm), whichever is less.
  - For t greater than2in.(50mm) the maximum permissible size of an isolated indication shall be increased to 3/8 in. (10 mm).

Figure 4-1
Aligned Rounded Indications



GENERAL NOTE: Sum of L_1 to L_x shall be less than t in a length of $12t$.

Figure 4-2
Groups of Aligned Rounded Indications



Maximum Group Length	Minimum Group Spacing
L = 1/4 in. (6 mm) for t less than 3/4 in. (19 mm) L = 1/3t for t 3/4 in. (19 mm) to 2 1/4 in. (57 mm) L = 3/4 in. (19 mm) for t greater than 2 1/4 in. (57 mm)	$3L$ where L is the length of the longest adjacent group being evaluated

GENERAL NOTE: Sum of the group lengths shall be less than t in a length of $12t$.

- Aligned Rounded Indications.
  - Aligned rounded indications are acceptable when the summation of the diameters of the indications is less than t in a length of 12t. See Figure 4-1.
  - The length of groups of aligned rounded indications and the spacing between the groups shall meet the requirements of Figure 4-2.

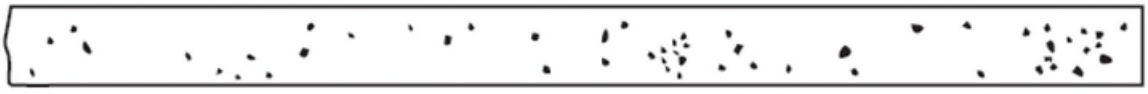
- Spacing.
  - The distance between adjacent rounded indications is not a factor in determining acceptance or rejection, except as required for isolated indications or groups of aligned indications.
  -

- Rounded Indication Charts.
  - The rounded indications characterized as imperfections shall not exceed that shown in the charts.
  - The charts in Figures4-3 through 4-8 illustrate various types of assorted, randomly dispersed and clustered rounded indications for different weld thicknesses greater than 1/8 in. (3mm).
  - These charts represent the maximum acceptable concentration limits for rounded indications.
  - The charts for each thickness range representfull-scale6in.(150mm) radiographs, and shall not be enlarged or reduced.
  - The distributions shown are not necessarily the patterns that may appear on the radiograph, but are typical of the concentration and size of indications permitted.
  -

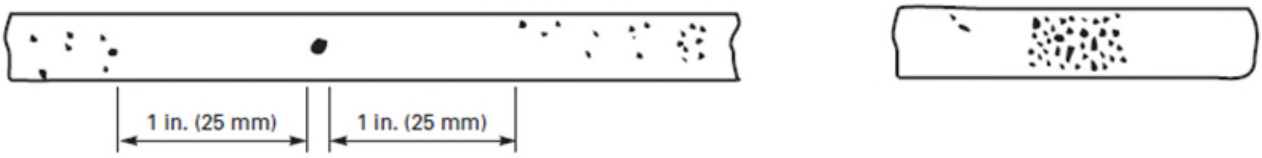
- Weld Thicknesst LessThan 1/8 in. (3mm).
  - For t less than 1/8 in. (3mm) the maximum number of rounded indications shall not exceed12in a 6in.(150mm) length of weld.
  - A proportionally fewer number of indications shallbepermittedinweldslessthan6in.(150mm)in length.
  -

- Clustered Indications.
  - The illustrations for clustered indications show up to four times as many indications in a loca larea, as that shown in the illustrations for random indications.
  - The length of an acceptable cluster shall not exceed thelesserof1in.(25mm)or2t .
  - Where more than one cluster is present, the sum of the lengths of the clusters shall not exceed1in.(25mm) in a 6in.(150mm) length weld.

Figure 4-3
Charts for *t* Equal to 1/8 in. to 1/4 in. (3 mm to 6 mm), Inclusive



(a) Random Rounded Indications [See Note (1)]

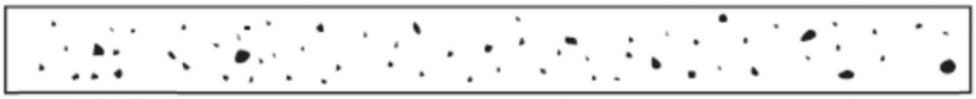


(b) Isolated Indication [See Note (2)]

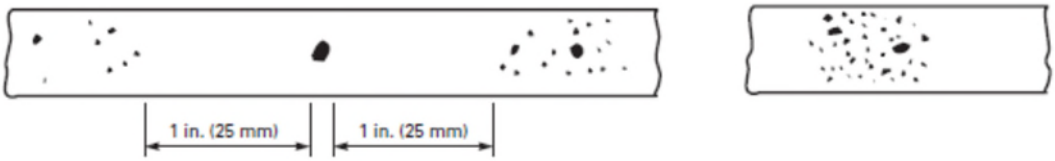
(c) Cluster

NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Maximum size per Table 4-1.

Figure 4-4
Charts for *t* Over 1/4 in. to 3/8 in. (6 mm to 10 mm), Inclusive



(a) Random Rounded Indications [See Note (1)]



(b) Isolated Indication [See Note (2)]

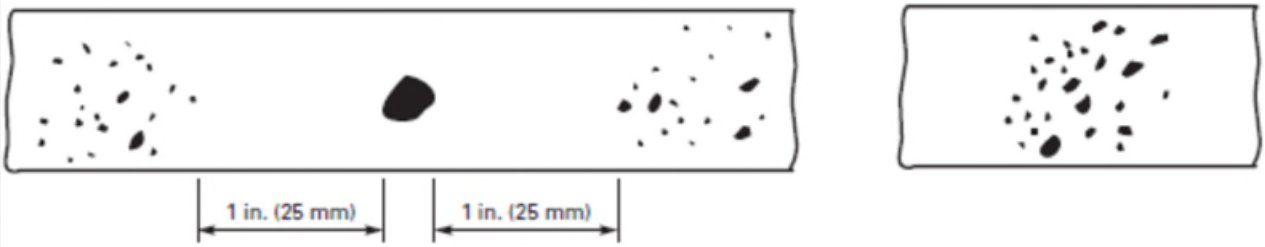
(c) Cluster

NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Maximum size per Table 4-1.

Figure 4-6
Charts for *t* Over 3/4 in. to 2 in. (19 mm to 50 mm), Inclusive



(a) Random Rounded Indications [See Note (1)]

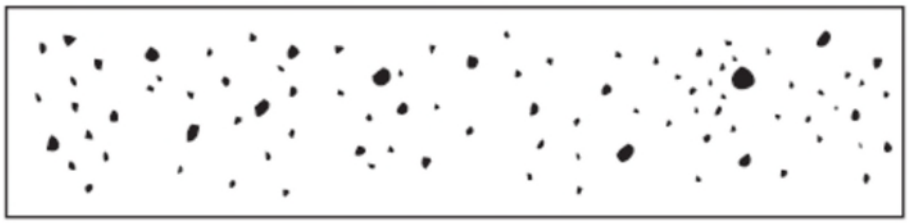


(b) Isolated Indication [See Note (2)]

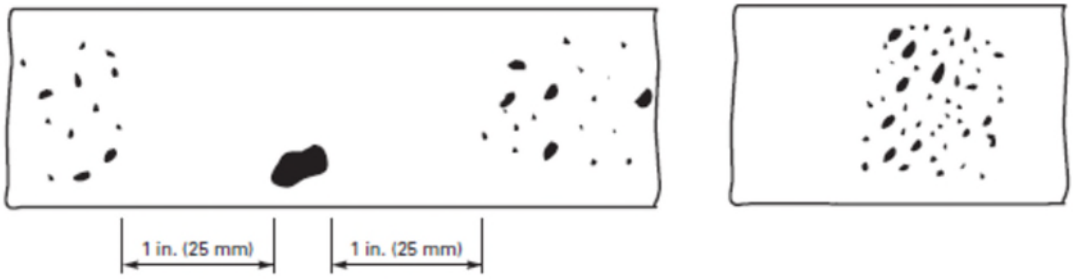
(c) Cluster

NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Maximum size per Table 4-1.

Figure 4-7
Charts for *t* Over 2 in. to 4 in. (50 mm to 100 mm), Inclusive



(a) Random Rounded Indications [See Note (1)]

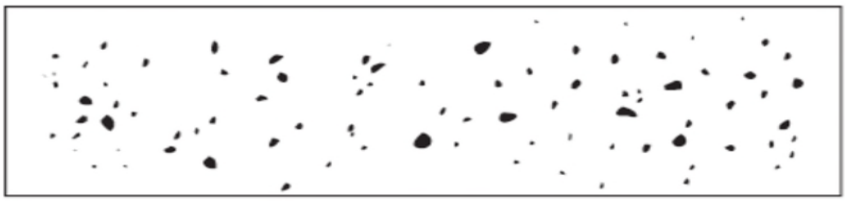


(b) Isolated Indication [See Note (2)]

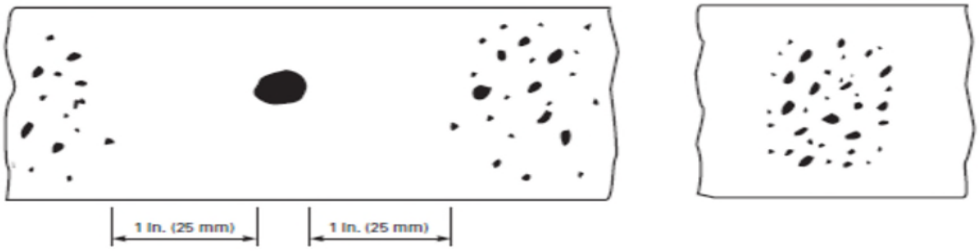
(c) Cluster

NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Maximum size per Table 4-1.

Figure 4-8
Charts for *t* Over 4 in. (100 mm)



(a) Random Rounded Indications [See Note (1)]



(b) Isolated Indication [See Note (2)]

(c) Cluster

NOTES:
(1) Typical concentration and size permitted in any 6 in. (150 mm) length of weld.
(2) Maximum size per Table 4-1.

17 WELD REPAIR

All unacceptable indications shall be removed. Where welding repair is required, the repair area, including 50 mm on either side, shall be re-examined for external defects prior to welding. Welding repairs (or replaced welds) shall be examined with the same methods prescribed for the original weld.

18 EXAMINATION REPORT

All NDT shall be documented, and all reports shall be generate by database (See attachment 7)

The documentation shall include as minimum the following information:

a) Job identification;
b) Item and weld number;
c) Radiographic testing procedure including acceptance criteria;
d) Isotope or XR identification Activity;
e) Isotope or max XR intensity Voltage used
f) Effective focal spot size;
g) Unsharpness geometry
h) Film brand and screen (thickness, dimension, material for the filter and film)
i) Number of exposures;
j) Base material type and thickness;
k) Exposure time and source to film distance;
l) Single or double wall exposure;
m) Single or double wall viewing.
n) Type and position of IQI;
o) required;
p) Film development: manual or automatic;
q) Test results, density
r) WPS identification

19 ATTACHMENT

Attachment 1 – Maximum permissible voltage

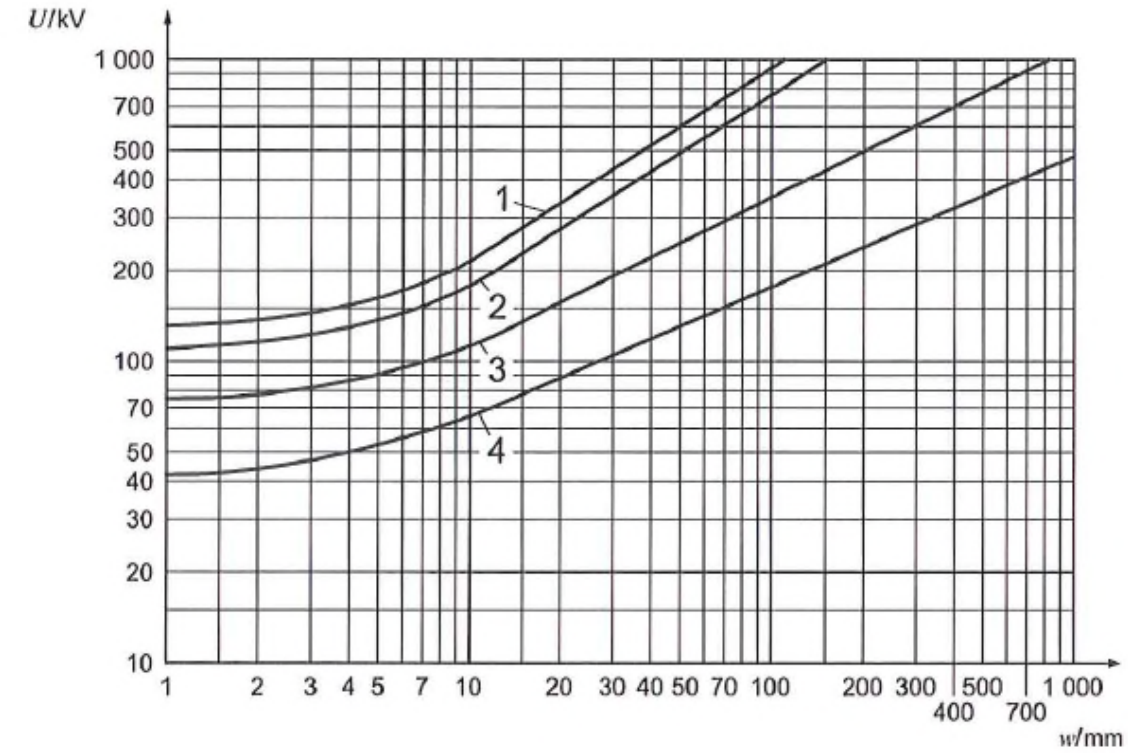
Attachment 2 – Radiographic techniques

Attachment 3 – Image quality indicators

Attachment 4 – Examination Report

ATTACHMENT 1 – MAXIMUM PERMISSIBLE VOLTAGE

Maximum X-ray voltage for X-ray devices up to 1 000 kV as a function of penetrated thickness and material.



Key

U	X-ray voltage	1	copper and nickel and alloys
w	penetrated thickness	2	steel
		3	titanium and alloys
		4	aluminium and alloys

ATTACHMENT 2 – RADIOGRAPHIC TECHNIQUES

Figure A-210-2
Double-Wall Radiographic Techniques

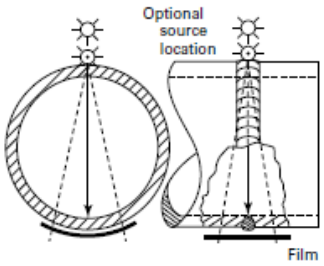
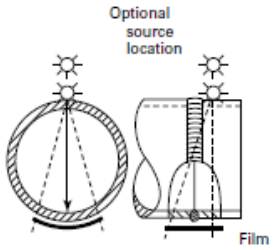
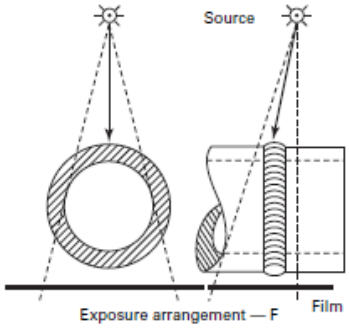
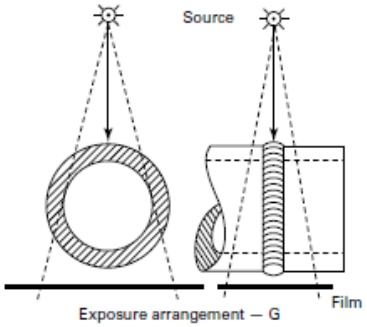
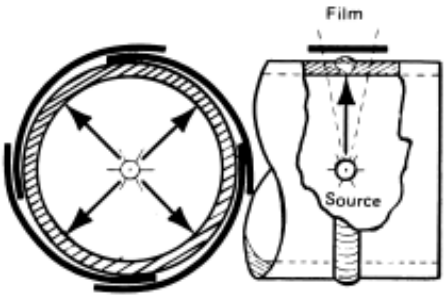
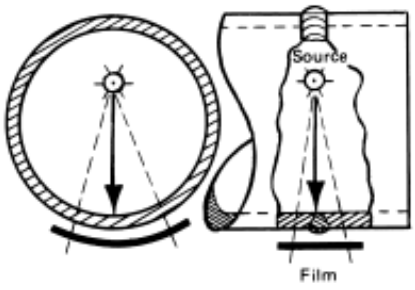
O.D.	Exposure Technique	Radiograph Viewing	Source-Weld-Film Arrangement		IQI		Location Marker Placement
			End View	Side View	Selection	Placement	
Any	Double- Wall: T-271.2(a) at Least 3 Exposures 120 deg to Each Other for Complete Coverage	Single-Wall	 Exposure arrangement — D		T-276 and Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Film Side T-275.1(b) (1)
Any	Double- Wall: T-271.2(a) at least 3 Exposures 120 deg to Each Other for Complete Coverage	Single-Wall	 Exposure arrangement — E		T-276 and Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Film Side T-275.1(b) (1)
$3^1/_2$ in. (88 mm) or Less	Double-Wall T-271.2(b)(1) at Least 2 Exposures at 90 deg to Each Other for Complete Coverage	Double-Wall (Ellipse): Read Offset Source Side and Film Side Images	 Exposure arrangement — F		T-276 and Table T-276	Source Side T-277.1(a)	Either Side T-275.2
$3^1/_2$ in. (88 mm) or Less	Double-Wall: T-271.2(b)(2) at Least 3 Exposures at 60 deg or 120 deg to Each Other for Complete Coverage	Double-Wall: Read Super-imposed Source Side and Film Side Images	 Exposure arrangement — G		T-276 and Table T-276	Source Side T-277.1(a)	Either Side T-275.2

Figure A-210-1
Single-Wall Radiographic Techniques

Pipe O.D.	Exposure Technique	Radio-graph Viewing	Source-Weld-Film Arrangement		IQI		Location Marker Place-ment
			End View	Side View	Selection	Place-ment	
Any	Single-Wall T-271.1	Single-Wall	 Exposure Arrangement — A		T-276 and Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Either Side T-275.3 T-275.1(c)
Any	Single-Wall T-271.1	Single-Wall	 Exposure Arrangement — B		T-276 and Table T-276	Source Side T-277.1(a) Film Side T-277.1(b)	Film Side T-275.1 (b)(1)

ATTACHMENT 3 – IQI SELECTION

Table 1: Wire numbers, diameters and limit deviations (Dimensions in millimetres)

Image Quality Indicator Including				Wire		
W1	W6	W10	W13	Wire Number	Nominal wire	Tolerances
x				W1	3,20	±0,03
x				W2	2,50	
x				W3	2,00	
x				W4	1,60	±0,02
x				W5	1,25	
x	x			W6	1,00	
x	x			W7	0,80	
	x			W8	0,63	
	x			W9	0,50	±0,01
	x	x		W10	0,40	
	x	x		W11	0,32	
	x	x		W12	0,25	
		x	x	W13	0,20	
		x	x	W14	0,16	
		x	x	W15	0,12	±0,005
		x	x	W16	0,10	
			x	W17	0,08	
			x	W18	0,06	
			x	W19	0,05	

Table 2 — Types of IQI and wire materials used for selected groups of materials

Image quality indicator	Wire number	Wire material	Suitable for test- the following materials
W 1 CU W 6 CU W 10 CU W 13 CU	W 1 to W 7 W 6 to W 12 W 10 to W 16	Copper	Copper, zinc, tin and their alloys
W 1 FE W 6 FE W 10 FE W 13 FE	W 1 to W 7 W 6 to W 12 W 10 to W 16	Steel (low alloyed)	Ferrous materials
W 1 TI W 6 TI W 10 TI W 13 TI	W 1 to W 7 W 6 to W 12 W 10 to W 16	Titanium	Titanium and their alloys
W 1 AL W 6 AL W 10 AL W 13 AL	W 1 to W 7 W 6 to W 12 W 10 to W 16	Aluminium	Aluminium and their alloys

COMPARISON TABLE BETWEEN IQI ISO and ASTM

Standard Image Quality Indicators - Wire Type

	ISO 19232--1					ASTM E747				
Nominal Diameter	Wire Number	1 - 7	6 - 12	10 - 16	13 - 19	Wire Number	SET D	SET C	SET B	SET A
8,00						21	8,00			
6,40						20	6,40			
5,10						19	5,10			
4,10						18	4,06			
3,20	1	3,20				17	3,20			
2,50	2	2,50				16	2,50	2,50		
2,00	3	2,00				15		2,03		
1,60	4	1,60				14		1,60		
1,25	5	1,25				13		1,27		
1,00	6	1,00	1,00			12		1,02		
0,80	7	0,80	0,80			11		0,81	0,81	
0,63	8		0,63			10			0,64	
0,50	9		0,50			9			0,51	
0,40	10		0,40	0,400		8			0,40	
0,32	11		0,32	0,320		7			0,33	
0,25	12		0,25	0,250		6			0,25	0,25
0,20	13			0,200	0,200	5				0,20
0,16	14			0,160	0,160	4				0,16
0,125	15			0,125	0,125	3				0,13
0,100	16			0,100	0,100	2				0,10
0,080	17				0,080	1				0,08
0,063	18				0,063					
0,050	19				0,050					

ATTACHMENT 4 – EXAMINATION REPORT

ROSETTI MARINO

NDT ACTIVITIES - TEST REPORT

RAPPORTO DI ESAME RADIOGRAFICO
RADIOGRAPHIC TEST REPORT

DATA RAPPORTO Report Date

FOGLIO / sheet n° 1 of 1

COMMESSA Job	PROGETTO Project	CLIENTE Client	NUMERO ORDINE Order number	DISCIPLINA Discipline

WPS	TECNICA SALD. Welding Process	CODICE SPECIFICA Standard Code	CODICE PROCEDURA Procedure code	ISTRUZ. DI LAVORO RT RT Work Instruction
			Rev.	Rev.

CRITERIO DI ACCETTABILITA Acceptance criteria	INSPECTION TEST PLAN ITP	FASE ITP ITP Phase
	Rev.	

FASE DEL CONTROLLO Examination Phase	MATERIALE Material	TRATTAMENTO TERMICO Post Weld Heat Treatment
		☐ PRIMA del TT Before PWHT ☐ DOPO TT After PWHT ☐ NON APPLICAB. Not Applicable

RADIOGRAPHIC TECHNIQUE DETAILS

Sorgente / Source	I.Q.I. Tipo / I.Q.I. Type	I.Q.I. Sensibilità richiesta / I.Q.I. Required Sensitivity	I.Q.I. Posizione / I.Q.I. Location

Unità / Unit	Tipo Film + Marca / Film type + Brand	Pellicole per cassetta (Nr) Films box	Schermi di rinforzo (mm) Intensifying screens Front-Back	Sviluppo / Development

Energia+Corrente / Energy+Current Attività /Activity	Nr. Films / Films Nr.	Tecnica radiografica Radiographic techniques	Densità film / Film density	Penombra Ug (mm) Unsharpness geom. Ug	Data esposizione Exposure date

Macchia Focale (mm) Focal Spot	Distanza sorgente-oggetto (mm) Distance Source-Object	Distanza lato sorgente oggetto-pellicola (mm) Distance from Source side object to film	Distanza focal (mm) Focal distance	Tempo di esposiz. Exposure time	No. di esposizioni Nr. of exposures

OGGETTO CONTROLLATO / Tested object

COMPONENTE / Item

RAPP. Report	SALD Weld	DISEGNO Drawing	Fg Sh	MARCA Mark	CIANF. Bevel	DIMENSIONE Dimension	Sp. Thk (mm)	POS. Film pos.	INDICAZIONI Indications	ESITO Result	SALDATORI Welders

NOTE / Remarks

TECNICO CND Livello 2 NDT Technician Level 2	CONTROLLO QUALITA' QC Supervisor	ISPETTORE CONTRATTISTA Contractor Repr.	ISPETTORE CLIENTE Company Repr.	ISPETTORE TERZA PARTE Third Party Inspector
Company: Operator:				