PETROBRAS	TECHNICAL SPECIFICATION	No.	I-ET-3010.00-1200-970-P4X-004
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SRGE	TITLE: NON-DESTRUCTIVE TESTING REQUIREMENTS FOR METALLIC AND NON-METALLIC MATERIALS		ESUP
			INTERNAL

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SUMMARY

1 SCOPE

This technical specification sets requirements for all Non-Destructive Testing (NDT) to be performed on all phases from fabrication, construction, erection and assembly of the Unit.

It applies to TOPSIDE and HULL parts.

The requirements herein listed are applicable to all players performing such related activities within the scope of this Unit, including manufacturers, packagers, main contractor, subcontractors, suppliers, sub suppliers, integrators, constructors, and all technical personnel involved. Within the scope of this document, they are all referred to as being a SELLER.

2 NORMATIVE REFERENCES

The requirements of the following normative references shall be fulfilled, as well as the additional requirements herein listed.

2.1 CLASSIFICATION

SELLER shall perform the work in accordance with the requirements of Classification Society.

2.2 CODES AND STANDARDS

The following codes and standards contain provisions which, through reference in this text, constitute requirements for this specification. The latest issue of the references shall be used. Other recognized standards may be used, provided it can be shown that they meet or exceed the requirements of the standards referenced below.

The following referenced documents are indispensable for the application of this document. For undated references, the latest edition of the referenced document applies:

- API RP 578 - Guidelines for a Material Verification Program (MVP) for New and Existing Assets
- ASTM A1038 - Standard Test Method for Portable Hardness Testing by the Ultrasonic Contact Impedance Method
- ASTM D2583 - Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor
- ASTM E92 - Standard Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials
- ASTM E94 - Standard Guide for Radiographic Examination
- ASTM E140 - Standard Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness
- ASTM E165 - Standard Test Method for Liquid Penetrant Examination
- ASTM E384 - Standard Test Method for Microindentation Hardness of Materials

- ASTM E562 - Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count
- ASTM E709 - Standard Guide For Magnetic Particle Examination
- ASTM E747 - Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology
- ASTM E1032 - Standard Test Method for Radiographic Examination of Weldments
- ASTM E1936-20 - Standard Reference Radiograph for Evaluating the Performance of Radiographic Digitization Systems
- ASTM E2445 - Standard Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems
- ASTM E2446 - Standard Practice for Manufacturing Characterization of Computed Radiography Systems
- ASTM E2597 - Standard Practice for Manufacturing Characterization of Digital Detector Arrays
- ASTM E2736 - Standard Guide for Digital Detector Array Radiology
- ASTM E2737 - Standard Practice for Digital Detector Array Performance Evaluation and Long-Term Stability
- ASME Boiler and Pressure Vessel Code – Section V – Nondestructive Examination
- ASME B31.3 - Process Piping
- AWS A4.2 -Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal
- AWS D1.1 – Structural Welding Code – Steel
- International vocabulary of metrology – Basic and general concepts and associated terms (VIM)
- ISO 3452-1 – Non-destructive testing – Penetrant testing – Part 1: General principles
- ISO 3452-2 – Non-destructive testing – Penetrant testing – Part 2: Testing of penetrant materials;
- ISO 3452-3 – Non-destructive testing – Penetrant testing – Part 3: Reference test blocks
- ISO 6507-1 - Metallic materials — Vickers hardness test — Part 1: Test method
- ISO 8249 - Welding – Determination of Ferrite Number (FN) in Austenitic and Duplex Ferritic-Austenitic Cr-Ni Stainless Steel Weld Metals
- ISO 9712 – Non-destructive Testing - Qualification and Certification of NDT Personnel
- ISO 10012 – Measurement management systems — Requirements for measurement processes and measuring equipment

- ISO 14096-1 - Non-destructive testing — Qualification of radiographic film digitisation systems - Part 1: Definitions, quantitative measurements of image quality parameters, standard reference film and qualitative control
- ISO 14096-2 - Non-destructive testing — Qualification of radiographic film digitisation systems - Part 2: Minimum requirements
- ISO 14692-4- Petroleum and natural gas industries — Glass-reinforced plastics (GRP) piping — Part 4: Fabrication, installation and operation
- ISO 16371-1 – Non-destructive testing — Industrial computed radiography with storage phosphor imaging plates — Part 1: Classification of systems
- ISO 16371-2 – Non-destructive testing — Industrial computed radiography with storage phosphor imaging plates — Part 2: General principles for testing of metallic materials using X-rays and gamma rays
- ISO 17636-2 – Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors
- ISO 19232-1 – Non-destructive testing — Image quality of radiographs — Part 1: Determination of the image quality value using wire-type image quality indicators
- ISO 19232-5 – Non-destructive testing — Image quality of radiographs — Part 5: Determination of the image unsharpness and basic spatial resolution value using duplex wire type image quality indicators
- ISO 22825 - Non-destructive testing of welds — Ultrasonic testing — Testing of welds in austenitic steels and nickel-based alloys

Governmental codes, laws, regulations, ordinances or rules applicable to the equipment in Brazil shall prevail over the requirements of above specification, including reference codes and standards and/or this Technical Specification, only in those cases where they are more stringent.

2.3 REFERENCE TECHNICAL SPECIFICATIONS

The following technical specifications are complimentary to this document and shall be considered for the NDT process.

- I-ET-3010.00-1200-955-P4X-001 – WELDING
- I-ET-3010.00-1200-970-P4X-003 – REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION
- I-ET-3010.00-1200-940-P4X-002 – GENERAL TECHNICAL TERMS
- I-ET-3010.00-1200-200-P4X-115 REQUIREMENTS FOR PIPING FABRICATION ASSEMBLY AND COMMISSIONING

2.4 CONFLICTING REQUIREMENTS

In case of conflicting information between this Technical Specification and the referred applicable standards, the most stringent requirement shall prevail.

In case of conflicting information between this Specification and other specific BUYER's document, a formal technical query shall be issued to BUYER seeking clarification.

Failure to observe this requirement may result in remedial work at SELLER expenses.

3 DEFINITIONS AND ABBREVIATIONS

3.1 DEFINITIONS

Definitions are in accordance with the technical specification I-ET-3010.00-1200-940-P4X-002 - GENERAL TECHNICAL TERMS.

3.2 ABBREVIATIONS

CNEN	Comissão Nacional de Energia Nuclear (Brazilian National Nuclear Energy Comission)
CS	Classification Society
DAC	Distance–Amplitude Correction
DC	Dimensional Control
DDA	Digital Detector Array
EDM	Electrical Discharge Machining
FT	Ferrite Testing
FRP	Fiber Reinforced Plastic
FSH	Full Screen Height
FMC	Full Matrix Capture
GRP	Glass Reinforced Plastic
HT	Hardness Testing
IQI	Image Quality Indicator
MT	Magnetic Particle Testing
NDT	Non-Destructive Testing
PAUT	Phased Array Ultrasonic Testing
PMI	Positive Material Identification
PT	Liquid Penetrant Testing (also known as dye penetrant examination)

RT	Radiographic Testing
$SR_{b,image}$	Image Basic Spatial Resolution
SNR_N	Normalized Signal to Noise Ratio
TCG	Time-Controlled Gain or Time-Corrected Gain
TFM	Total Focusing Method
TMCP	Thermo-Mechanical Control Process
ToFD	Time of Flight Diffraction
UT	Ultrasonic Testing
VT	Visual Testing

NOTE: the terms “testing” and “examination” are applied interchangeably when it comes to the inspection methods of welds.

4 GENERAL REQUIREMENTS

4.1 NDT EXTEND

The extend of NDT to be applied on materials, components and welds is defined elsewhere.

I-ET-3010.00-1200-200-P4X-115 REQUIREMENTS FOR PIPING FABRICATION ASSEMBLY AND COMMISSIONING for example contains the NDT extend applied to piping.

Similar requirements are found on the specific contractual technical requirements for pressure vessels, heat exchangers, tanks, compressors, pumps, structures and for package Units.

4.2 NDT PROCEDURES AND REPORTS

SELLER shall issue a written procedure and qualify the following procedures in accordance with applicable standard, design code and requirements established in this technical specification before beginning of activities:

- Visual Testing (VT)
- Dimensional Control (DC);
- Penetrant Testing (PT)
- Magnetic Particles Testing (MP)
- Radiographic Testing (RT)
- Ultrasonic Testing (UT)
- Eddy Current Testing (ET)
- Positive Material Identification Testing (PMI)

- Hardness Testing
- Ferrite Testing
- Leak (Tightness) Testing

The following NDT procedures shall be qualified by a certified inspector level 3:

- Visual Testing (VT)
- Penetrant Testing (PT)
- Magnetic Particles Testing (MP)
- Radiographic Testing (RT)
- Ultrasonic Testing (UT)
- Eddy Current Testing (ET)

VT procedure may be, alternatively, qualified by a Welding Inspector Level 2.

The following NDT procedures shall be qualified and approved by a professional with appropriate competence:

- Hardness Testing
- Positive Material Identification
- Ferrite Testing
- Dimensional Control
- Leak (Tightness) Testing

Respective reports shall comply with design code, applicable standard and this technical specification. NDT reports shall contain full traceability to the part inspected.

4.3 NDT PERSONNEL QUALIFICATION AND CERTIFICATION

Non-destructive testing shall be performed by qualified and/or certified professional according to I-ET-3010.00-1200-970-P4X-003 REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION.

4.4 NDT SUPERVISION

Execution of NDT shall be supervised by a certified inspector level 3, according to I-ET-3010.00-1200-970-P4X-003 REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION.

4.5 NDT STANDARDS: MODIFICATIONS, ADDITIONS AND DELETIONS TO SPECIFIED STANDARDS

Non-destructive testing shall be performed as specified in the applicable standard or design code to each equipment, considering the modifications, additions and deletions established in section 5 of this technical specification.

4.6 METROLOGY

The SELLER shall have a Calibration Plan, which provide the list of instruments and calibration and maintenance requirements, such as periodicity, resolution, study of error, calibration certificate, conditions of handling and storage.

The periodicity of calibration must be in accordance with the applicable standards, if any, and Quality System, considering the recommendation of instrument manufacturer. The SELLER shall consider that the periodicity of the long-term stability assessment depends on the frequency of use of the systems and their conditions of use.

NOTE: it's recommended to follow ISO 10012 to manage the measurement system.

The Quality System shall fulfill contractual requirements regarding monitoring and measurement features, especially, but not limited to, the following:

- The SELLER shall evaluate and ensure that the measurement uncertainty of the calibration standards used in its process and the Sub-supplier meets the design requirements.
- All monitoring, control and recording systems (software and hardware, transducers, sensors, registers etc.) shall be calibrated and certified at specified intervals or before use.
- International vocabulary of metrology – Basic and general concepts and associated terms (VIM) is applicable.

4.7 SURFACE PREPARATION

For austenitic stainless steels, nickel alloys and aluminum alloys, the surface preparation tools of those materials shall be used only for the same materials and shall comply with the following requirements:

a) made of stainless steel or covered with that material for austenitic stainless steels and nickel alloys

b) cutting and grinding disks shall have a nylon or similar core

4.8 ACCEPTANCE CRITERIA

Acceptance criteria shall be as established in the design standard applicable to each equipment, structure or piping system being examined, as well complementary technical specification. NDT procedures shall include the acceptance criteria in accordance with its scope.

5 REQUIREMENTS FOR METALLIC MATERIAIS

All the requirements herein listed are linked to a main NDT standard and shall be interpreted as additions or modifications to it.

5.1 VISUAL TESTING

Visual testing procedure shall be issued in accordance with design code, technical specification and specific standard applicable to its purpose. Methodology, apparatus and acceptance criteria shall be prescribed in the procedure. VT report shall be issued, as well.

When Borescope inspection is required, the equipment shall attend, at least, the following requirements:

a) water proof equipment

b) minimum length of cable 5 meters or compatible with object to be inspected

c) minimum resolution of camera 640x480 pixel

d) internet connection in order to provide remote witnessing

e) minimum 4 hours autonomy for video recording

f) high definition screen and minimum 7" size

g) light source of LED or optical fiber shall provide minimum intensity 1000 lux

h) videoscope shall be articulated minimum 120º

i) measurements through stereoscopy

5.2 LIQUID PENETRANT TESTING

5.2.1 PENETRATION (DWELL) TIME

(ASME Section V, Article 6: Add to T-672; ASTM E165: Add to item 8.5.2)

For temperature ranging from 10 °C to 52 °C, the minimum penetration time indicated by the manufacturer shall be adopted, but it shall in all cases be longer than 10 minutes and shorter than 60 minutes.

For temperatures from 5 °C to 10 °C minimum penetrant dwell time shall be 2 times the value indicated above.

For temperatures above 52 °C, the penetration time is also an essential variable which shall be described in the qualified procedure.

5.2.2 PROCEDURE QUALIFICATION AND PERFORMANCE DEMONSTRATION

(ASME Section V, Article 6: Add to T-621.1; ASTM E165: Add to item 10.2)

Procedure Qualification and Performance Demonstration are always required, even for standard temperatures. The sensitivity test shall be performed using a liquid penetrant reference test block in accordance with ISO 3452-3. The minimum sensitivity level shall be:

For ASTM E165 Type I Penetrant Materials — Fluorescent Penetrant Examination: Detection of 100% of indications of the 10 µm comparator block;

For ASTM E165 Type II Penetrant Materials — Visible Penetrant Examination: Detection of 100% of indications of the 30 µm comparator block.

To qualify the procedure and performance demonstration, the proposed procedure shall be applied to liquid penetrant comparator block according to ASME V – Article.6 – Appendix III requirements.

5.2.3 RECEIVING INSPECTION

In the receiving inspection of liquid penetrant materials, it is required to perform sensitivity test, according to ISO 3452-3, at a temperature within the range qualified in the procedure to check if the test sensitivity, as defined in the procedure, is being maintained. This sensitivity test shall be performed as stated above in accordance with the parameters described in the procedure.

5.2.4 PENETRANT MATERIALS

(ASME Section V, Article 6: Add to T-630; ASTM E165: Add to item 7.1)

Only Penetrant materials that fulfill the requirements of ISO 3452-1, ISO 3452-2 or ISO 3452-3 shall be used.

5.3 MAGNETIC PARTICLE TESTING

5.3.1 WRITTEN PROCEDURES REQUIREMENTS

(ASME Section V, Article 7: Add to T-721.1)

Magnetic particle examination shall be performed in accordance with a written procedure, which shall, as a minimum, contain the requirements listed in Table T-721, and sketches indicating yoke pole positioning and overlapping.

(ASTM E709: Add to item 21.1)

Magnetic particle examination shall be performed in accordance with a written procedure, which shall, as a minimum, contain the requirements listed in item 21.1, and sketches indicating yoke pole positioning and overlapping.

5.3.2 MAGNETIZING PROCEDURE

(ASME Section V, Article 7: Modify T-755; ASTM E709: Modify items 6.3 and 12.3.3.4)

For YOKE technique, only alternating current electromagnetic yokes shall be used. The use of direct current electromagnetic yokes, and of permanent magnet yokes, is not permitted.

For YOKE technique, piping, branch and nozzle inspection the scope shall be limited to nominal diameter of 4" and higher. Nominal smaller diameters may be examined by YOKE provided that the procedure qualification is demonstrated and evaluated for BUYER.

5.3.3 MAGNETIC FIELD ADEQUACY AND DIRECTION

(ASME Section V, Article 7: ModifyT-764; ASTM E709: Modify item 14.2)

The use of the Pie-Shaped Magnetic Particle Field Indicator is not permitted to verify the adequacy of the magnetic field strength.

The magnetic field strength shall be evaluated by artificial flaw shims type indicators.

5.3.4 WET PARTICLE CONCENTRATION AND CONTAMINATION

(ASME Section V, Article 7: Add to T-765)

All particle suspensions shall have their bath concentration and bath contamination determined by measuring its settling volume in accordance with T-765, as stated for Wet Horizontal Units.

(ASTM E709: Add to item 20.6)

All particle suspensions shall have their bath concentration and bath contamination determined by measuring its settling volume in accordance with item 20.6, as stated for Wet Horizontal Units.

5.3.5 COATING THICKNESS MEASUREMENT

(ASME Section V, Article 7: Add to T-741; ASTM E709: Add to 9.1.1)

The maximum paint/coating film thickness permitted is 25 µm (25 micra).

5.4 RADIOGRAPHIC TESTING

5.4.1 WRITTEN PROCEDURE

(ASME Section V, Article 2: Replace T-221.1; ASTM E1032: Add to item 7.1; AWS D1.1: Add to item 8.17)

Radiographic examination shall be performed in accordance with a written procedure. Each procedure shall include at least the following information, as applicable:

a) objective

b) reference standards

c) material (e.g., carbon steel material and manufacturing process)

d) type of source or X-ray tube, mentioning radioactive isotope or maximum voltage, power

e) maximum dimensions of source or X-ray tube focal spot size

f) film brand and type

g) intensifying screens or filters for protection against scattered radiation, mentioning type, quantity, dimensions and thickness

h) condition required for surfaces to be tested and preparation methods

i) exposure arrangement

j) description of location marking method

k) density range

l) image quality indicators (IQI):
- type
- material
- location
- shims

m) execution tables

n) radiographic identification drawing and systems

o) radiographic lab data

p) film processing

q) supplementary requirements, including:
- cassette arrangement
- summarized testing sequence
- supplementary information

r) radiological protection

s) safety and environmental requirements

t) systematic procedure for recording results

u) report form

NOTE: Subparagraphs c), d), e), f) and g) mentioned above are found in ASME Section V.

The name of the issuer (responsible company), the number and the revision of the procedure shall be included therein.

5.4.2 SYSTEM OF IDENTIFICATION

(ASME Section V, Article 2: Change and add to T-224 as stated below; ASTM E1032: Add to item 8.12; AWS D1.1: Add to item 8.17.12)

A system shall be used to produce permanent identification on the radiograph traceable to the contract, component, weld or weld seam, or part numbers, as appropriate. In addition, the

Manufacturer's symbol or name and the date of the radiograph shall be plainly and permanently included on the radiograph. It is required that the information provided by this identification system appear necessarily in radiographic images and obtained simultaneously with the X or gamma ray shot. In any case, this information shall not obscure the area of interest.

At least the following information shall appear on the radiographic image:

a) number of equipment, piping or part

b) joint number

c) thickness

d) material or optionally, in the case of piping, its class

e) film identification number

f) date service was performed

g) identification of level 1 professional

h) the following inscriptions, as the case may be:
- NR - radiograph of partially repaired weld
- NE - radiograph of weld after grinding
- NT - radiograph of fully redone weld
- NX - repetition of radiograph due to error in performance
- RX - repetition of radiograph for confirmation of defect
- AM - radiograph taken to increase number of samples due to defects in the previous radiograph
- EX - radiograph taken to delimit the defect

5.4.3 FILM SELECTION

(ASME Section V, Article 2: Add to T-231.1; ASTM E1032: Add to item 7.2)

The length of the film undergoing radiographic testing on a sampling basis shall not be less than 152 mm.

The nominal overlap for fully radiographed circumferential joints shall never be less than 30 mm.

5.4.4 INTENSIFYING SCREENS

(ASME Section V, Article 2: Add to T-232; ASTM E1032: Add to item 6.3; AWS D1.1: Add to item 8.17.4)

Intensifying screens shall have an identification system allowing their traceability, positioned outside the area of interest.

5.4.5 RADIOGRAPHIC TECHNIQUE DOCUMENTATION DETAILS

(ASTM E1032: Add to item 11; AWS D1.1: Add to item 8.18.2)

The Manufacturer shall prepare and document the radiographic technique details. As a minimum, the following information shall be provided:

a) Identification

b) the dimensional map (if used) of marker placement

c) number of radiographs (exposures)

d) X-ray voltage or isotope type used

e) source size

f) base material type and thickness, weld thickness, weld reinforcement thickness, as applicable

g) source-to-object distance

h) source-film distance

i) distance from source side of object to film

j) film manufacturer and Manufacturer's type/designation

k) number of film in each film holder/cassette

l) single- or double-wall exposure

m) single- or double-wall image

5.4.6 ARTICLE 2- MANDATORY APPENDICES

(ASME Section V: Change as follow)

The following appendices shall not be used:

Appendix I — In-Motion Radiography

Appendix II — Real-Time Radioscopic Examination

Appendix III — Digital Image Acquisition, Display, and Storage for Radiography and Radioscopy

Appendix IV — Interpretation, Evaluation, and Disposition of Radiographic and Radioscopic Examination Test Results Produced by the Digital Image Acquisition and Display Process

Appendix VI — Acquisition, Display, Interpretation, and Storage of Digital Images of Radiographic Film for Nuclear Applications

Appendix VIII — Radiography Using Phosphor Imaging Plate

Appendix IX — Radiography Using Digital Detector Systems

5.5 DIGITIZATION OF INDUSTRIAL RADIOGRAPHIC FILMS

The digitization of industrial radiographic films is mandatory for all radiographic examinations of welds performed in piping fabrication and manufacturing (e.g., pipe shop or field welding) and any pressure retaining welds performed on site.

The film digitization is not required for raw material fabrication (e.g., welded pipe and fitting), equipment manufacturing (e.g., pressure vessel, heat exchanger, valves, rotating equipment) and structural welding (e.g., hull and modules structures).

This requirement is applicable to all work being performed by SELLER, as well as for all subcontractors and sub suppliers. The file name extension of the digital image shall be use DICONDE (Digital Imaging and Communication in Non-Destructive Evaluation) or TIFF format. The digital copies of the radiographic examinations shall be handed to BUYER in portable media, type solid state drive, encompassing RT examination performed in the period every 60 days or whenever requested by the BUYER.

5.5.1 WRITTEN PROCEDURES REQUIREMENTS

The radiographic film digitization shall be performed according to a written procedure, which shall include, at least, the requirements listed in Table 1. The film digitization process shall be performed as described in ISO 14096 (parts 1 and 2). The image quality shall attend the Class DS or DB, according to ISO 14096-2.

5.5.2 QUALIFICATION OF FILM DIGITIZATION PROCEDURE

The procedures shall be qualified by a certified Digital Radiographic Testing inspector or RT inspector level 3. The procedure is considered qualified if it complies with the following:

a) the digitized image of the standard reference film reaches the minimum values described below:
   i) The minimum spatial resolution required and the scanner pixel size as a function of the radiation energy used to obtain the radiograph are presented in Table 1 of ISO 14096-2. Although the parallel line pair target can be used for this purpose, the spatial resolution shall be measured using the converging line pairs targets due to their greater versatility and ease of reading on the standard reference film.
   ii) The contrast sensitivity obtained in the digitized image shall meet the requirements of ISO 14096 (parts 1 and 2), if the concentric blocks of the contrast sensitivity targets can be sharply distinguished, as well as each step of the stepped density targets.
   iii) The maximum permissible spatial linearity deviation for a digitized radiographic image is 3%, measured in relation to the dimensions of the spatial linearity target.
   iv) The minimum density range of the radiographic digitization system shall be from the values of 0.5 H&D to 4.0 H&D, that is, the system shall be able to recognize all the steps of the stepped density targets.

v) For checking the digitized radiographic film quality, only image magnification (zoom) and contrast enrichment operations are applicable. The use of filters or any other processing features is not allowed

b) A minimum of 5 radiographic films from welding inspection shall be used for qualification. All digitized images shall present the image quality indicators (IQI) perfectly established, as observed in the original radiograph.

c) The radiographic density used in the procedure qualification shall be of the range specified in the radiographic procedure used, being mandatory a radiographic film with minimum density and another with predicted maximum density.

Table 1 - Variables of the Written Procedure

Requirements	Essential variable	Non essential variable
Issuer name, numbering and revision indication		X
Purpose		X
Reference Standards for procedure elaboration and qualification	X	
Type of radiation source (specifying radioactive isotope or maximum tension of the X-ray equipment)		X
Digitalization of industrial radiographic films system		
1- Manufacturer and model of scanner, specifying:		
a) size of scanner pixel (in µm)	X	
b) focal spot size of scanner (in µm)	X	
c) dynamic range		X
d) spatial resolution (in lp/mm)	X	
e) density range	X	
f) dynamic range of the digitalization system	X	
g) sensitivity to contrast in terms of optical density	X	
h) spatial linearity	X	
i) maximum film size for digitalization		X
2 - Manufacturer and model of monitor, specifying:		
a) monitor characteristics: luminance, luminance rate, resolution, pixel size and dynamic range	X (see NOTE)	
b) physical size and viewable area of monitor		X
3 - Image visualization software		
a) imaging processing system used	X	
b) imaging processing system version		X
Sequence of imaging processing steps:		
a) contrast enrichment operations		X
b) magnification (zoom)		X
Storage:		
a) image identification		X
b) file format		X
c) media (including data loss protection)		X
Reference film serial number		X
Reference film certification date and expiration date		X
Scanner stability inspection periodicity		X
Digitalized radiographic film identification system		X

NOTE: Replacing the monitor with another having the same luminance, luminance rate, resolution, pixel size and dynamic range characteristics do not constitute an essential variable.

5.6 DIGITAL RADIOGRAFIC EXAMINATION

5.6.1 GENERAL REQUIREMENTS

Digital Radiography in lieu of conventional radiography techniques may only be used upon formal approval from BUYER.

5.6.2 RADIOGRAPHIC TESTING X AND GAMMA-RAY TECHNIQUES WITH DIGITAL DETECTORS

Digital Radiographic Examination shall comply with requirements of ISO 17636-2, complemented by this technical specification, according to Appendix I for inspection of welded joints in metallic materials by computed radiography (CR) or radiography with digital detector arrays (DDA).

5.6.3 SOFTWARE AND TRAINING REQUIREMENTS

BUYER shall receive from the Contracted Party, without any burden, at least one media of the installation program, original, in updated and compatible version with the platform of the operating systems used by BUYER with the respective licenses and activation keys of the radiographic image treatment and visualization, along with the manuals for the program usage.

Digital radiographies shall be identified through an exclusive code, but generated by the user, allowing traceability with the corresponding equipment or piping. It is shall be use of protocol “Digital Imaging and Communication in Non-Destructive Evaluation” (DICONDE) for image storing.

The Contracted Party shall provide technical support and training in the use of the software to BUYER, without any extra cost, during the duration of the contract and performance guarantee.

5.7 ULTRASONIC TESTING

5.7.1 BEAM ANGLE

(ASME Section V, Article 4: Add to T-472.1.1)

For butt joints, probe angles should be selected according to the following requirements:

a) the probe shall be compatible with the dimensional detail of the welded joint

b) the probe shall be compatible with the type of discontinuity to be detected

c) use 60° and 70° probe angles for thicknesses up to 15 mm

d) use 60° and 70° or 45° and 60° probe angles for thicknesses between 15 mm and 25 mm

e) use 45° and 60° or 45° and 70° probe angles for thicknesses between 25 mm and 40 mm

f) use 45° and 60° probe angles for thicknesses greater than 40 mm

For joint types different from butt joints, paragraphs a) and b) above shall be applied and at least 2 probes of different angles shall be used.

5.7.2 SCANNING SENSITIVITY LEVEL

(ASME Section V, Article 4: Add to T-471.4)

Correction due to transfer losses of normal and double elements probes is required and shall be performed as follows:

a) maximize a backwall echo of the reference block and with the help of the gain control, position it at 80 % of the total height of the apparatus screen

b) with the same gain, position the probe on the part to be examined

c) check the difference in height of the echoes in decibels, such difference being denominated to as transfer loss (PT), which shall be added to or decreased in the primary gain (GP)

d) the resulting gain is denominated corrected gain (GC), (GC = GP ± PT)

Correction due to transfer losses of angular probes shall be made as follows:

a) with the reference block, the curve shown in APPENDIX II shall be traced, with 2 probes of the same angle, frequency, type, and manufacturer, used in the test, one as transmitter and the other as receiver

b) the probes shall be positioned according to APPENDIX II in such a way as to obtain signal E/R1, the signal being maximized and placed at 80 % of the screen height

c) without changing the gain, the signals of positions E/R2 and E/R3 shall be marked on the screen

d) interconnect the points from E/R1 to E/R3 obtaining a curve on the screen

e) with the same gain, place the probes on the part to be examined (see APPENDIX II) in the position E/P1 and, if the echo height of this position is equal to the curve height (see paragraph b), corrections are not necessary

f) if there are differences, the height found in the material of the part is adjusted to the same height of the curve (see paragraph b) and the number of decibels (PT) that shall be added or decreased in the primary gain (GP) or auxiliary gain (GA) is noted down

g) the resulting gain is denominated corrected gain (GC = GP ± PT) or (GC = GA ± PT).

Optionally, the following nonmandatory appendices can be used:

Nonmandatory Appendix S – General Techniques for Straight-Beam Transfer Correction.

Nonmandatory Appendix U – General Techniques for Angle-Beam Transfer Correction.

5.7.3 EXAMINATION COVERAGE (DIRECTIONS AND EXTENT OF SCANNING)

(ASME Section V, Article 4: Add to T-471.1)

For each type of equipment or installation, schematic drawings of the joints shall be attached to the procedure, indicating probe angles, scanning surfaces and sides to be used to inspect the total volume of the weld.

For narrow gap type joints, the use of the Tandem technique is recommended.

5.7.4 CORRECTIONS FOR ULTRASONIC TESTING OF TMCP MATERIALS

Whenever ultrasonic testing of welds in TMCP steel is performed, the difference in attenuation between transverse and longitudinal rolling direction shall be checked when the scanning direction changes between transverse and parallel to the rolling direction. The UT procedure shall consider possible changes in acoustic properties resulting from anisotropic steels. The actual refraction angle varies with the propagation direction and may be greater or smaller than the nominal angle in the rolling direction (longitudinal or transverse direction respectively). When ultrasonic testing is performed on such materials, reference blocks shall be made from the same material grades (and traceable to heat no.) used in the production, considering the same rolling direction in relation to the predicted directions for ultrasonic scanning.

5.8 AUTOMATED ULTRASONIC EXAMINATIONS (PAUT AND TOFD)

5.8.1 PROCEDURE QUALIFICATION AND DEMONSTRATION

The procedure shall be qualified and approved by a Level 3 inspector in the respective technique, such as PAUT and ToFD.

The inspection procedures performance shall be demonstrated by the SELLER to BUYER representatives, which may then validate its use. Performance demonstration shall be according to ASME V Article 14, intermediate rigor.

Welds in austenitic steels, austenic-ferritic steels, nickel-based alloys, dissimilar metal joints and other coarse grain materials cannot be tested by conventional UT. Only advanced ultrasonic techniques, e.g., phased array, FMC/TFM shall be used in these situations and the inspection procedure performance shall be demonstrated to BUYER. Reference blocks for these materials shall be welded and have at least reflectors in the fusion line and in the weld centerline. ISO 22825 shall be used as a reference. It is recommended to adopt dual linear arrays or matrix linear arrays transducers to perform these inspections.

Procedure performance demonstration shall be on welded mockups with at least the number of flaws described in Table 2, using surface flaw on the side of the block representing the component O.D. surface, surface flaw on the side of the block representing the component I.D. surface, and subsurface flaws. All mockups and reference blocks shall contain artificial and/or natural reflectors that are representative of welded joints in field conditions, therefore, the application of blocks with dimensions established by ASME V article 4 is adopted as a premise of this instrument, however, for reflectors with a non-rounded profile, of notch type, their opening cannot exceed 0.25 mm. These reflectors,

alternatively, may be manufactured by EDM, laser or by another manufacturing method that guarantees the tolerances defined here. Flaw size shall be no larger than the limit of the acceptance criteria specified on the reference code. Flaw depth shall be limited to the minimum of 3mm or 11% of the thickness. Flaw length shall be no larger than the limit of the acceptance criteria specified on the reference code.

Whenever inspection will be performed from only one side to evaluate the whole joint, e.g. welded joints between pipe-fitting, procedure performance shall be demonstrated to BUYER. For this condition, procedure performance demonstration shall be on welded mockups and include one flaw at the toe of the weld on the opposite bevel from which the inspection is performed. The grinding of weld reinforcement, when required, is fundamental for the reliability of the examinations, so it shall provide continuity, alignment, flatness in relation to the parent metal. Minimum designed clad and/or wall thickness shall be maintained as applicable.

The digital copies of the PAUT or ToFD examinations shall be handed to BUYER in portable media, e.g., solid state drive, encompassing examination performed in the period every 60 days or whenever requested by the BUYER.

Table 2 - Minimum quantity and location of flaws in welded mockups

Thickness range (mm)	Minimum flaw amount	Bevel location		weld Central location	
		weld cross section	position in relation to thickness	weld cross section	position in relation to thickness
≤12.7	3	3	OS, IS, I	0	N.A.
>12.7 through 25.4	4	3	OS, IS, I	1	I
>25.4 through 38.1	5	3	OS, IS, I	2	OS, I
>38.1 through 50.8	6	3	OS, IS, I	3	OS, I, I
>50.8 through 101.6	8	4	OS, IS, I, I	4	OS, I, I, I
>101.6 through 152.4	10	5	OS, IS, I, I, I	5	OS, I, I, I, I
>152.4 through 203.2	12	6	OS, IS, I, I, I, I	6	OS, I, I, I, I, I

Legend:
OS – Outer Surface / IS – Inner Surface / I – Internal / NA – Not applicable

5.9 FERRITE TESTING

The requirements here stated applies to ferrite testing on field (material receiving inspection, production welds etc). Ferrite testing by laboratory methods is not covered by this technical specification.

The instruments and standard blocks, used in the ferrite testing, shall be calibrated, and their calibration shall be maintained, according to AWS A4.2 requirements.

Prior the tests be carried out, the calibrated instrument (ferritoscope) shall be checked with appropriate standard blocks (NIST or TWI), in accordance with AWS A4.2 standard requirements, e.g., using standard blocks with ferrite content (or Ferrite Number) close to the values specified for each material to be tested.

The ferrite testing at each location shall consist of 5 readings averaged.

Ferrite testing shall be performed in accordance with a written procedure. Each procedure shall include at least the following information, as applicable:

a) Identification of issuer (company)

b) numerical identification and procedure revision

c) objective

d) personnel qualification requirements

e) method and frequency of ferrite content measuring instruments calibration

f) testing method to be used

g) identification of calibration blocks

h) specification of base and/or weld metal for which the procedure applies

i) drawings of welded joints with measurement points

j) identification of ferritoscope, including model and serial number

k) calibration certificate of ferritoscope and standard calibration blocks

l) surface preparation technique prior to testing

m) reference standards and/or values for performance and interpretation of results

n) identification and signature of the professional responsible for the procedure

o) report form for presentation of results

Ferrite testing report shall be issued in accordance with procedure report form and shall include at least the following information:

a) entity performing the test

b) number of reports

c) number and revision of the test procedure

d) number of the PQR/WPS of the tested weld joint (when applicable)

e) specification of the base materials and weld metal (when applicable)

f) identification of the weld joint on the equipment/piping (when applicable)

g) identification of the piece (part) tested

h) schematic drawing of the weld joint/piece with indication of the measurement points

i) preparation technique and surface condition of the piece

j) test method/standard applied

k) identification of the ferrite measuring instrument (manufacturer, model, serial number)

l) calibration certificate number of the instrument itself and of the standard calibration blocks

m) base standard and reference values for the ferrite content results

n) assessment of the results, indicating approval, rejection or need of additional actions

o) date

p) identification of the personnel performing the test

q) record of all measurements results obtained during the test

6 REQUIREMENTS FOR NON-METALLIC MATERIALS

This section presents the essential variables to be considered, minimum requirements for procedure demonstration and best practices to perform an effective and reliable inspection to achieve the contractual requirements.

This NDT approach does not waive VT as the main inspection method. VT, both internally (as far as physical access allows) and externally, shall be carried out on all joints and surfaces as required by ISO 14692-4 and contractual technical specifications.

6.1 ULTRASONIC TESTING

6.1.1 GENERAL

UT has been extensively tested and developed to achieve better results as an NDT method for quality control and assurance for piping and pipelines. However, as any NDT method, it has its own potential and limitations and is not able to detect every possible defect that may occur during FRP adhesive-bonded or laminated joints fabrication.

Considering the latest Petrobras projects, UT techniques are considered mainly suitable for detection of delamination, lack of adhesive, inclusions, voids, and incorrect spool dimensions. UT pulse-echo technique with 0° bulk waves is recommended for these examinations.

Note: The contractor may propose and adopt other methods and techniques, considering required procedure validation, defined acceptance criteria, and submit to BUYER approval.

6.1.2 WRITTEN PROCEDURE REQUIREMENT

Ultrasonic examination shall be performed in accordance with a written procedure which shall contain the minimum requirements stated in table 3.

Table 3: Variables of the Written Procedure

Variables	Essential	Non-essential
Joint configurations to be examined, including thickness dimensions and base material specification	X	
The surfaces from which the examination shall be performed	X	
Technique(s) (straight beam, contact, and/or immersion)	X	
Angle(s) and mode(s) of wave propagation in the material	X	
Search unit type(s), frequency(ies), and element size(s)/shape(s)	X	
Special search units, wedges, shoes, or saddles, when used	X	
Ultrasonic instrument(s)	X	
Calibration [calibration block(s) and technique(s)]	X	
Directions and extent of scanning	X	
Scanning (manual vs. automatic)	X	
Scan increment (decrease in overlap amount)	X	
Method for sizing indications	X	
Scan overlap (decrease only)	X	
Scan plan (when PAUT is applied: range of element numbers used, element increment change, rastering angle, aperture start and stop numbers)	X	
Personnel qualification requirements		X
Surface condition (examination surface, calibration block)		X
Couplant: brand name or type		X
Post-examination cleaning technique		X
Records, including minimum calibration data to be recorded (e.g., instrument settings)		X

The written procedure shall establish a single value, or range of values, for each requirement.

6.1.3 WRITTEN PROCEDURE QUALIFICATION

Procedure shall be qualified in a mockup joint with natural or artificial reflectors. Mockup shall be produced by the same manufacturer of the joint to be examined, using same material and process.

The mockups shall include at least one discontinuity representative of inadequate bond, lack of adhesive, inclusion and void. Dimensions of discontinuities shall be as close as possible to the ones defined in the acceptance criteria.

For laminated joints, it shall be included discontinuities in, at least, 2 different depths.

6.1.4 EQUIPMENT

Instruments shall comply with ASME Section V paragraphs T-431 and T-461 requirements.

Search units shall comply with ASME Section V paragraph T-432 requirements, except for nominal frequencies that may vary according to the contractor past experiences.

The same contact wedges to be used during the examination shall be used for calibration.

NOTE: Previous Petrobras Projects achieved better results with nominal frequency between 0,5 and 2,25 MHz and diameter of 12,7 mm. For PAUT, 2,25 MHz and 16 elements with small pitch (less then 1mm) also presented satisfactory results.

6.1.5 CALIBRATION BLOCKS

The material from which the block is fabricated shall be of the same product form, specification, and manufacturer of the joint to be examined. The block shall be cut from a joint produced with the same procedure as the joint to be examined.

The basic calibration blocks configurations and reflectors shall be as shown in figures 1 and 2 below.

NOTE: The contractor may propose and adopt other calibration blocks, considering required procedure validation and defined acceptance criteria.

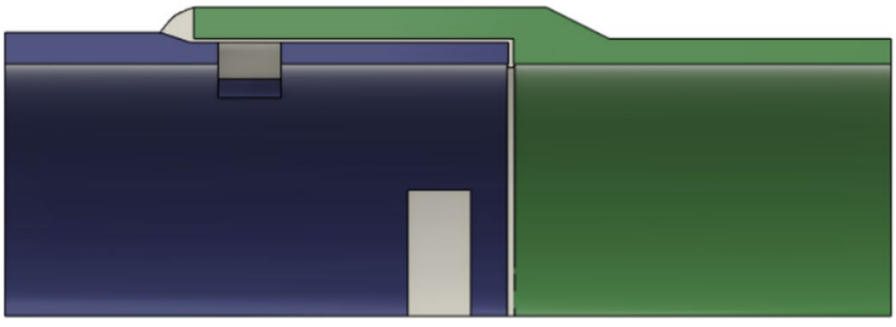


Figure 1 – Calibration block for adhesive-bonded joints. Notches shall be 12,5mm wide and their depths shall be equal to inner tube thickness.

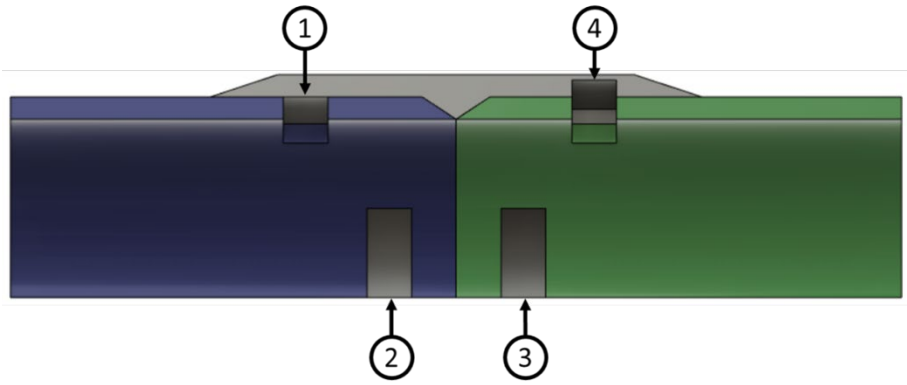


Figure 2 – Calibration block for laminated joints. Notches shall be 12,5mm wide and their depths shall be equal to: 1- tube thickness; 2- tube thickness + 25% laminate overlay thickness; 3- tube thickness + 50% laminate overlay thickness; 4- tube thickness + 75% laminate overlay thickness.

6.1.6 CALIBRATION

Instrument calibrations defined on ASME Section V paragraphs T-461, V-461, V-462 and V-467 shall be performed.

Calibrations shall include the complete ultrasonic system and shall be performed prior to use of the system in the thickness range under examination.

Calibrations shall be performed from the convex surface of the block, corresponding to the surface of the component from which the examination will be performed.

The same couplant to be used during the examination shall be used for calibration. Couplant shall not be detrimental to examined material. It is recommended to adopt water based couplants.

Couplant viscosity may be adjusted previously to better suits the examination surface roughness.

Any control which affects instrument linearity (e.g., filters, reject, or clipping) shall be in the same position for calibration, calibration checks, instrument linearity checks and examination.

The temperature differential between the calibration block and examination surfaces shall be within 14°C.

For adhesive-bonded joints, DAC or TCG shall be generated with, at least, three points:

a) First point shall be near inspection surface to filter and adjust entrance echo to 100% full screen height (FSH).

b) Second point shall correspond to adhesive layer interface and shall be set to 80% FSH.

c) Third point shall correspond to the inner backwall depth (internal diameter) and the echo shall be set to 80% FSH.

For laminated joints, DAC or TCG shall be generated with, at least, four points:

a) First point must be near inspection surface to filter and adjust entrance echo to 100% full screen height (FSH).

b) Second point shall correspond to the notch machined to tube thickness + 0,5 laminate overlay thickness and shall be set to 80% FSH.

c) Third point shall correspond to the notch machined to tube thickness and shall be set to 80% FSH.

d) Fourth point shall correspond to the inner backwall depth (internal diameter), and the echo shall be set to 80% FSH.

NOTE 1: It is recommended to adopt all the notches machined on the calibration blocks, but their applicability shall be evaluated by responsible Level 3 inspector.

NOTE 2: The contractor may propose and adopt other calibration techniques, considering required procedure validation and defined acceptance criteria.

6.1.7 CALIBRATION CONFIRMATION

ASME Section V paragraph T-467 shall be considered.

6.1.8 SURFACE PREPARATION

Surface preparation is critical condition for examination performance, thus minimum requirements shall be clearly stated by the responsible Level 3 inspector to avoid coupling issues and easy examination execution.

Examination surface shall be clean and free from any condition that may prevent coupling or ultrasonic transmission into the material.

Previous surface sanding is recommended to produce a smoother and more uniform surface condition. Fibers cannot be hit or exposed during preparation. The manufacturer shall approve the surface preparation method and final surface condition.

It is advised to consult manufacturer to supplement bonding and laminating process in order to produce a more suitable surface for UT.

6.1.9 EXAMINATION

Encoded inspection is recommended to produce C-Scan visualization and easy result evaluations and reporting.

Grid lines and matrix may be proposed by responsible Level 3 inspector, considering the minimum necessary overlap to ensure the acceptance criteria fulfillment.

6.1.10 ACCEPTANCE CRITERIA

Indications shall be sized by the 6dB drop technique.

The following indications shall be considered as discontinuities:

a) For adhesive-bonded joints and laminated joints, any area where it is identified a reduction of the inner backwall to 20% FSH or less.

b) For laminated joints, any indication with amplitude above 40% the reference level.

The following criteria shall be adopted:

a) The sum of the area of the identified discontinuities shall not be 30% or more of the total bond area or laminate length.

b) In any line parallel to the axial line of the joint, the sum of the length of intercepting discontinuities shall not be 20% or more of the total axial bond length or laminate length.

6.1.11 EXAMINATION RECORDS

As a minimum, ASME Section V paragraph T-492 shall be accomplished.

6.2 RADIOGRAPHIC TESTING

RT has been developed specially focusing on digital techniques and X-ray sources as an NDT method for quality control and assurance for non-metallic piping and pipelines. However, as any NDT method, it has its own potential and limitations and is not able to detect every possible defect that may occur during FRP adhesive-bonded or laminated joints fabrication.

Considering the latest Petrobras projects, RT is mainly suitable for detection of lack of adhesive, inclusions, voids and misalignment. Computed Radiography (using imaging plates) and Direct Radiography (using DDAs as flat panel detectors) in combination with portable X-ray equipment are recommended for these examinations according to ISO 17636-2, but Film-based Radiography can be applied as well.

Note: The contractor may propose and adopt other methods and techniques, considering required procedure validation, defined acceptance criteria, and submit to BUYER approval.

6.2.1 WRITTEN PROCEDURE REQUIREMENTS

RT shall be performed in accordance with a written procedure which shall, as a minimum, contain the requirements stated in table 4.

Table 4: Variables of the Written Procedure

Variables	Essential	Non-essential
Joint configurations to be examined, including material, thickness and diameter range	X	
Type of radiation (specifying maximum voltage of X-ray instrument or radioactive isotope) and filters	X	

Maximum dimensions of the X-ray device focus or source size	X	
Film-based Radiography: film density range and film type, brand and dimensions	X	
Digital Radiography system: 1 - manufacturer and monitor model (monitor features: luminance, luminance ratio, resolution, pixel size and dynamic range), 2 - image viewing program (image processing system), 3 – Computed Radiography (manufacturer and scanner model describing pixel size, focal spot size, dynamic range and basic spatial resolution; manufacturer and imaging plate trademark), 4 - Direct Radiography (manufacturer and flat panel model describing pixel size, active area and dynamic range)	X	
Intensifying screens mentioning their type, quantity, and thickness	X	
Radiographic technique and indicative scheme of exposure arrangement	X	
Execution Tables	X	
Minimum source to object distance	X	
Image Quality Indicators (IQI): type, material, location and shims, if applicable	X	
Personnel qualification requirements		X
Condition applied to the surfaces to be tested and preparation method, if required		X
Sequence of image processing steps (image contrast enhancement operations, image filters, magnification/zoom)		X
Imaging storage (image identification, file format, media, including precautions to avoid loss of data)		X
Systematic procedure for radiographies identification		X
Description of positioning marking method		X
Chassis arrangement		X
Handling of detectors		X
Radioprotection		X
Systematic of results records		X
Form for results records report		X

Radiographic laboratory layout		X
Film processing		X
Schedule to check Digital Radiography system long term stability		X
The written procedure shall establish a single value, or range of values, for each requirement.		

6.2.2 WRITTEN PROCEDURE QUALIFICATION

Procedure shall be qualified in a mockup joint with natural or artificial defects. Mockup shall be produced by the same manufacturer of the joint to be examined, using same material and process.

The mockups shall include at least one discontinuity representative of lack of adhesive, inclusion, and void. Dimensions of discontinuities shall be as close as possible to the ones defined in the acceptance criteria.

For laminated joints, it shall be included discontinuities in, at least, 2 different depths.

The procedure is considered qualified when the radiographies performed in the thickness and diameter ranges established present:

a) clearly defined image of interest area

b) essential hole visible in interest area

c) first unresolved wire pair specified, basic spatial resolution of a digital Radiography (SRb, image)

d) required normalized signal to noise ratio, SNR_N (Digital Radiography) or density within the required range (Film-based Radiography)

e) absence of spots, artifacts or developing defects within area of interest

f) visible identification.

NOTE 1: Procedure qualification shall be performed for each thickness range in accordance with Table 5.

NOTE 2: RT shall be performed only for ranges that include the thickness values specified in the inspection procedure.

6.2.3 EQUIPMENT

6.2.3.1 INSTRUMENT

The X-ray equipment shall be either directional or panoramic type (if internal pipe access is provided), in the range up to 200 kV. The requirement of an equipment in the range up to 300 kV or more, if available, shall be evaluated by responsible Level 3 inspector.

The apparatus shall be in good condition, properly maintained and subject to weekly checks by the Radiation Protection Supervisor. The X-ray equipment also shall be tested for electrical safety prior to use.

The determination of the source size, if not provided by the equipment supplier, shall comply with ASME Section V paragraph T-261.2.

Note: The adoption of isotopes like ^{75}Se or ^{192}Ir shall have their applicability evaluated by responsible Level 3 inspector, comprising the requirements attendance.

6.2.3.2 DETECTORS

The radiographies shall be performed using films in conventional RT (see ASME Section V paragraph T-231.1), imaging plates or Digital Detector Arrays as flat panels in digital radiography (see ISO 17636-2) developed for the industrial area.

The contractor shall ensure the traceability of the imaging plates or flat panel used, in order to provide the unmistakable identification of the applied detector quality (type and model). This identification shall be presented in the radiographic image.

The read out of imaging plates shall be performed with a scanner pixel size that provides the required image resolution (SR_b, image).

Dynamic range, in levels of gray, minimum of 12 bits (4 096 levels).

Manufacturers' requirements regarding temperature and humidity conditions for operation and transportation shall be met. All exposures shall be within the detectors operational range.

If used, the flat panel shall be calibrated in accordance with the manufacturer's recommendation, both in relation to the periodicity and in relation to the method used. Other calibration methodologies are allowed, if they are agreed between the contracting parties. The flat panel cannot be used if the calibration adopted is not sufficient to eliminate bad pixels and clusters of dead pixels which can affect the interest area. Bad pixel interpolation is acceptable and an essential procedure for radiography with DDAs.

Damaged detectors that generate artifacts in the images, for example: scratches, shinning spots, clusters of bad pixels, bad lines or any others that induce interpretation errors or harm the radiographic image quality shall not be used.

6.2.4 PROCESSING

Film processing shall be in compliance with ASME Section V paragraph T-231.2.

Computed Radiography: detectors or read-out unities are to be used in accordance with the conditions recommended by manufacturer to obtain the selected image quality. The digital radiographies should be free from artefacts due to processing and handling or other causes, which would interfere with interpretation.

It is recommended that the imaging plate, the read-out unity and the computer software for acquisition and image processing applied are from the same manufacturer.

The time interval between exposure and reading out of the imaging plates shall be the maximum of 30 min, to avoid the fading effect over the latent image.

Direct Radiography: the flat panel calibration procedure, as recommended by the manufacturer, shall be applied. The detector shall be calibrated with a background image (without radiation) and at least with one gain image (X-ray equipment on and homogeneously exposed). Calibrated images should be treated as original images for quality assurance if the procedure has been documented. The calibration shall be performed periodically and if the exposure conditions change significantly.

6.2.5 HANDLING

The storing of imaging plates shall be done in an environment and conditions that ensure the integrity for use in subsequent inspections. It is recommended that the maximum temperature be of 25 ºC and relative humidity less than 50 %.

The imaging plates shall be handled with clean and dry hands. The chassis and filters shall be clean of any impurities that may harm the radiographic image.

The removal of latent image, for subsequent exposures, shall be made with the exposure of the imaging plate to high density white light. It is not allowed erasure of latent images on imaging plates with the use of sunlight.

During the assembly of imaging plates on the read-out unity, it shall be ensured that the environment has no direct light over the plate. The maximum illumination level is 10 lux.

The cleaning of the imaging plates and DDA shall be performed only with the use of the product recommended by the manufacturer.

The radiographic testing shall not be performed in piping or equipment which recorded temperature in the external wall exceeds 35 ºC.

6.2.6 IQI DESIGN

The radiographic sensitivity shall be verified by using hole type IQI. The IQIs shall be manufactured in the same material to be inspected or Group 001 IQI for non-metallics as described in ASME V Article 22, SE-1025.

The essential dimensions of the IQIs shall be in accordance with ASME Section V Table T-233.1.

The required hole shall be as specified in table 5.

Table 5: IQI selection

Pipe nominal wall thickness (mm)	IQI			
	Source side		Detector side	
	Hole-type designation	Essential hole	Hole-type designation	Essential hole
Up to 9.5, incl.	20	2T	17	2T
Over 9.5 through 19.0	30	2T	25	2T
Over 19.0 through 38.1	50	2T	40	2T
Over 38.1 through 63.5	60	2T	50	2T

The placement of IQIs shall be as defined in ASME Section V paragraph T-277.1. In addition to T-277.1 (3) (e) the area of interest is considered as follows:

a) Adhesive-bonded joints: the whole area of adhesive

b) Laminated joints: the whole laminated area.

The duplex wire IQI complying with ISO 19232-5 shall be used for determination of the image basic spatial resolution (SR_b, image). The IQI shall be positioned in the area of interest and tilted by a few degrees (2° to 5°) to the digital rows or columns of the digital image. The SR_b, image shall be determined in accordance with ISO 17636-2 or ASTM Practice E2445 for the Computed Radiography or Practice ASTM E2597 for Direct Radiography.

6.2.7 MONITOR

When using Computed or Direct Radiography, the monitor shall have a minimum luminance of 250 cd/m2 and a resolution equal or higher than 1280 pixels x 1024 pixels, with a maximum size of pixel of 250 µm. The ratio for presentable luminance (maximum luminance/minimum luminance) shall be equal or higher than 250:1.

The monitor must provide a minimum dynamic range of 8 bits (256 gray levels).

6.2.8 ACCEPTANCE CRITERIA

6.2.8.1 IMAGE QUALITY

The essential hole according to Table 5 shall be visible in area of interest.

Radiographic density in the interest area shall be within 2.0 to 3.5 range.

For Digital Radiography, in addition to the sensitivity requirement, the image basic spatial resolution (SR_b) shall comply to the table 6. The digital data of the radiographic detector shall be evaluated with linearized grey value representation, which is directly proportional to the radiation dose, for determination of basic spatial resolution (SR_b) and normalized signal to noise ratio (SNR_N).

Table 6: Image resolution requirement.

Pipe nominal wall thickness (mm)	IQI
	Pair [$SR_{b,image}$] (µm)
Up to 9.5, incl.	10 D [100]
Over 9.5 through 38.1	9 D [130]
Over 38.1	8 D [160]

For flat panel detectors the values of image resolution showed in Table 6 might be missed in one pair (e.g., 9D instead of 10D for thickness up to 9.5 mm) if the SNR_N in the interest area is equal or superior to 150 and one smaller diameter can be seen.

The SNR_N shall be equal or superior to 100 and shall be achieved from measurement over a uniform region at the area of interest. The measurement procedure of the SNR shall be in accordance with ISO 17636-2 or the procedure of ASTM Practice E2445 for Computed Radiography or ASTM Practice E2597:2014 for Direct Radiography.

If further image processing (e.g. filtering) is used when evaluating IQI images (duplex wire or hole type), then the same filter parameters shall be used for both joint evaluation and IQIs.

6.2.8.2 INDICATIONS

The following indications shall be considered as discontinuities:

a) Indications at least 15% darker or brighter than the average of the area of interest (measured in terms of linearized grey value for digital images) can be characterized as voids, inclusions or lack of adhesive areas.

b) Crack-like indications.

The following criteria shall be adopted:

a) The sum of the area of the identified discontinuities shall not be 30% or more of the total bond area or laminate length.

b) In any line parallel to the axial line of the joint, the sum of the length of intercepting discontinuities shall not be 20% or more of the total axial bond length or laminate length.

c) Cracks are not acceptable.

6.2.8.3 DOCUMENTATION

As a minimum, a form for results records report shall be issued according to ASME Section V – Art.2.

7 REQUIREMENTS FOR PMI

7.1 GENERAL REQUIREMENTS

SELLER shall prepare and submit to BUYER evaluation a written procedure, specific for the test method and apparatus to be used, containing at least the following information:

a) Objective

b) Reference standards and specifications

c) Test method (X-ray Fluorescence Spectrometry Method or Optical Emission Spectrometry Method)

d) Apparatus, with indication of manufacturer, brand mark and model

e) Material classes that can be identified, relevant chemical elements and acceptance criteria

f) Sequence to performing the test (sequence and details)
- calibration (reference blocks to be used and operational sequence)
- surface preparation to perform the test
- operational precautions to perform the test (e.g., geometric limitations, temperature, distance from the surface, etc.)
- safety precautions related to the radiological protection of the inspector and others, in accordance the approved radiological protection plan (additionally, in Brazil this plan shall be approved by CNEN – Comissão Nacional de Energia Nuclear)

g) Systematic to report the inspection results (to establish an identification and traceability system that allows to correlate the tested area or component with the report and vice-versa);

h) Report form

The procedure shall be qualified with reference blocks of metals, metal alloys and/or polymer (resin) stipulated for purposes of identification. It is considered qualified when it permits identification of the characteristics of the stipulated of metals and metal alloys.

A report shall be issued containing, as a minimum:

a) Name of issuing entity (responsible company)

b) Test instrument identification number or serial number, where appropriate

c) Identification of component part, equipment or piping

d) Number and revision of procedure

e) Record of results

f) Evaluation indicating acceptance, rejection or recommendation of additional test

g) Date

h) Identification and signature of responsible inspector

NOTE: It is acceptable the emission of digital reports.

7.2 METALIC MATERIALS

According to API RP 578, Positive Material Identification (PMI) testing is defined as any physical evaluation or test of a material to confirm that the material which has been or will be placed into service is consistent with the selected or specified material designated by the BUYER/user. These evaluations or tests may provide either qualitative or quantitative information that is sufficient to verify the nominal alloy composition.

The identification of metals and metal alloys shall be performed by quantitative analysis, through portable apparatus, by the test methods specified in API RP 578 standard.

Test methods, equipment calibration and precision shall comply with the requirements of API RP 578.

Metallic materials shall be confirmed to contain the nominal amounts of alloying elements specified in the relevant materials specification.

8 DIMENSIONAL CONTROL

Dimensional Control shall be carried out in accordance with a proper procedure, which shall contain, at least, following information:

a) identification of issuer (company)

b) numerical identification and procedure revision

c) objective

d) personnel qualification requirements

e) scope of measurements and instruments

f) methods of measurements

g) verifications prior inspection, such a calibration, resolution, scale and handling

h) identification of instruments

i) previous adjustments of instruments

j) lecture of measurements and tolerances

k) identification of calibration blocks

l) reference standards and/or values for interpretation of results

m) identification and signature of the professional responsible for the procedure

n) report form for presentation of results

DC report shall be issued in accordance with procedure report form and shall include, at least, the following information:

a) entity performing the inspection

b) number of report

c) number and revision of the inspection procedure

d) identification of the piece inspected (equipment, piping, structure etc.)

e) drawing or another reference document that establishes dimensional requirements

f) surface condition of the piece

g) schematic drawing of measurement points

h) identification of instruments used with TAG

i) result of measurements (values and units) and respective tolerances

j) assessment of the results, indicating approval, rejection or need of additional actions

k) date

l) identification of the personnel performing the test

9 HARDNESS TESTING

9.1 GENERAL REQUIREMENTS

Hardness test shall be performed in accordance with a written procedure. Each procedure shall include at least the following information, as applicable:

a) identification of issuer (company)

b) numerical identification and procedure revision

c) objective

d) personnel qualification requirements

e) method and frequency of hardness tester calibration

f) hardness method to be used

g) identification of calibration blocks

h) identification of hardness tester, including model and serial number

i) calibration certificate of hardness tester and standard calibration block

j) reference standards and/or values for performance and interpretation of results

k) specification of base and weld metal for which the procedure applies; (e.g., carbon steel material and manufacturing process, GRP material)

l) drawings of welded joints with measurement points

m) condition required for surfaces to be tested and preparation methods

n) procedure of execution

o) identification and signature of the professional responsible for the procedure

p) report form for presentation of results

Hardness testing report, with the results, shall be issued in accordance with procedure report form and shall include at least the following information:

a) entity performing the test

b) number and revision of the test procedure

c) number of the PQR/WPS of the tested weld joint (when applicable)

d) specification of the base materials and weld metal (when applicable)

e) identification of the weld joint on the equipment/piping (when applicable)

f) schematic drawing of the weld joint/part with indication of the measurement points (when applicable)

g) preparation technique and surface condition of the piece

h) surface temperature of the piece

i) hardness method/standard, including the applied load

j) system applied to properly determine the hardness profile (with or without additional fixtures/accessories)

k) identification of the hardness instrument (manufacturer, model, serial number)

l) calibration certificate number of the instrument itself and of the standard calibration block

m) base standard and reference values for the hardness results

n) assessment of the results, indicating approval, rejection or need of additional actions

o) date

p) identification of the personnel performing the test

q) record of all measurements results obtained during the test

9.2 METALIC MATERIALS

Hardness measurement test for qualification of welding procedure shall be performed in accordance with I-ET-3010.00-1200-955-P4X-001.

Portable instruments based on “Leeb” (rebound) method, “Poldi” or “Telebrineller” type instruments are not acceptable for hardness measurement.

The conversion of hardness measured values may be done in accordance with ASTM E140.

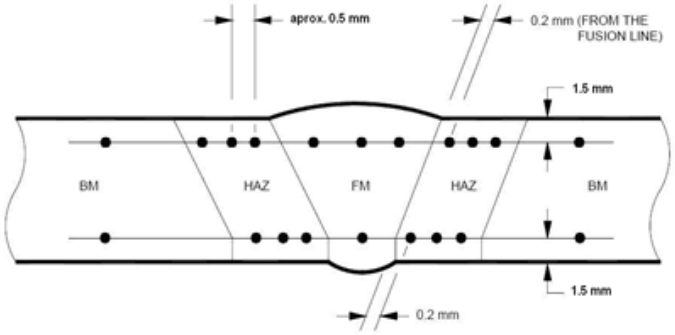
9.2.1 QUALIFICATION OF HARDNESS PROCEDURE

For field hardness examinations, only portable instruments with ultrasonic contact impedance (UCI) shall be used, according to ASTM A 1038 standard requirements.

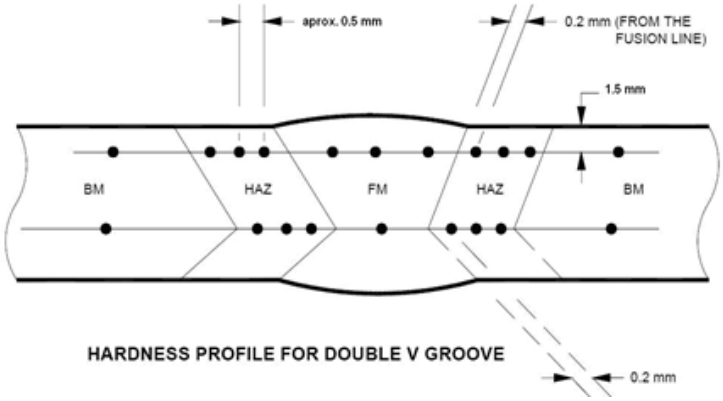
In order to demonstrate the portable instrument suitability to test performance in welded joints, hardness measurements must be carried out previously with the portable instrument on a welded joint of material of same applicable specification, such as ASTM and ASME, of that of the equipment or pipping to be tested, indentations according to Figure 3, and comparing the obtained values with the hardness measurements values performed in adjacent positions with a bench instrument in accordance with ASTM E 92 or ISO 6507-1, Vickers hardness method, HV 5 or HV 10. If these last hardness measurement values are similar to those obtained in adjacent positions with the portable instrument, this last one is considered as adequate for hardness measurements.

NOTE: Comparisons between measurements carried on hardness calibration blocks are not permitted to establish the portable instrument suitability for hardness measurement in welded joints.

Prior to initiate the field hardness testing, the instrument shall be calibrated, according to ASTM A1038, against a standard calibration block made of the same piece material (same modulus of elasticity) and preferably with a surface hardness within the expected hardness range for the piece.



HARDNESS PROFILE FOR V GROOVE



HARDNESS PROFILE FOR DOUBLE V GROOVE

NOTE: If necessary, intermediate readings may be slightly dislocated from the horizontal line.

Figure 3 - Location of Vickers hardness indentations.

9.2.2 FIELD MEASUREMENTS

To perform the field hardness test, the regions to be measured shall be delimited and properly identified. According to ASTM A1038, five readings taken in an area of approximately 1 in^2 (645 mm^2) shall constitute one test, e.g. the single hardness value of the region shall be the average of those five readings.

For welded joints, the hardness test shall include measurements on the weld metal, heat-affected zone, and base metal. For field measurement of hardness values in welded joints, the weld reinforcement shall be removed (ground flush), and the surface shall be properly grinded (up to grit 220) and chemically etched to properly reveal the heat affected zone.

9.3 NON METALIC MATERIALS

For non-metallic material, the hardness testing shall be performed according to ASTM D2583.

The surface preparation for composite shall be the removal of contaminants, performed by cleaning with isopropyl alcohol, heptane or hexane. Utilize detergent and water only if there are oils or greases.

APPENDIX I – DIGITAL RADIOGRAPHY IN WELDED JOINTS

I-1 OBJECTIVE

I-1.1 This Appendix states the requirements for digital radiographic X- and gamma-ray testing by either computerized radiography (CR) or radiography with digital detector arrays (DDA) in metallic welded joints for the detection of discontinuities.

I-2 GENERAL CONDITIONS

I-2.1 The radiographic testing shall be performed as established in the ISO 17636-2 standard and mentioned in specific conditions.

I-3 SPECIFIC CONDITIONS

I-3.1 PROCEDURE QUALIFICATION

I-3.1.1 The procedure shall be qualified and certified by Radiography Level 3 inspector.

I-3.1.2 The objective evidences of procedure qualification shall be kept in order to enable its confirmation to BUYER, at any time, when requested.

I-3.2 DISCONTINUITY ACCEPTANCE CRITERIA

The acceptance criteria shall be established by the design specification.

I-3.3 WRITTEN PROCEDURE

The radiographic testing shall be performed according to a written procedure, which shall include, at least, the requirements listed in Table I.1.

Table I.1 - Items of Procedure and Essential Variables

Requirements	Essential Variable	Non-Essential Variable
Issuer´s name, number and review indication		X
Objective		X
Reference standards for procedure elaboration and qualification	X	
Type of radiation (specifying radioactive isotope or maximum tension of X-ray instrument) and filters	X	
Type of material, thickness range and diameter	X (see NOTE1)	
Maximum dimensions of source or focus of x-ray devices	X (see NOTE 2)	
1- Computerized radiography system		
1.1- Manufacturer and scanner model:	X	
a) pixel size (in µm);	X	
b) focal spot size (in µm);	X	

Requirements	Essential Variable	Non-Essential Variable
c) dynamic range;	X	
d) basic spatial resolution (in µm);	X	
1.2- Manufacturer and type of imaging plate;	X	
2- Direct Radiography system		
2.1- Manufacturer and type of DDA	X	
a) pixel pitch (in µm);	X	
b) active area;	X	
c) dynamic range;	X	
3- Manufacturer and monitor model:		X
a) monitor characteristics: luminance, luminance ratio, resolution, pixel size and dynamic range;	X (see NOTE3)	
b) physical size of the useful area of the monitor;		X
Image viewing program		
a) used image processing system;	X	
b) used version of the image processing system;		X
Sequence of image processing stages		
a) image contrast enhancement operations;		X
b) image filters;		X
c) magnification (zoom).		X
Storage		
a) image identification;		X
b) file format;		X
c) media (including precautions to prevent loss of data).		X
Intensifying screens mentioning type, quantity and thickness	X	
Condition required for the surfaces to be tested and preparation method		X
Radiographic technique and indicative scheme of the exposure arrangement	X	
Execution tables	X	
Systematic procedure for radiographies identification		X
Image quality indicators (IQI): type, material and location	X	
Chassis arrangement		X
Handling of imaging plates and DDA		X
Radioprotection		X
Systematic of results records		X
Form for results records report		X

Requirements	Essential Variable	Non-Essential Variable
Verification periodicity of the CR system and DDA long term stability		X
NOTE 1: Except for material of the same group (see SE-747). NOTE 2: Except when shortened. NOTE 3: The replacement of monitor does not constitute alteration in essential variable provided the minimum specification requirements for monitors (I-3.9.1 of APPENDIX I) are met.		

I-3.4 REVISION AND/OR REQUALIFICATION OF WRITTEN PROCEDURE

Whenever any variable in Table I.1 is changed, it shall be issued a procedure review. If the variable is essential, the procedure shall be requalified and reevaluated.

I-3.5 PROCEDURE DEMONSTRATION

The procedure is considered qualified when the radiographies performed in the thickness and diameter ranges established present:

a) Image quality perfectly defined

b) Essential wire visible in all interest area

c) First unresolved wire pair specified

d) Required normalized signal to noise ratio

NOTE 1: Radiography shall be performed for each thickness range.

NOTE 2: Radiography shall be performed only for ranges that include the thickness values specified in the inspection procedure.

I-3.6 PROCEDURE VALIDATION

I-3.6.1 The CONTRACTED PARTY to BUYER representatives, which may then validate its use, shall demonstrate the inspection procedures. The validation process must be approved by an inspector level 3 of BUYER or its representatives

I-3.6.2 Additionally to the established in I-3.5, the procedure shall be validated in comparison with the conventional radiography using test samples or parts under inspection for each applicable diameter and thickness range covered by the procedure. Shall be agreed between the contracted parts and approved by BUYER inspector level 3, the samples quantities.

I-3.6.3 In order to validate the procedure, can be used welded joints containing defects in the parts under inspection or test samples shall be prepared presenting typical planar and/or volumetric defects inherent to the welding process applicable. These samples shall be used to verify that the digital radiography technique is equivalent / satisfactory in comparison with conventional radiography considering detectability and sizing flaws.

I-3.6.4 The quality requirements expressed in ISO 17636-2 shall be integrally met by digital radiography. CR or DDA must detect all discontinuities detected by conventional radiography. Otherwise, the digital radiography may not be used.

I-3.7 SOURCE

I-3.7.1 For digital radiography, the application of X-rays sources is preferential.

I-3.7.2 If it is impossible to apply X-rays sources, due to local access problems or others previously related by the CONTRACTOR, an isotope may be used, before agreement between the parties.

I-3.7.3 In order to improve the results quality, it is recommended that the maximum diameter of source is equal to 1 mm. This recommendation will not be applicable for penetrable thicknesses greater than 40 mm of steel.

I-3.8 DIRECTION OF RADIATION

Whenever possible, the direct radiation over the section to be examined shall be collimated.

I-3.9 EQUIPMENT

I-3.9.1 Monitor

I-3.9.1.1 The monitor used shall have a minimum luminance of 250 cd/m2 and a resolution equal or higher than 1280 pixels x 1024 pixels, with a maximum size of pixel of 250 µm. The ratio for presentable luminance (maximum luminance/minimum luminance) shall be equal or higher than 250:1.

I-3.9.1.2 The monitor must provide a minimum dynamic range of 8 bits (256 gray levels).

I-3.9.2 CR Scanner

I-3.9.2.1 The read out of imaging plates shall be performed with a scanner pixel size that provides the best image resolution.

I-3.9.2.2 Dynamic range, in levels of gray, minimum of 12 bits (4 096 levels).

I-3.9.3 Digital Detector Array

I-3.9.3.1 The pixel size of the dimensionally calibrated image cannot exceed 200 µm. The contracting parties can agree different values.

I-3.9.3.2 Manufacturers' requirements regarding temperature and humidity conditions for operation and transportation must be met. All exposures must be within the DDA's operational range.

I-3.9.3.3 The DDA shall be calibrated in accordance with the manufacturer's recommendation, both in relation to the periodicity and in relation to the method used. Other calibration methodologies are allowed, as long as they are agreed between the contracting parties.

I-3.9.3.4 DDA cannot be used if the calibration adopted is not sufficient to eliminate deadlines (bad pixels) and clusters of dead pixels. Bad pixel interpolation is acceptable and an essential procedure for radiography with DDAs. The ASTM E2597 shall be used as reference standard for this evaluation.

I-3.10 DETECTOR SELECTION

I-3.10.1 The radiographies shall be performed using "Imaging Plates" or "Digital Detector Arrays" developed for the industrial area.

I-3.10.2 The inspection company shall ensure the traceability of the imaging plates or DDA used, in order to provide the unmistakable identification of the applied detector quality (type and model). This identification shall be presented in the radiographic image.

I-3.10.3 Damaged plates that generate artifacts in the images, for example: scratches, shinning spots or any others that induce interpretation errors or harm the radiographic image quality shall not be used.

I-3.11 IMAGE PROCESSING

I-3.11.1 Scan and read-out of image

Detectors or scanners are to be used in accordance with the conditions recommended by the detector or scanner manufacturer to obtain the selected image quality. The digital radiographs should be free from artefacts due to processing and handling or other causes, which would interfere with interpretation.

I-3.11.2 It is recommended that the imaging plate, the scanner and the computer software for acquisition and image processing applied are from the same manufacturer.

I-3.11.3 The time interval between exposure and reading out of the imaging plates shall be the maximum of 30 min, in order to avoid fading of the latent image (fading effect).

I-3.11.4 If using DDAs, the detector calibration procedure, as recommended by the manufacturer, shall be applied. The detector shall be calibrated with a background image (without radiation) and at least with one gain image (X-rays on and homogeneously exposed). To minimize the noise due to calibration, all calibration images shall be taken with a high number of frames per image. It is recommended to set a number of frames for calibration ten times higher than those set for image acquisition for inspection. Calibrated images should be treated as original images for quality assurance if the procedure has been documented. The calibration shall be performed periodically and if the exposure conditions change significantly.

I-3.11.5 The digital data of the radiographic detector shall be evaluated with linearized grey value representation which is directly proportional to the radiation dose for determination of SNR, $SR_b^{detector}$ and SNR_N. ISO 17636-2 Table 4 shall be used as acceptance criteria for image quality. For optimal image display, contrast and brightness should be interactively adjustable. Optional filter functions, profile plots and an SNR, SNR_N tool should be integrated into the software for image display and evaluation. For critical image analysis, the operator shall interpret the image with a zoom factor between 1:1 (meaning one pixel of the digital radiograph is presented by one monitor pixel) and 1:2 (meaning one pixel of the digital radiograph is presented by four monitor pixels).

I-3.11.6 Further means of image processing applied on the stored raw data (e.g. high pass filtering for image display) shall be documented, be repeatable and be agreed between the contracting parties.

I-3.11.7 If further image processing (e.g. high pass filtering) is used when evaluating single wire IQI values, then the same filter parameters shall be used for both weld evaluation and IQI value determination.

I-3.12 FACILITIES FOR VIEWING OF RADIOGRAPHS

The report room shall have maximum illumination of 50 lux. This measure shall be performed when the monitor is turned off and with 1 m distance from the monitor.

I-3.13 HANDLING

I-3.13.1 The storing of imaging plates shall be done in an environment and conditions that ensure the integrity for use in subsequent inspections. It is recommended that the maximum temperature be of 28 ºC and relative humidity less than 50 %.

I-3.13.2 The imaging plates shall be handled with clean and dry hands. The chassis and filters shall be clean of any impurities that may harm the radiographic image.

I-3.13.3 The removal of latent image, for subsequent exposures, shall be made with the exposure of the imaging plate to high density white light. Is not allowed erasure of latent images on imaging plates with the use of sunlight.

I-3.13.4 During the assembly of imaging plates on the scanner, it shall be ensured that the environment has no direct light over the plate. The maximum illumination level is 10 lux.

I-3.13.5 The cleaning of the imaging plates and DDA shall be performed only with the use of the product recommended by the manufacturer.

I-3.13.6 The radiographic testing shall not be performed in piping or equipment which recorded temperature in the external wall exceeds 35 ºC.

I-3.14 INTENSIFYING SCREENS

I-3.14.1 Usually the use of front lead screens is not recommended, due to its deleterious to the basic spatial resolution and the signal to noise ratio.

I-3.14.2 Back lead screens shall be used in the protection against backscattered radiation.

I-3.15 SURFACE PREPARATION

For stainless austenitic steel, duplex or superduplex, nickel alloy, aluminum alloy or other required materials, the surface preparation tools of these materials shall be used only for the same materials and shall meet the following requirements:

a) Be made of stainless austenitic steel or covered with this material for stainless steel (austenitic, duplex and superduplex) and nickel alloys;

b) Cutting and grinding disks shall have nylon core or similar.

I-3.16 RADIOGRAPHIC TECHNIQUE

Sketches showing source position, detector and IQIs (contrast and duplex wire) for piping shall be presented in the procedure.

I-3.16.1 It is recommended that the ellipse present the same size of the minor internal axis, between 10 mm and 15 mm.

I-3.16.2 For the DWDI technique ellipse, the procedure shall consider the possibility of three exposures to 60º when, due to diameter/thickness ratio the complete view of the interest area is not possible.

I-3.16.3 For the overlapped DWDI technique the procedure shall consider the possibility of four exposures to 45º when, due to diameter/thickness ratio the complete view of the interest area is not possible.

I-3.17 EXECUTION TABLES

I-3.17.1 Table of the exposure data shall contain the following information:

a) Diameter range

b) Thickness range

c) Minimum source to detector distance

d) Indication of wire IQI (contrast) used and the required sensitivity

e) Indication of duplex wire IQI and the first unresolved wire pair (resolution)

f) Radiographic technique

I-3.17.2 The table of detector arrangement shall include the following information:

a) Diameter range

b) Thickness range

c) Image quantity

d) Size of imaging plate

e) Nominal overlap

f) Minimum overlap

g) kV, mA, time and number of frames

I-3.17.3 When digitally radiographing an area with two or more separate detectors (imaging plates), they shall overlap sufficiently to ensure that the complete region of interest is digitally radiographed. This shall be verified by a high density marker on the surface of the object which is to appear on each digital image. If the radiographs are taken sequentially, the high density marker shall be visible on each of the radiographs.

I-3.17.4 The nominal overlap for circumferential joints fullly radiographed shall never be less than 30 mm.

I-3.18 STANDARD IQI DESIGN

I-3.18.1 The radiographic sensitivity shall be verified by the use of contrast IQI. Only the wire IQI, according to ISO 19232-1 or ASTM E747, may be used. The hole IQI shall not be used in the weld inspection by digital radiography.

I-3.18.2 For the determination of basic spatial resolution need to comply with ISO 19232-5. The duplex wire IQI shall be positioned tilted by a few degrees (2° to 5°) to the digital rows or columns of the digital image. If the IQI is positioned at 45° to the digital lines or rows the obtained IQI number shall be reduced by one, complying with a minimum distance of 3 mm from the weld toe.

I-3.19 IQI SELECTION

I-3.19.1 MATERIAL

The IQI material selection shall be in accordance with the material group to be radiographed as identified in ASTM E747 or ISO 19232-1, when applicable or from a group of materials with smaller radiation absorption capacity than the material being radiographed.

NOTE: This requirement is not applied to duplex wire IQIs, which shall follow ISO 19232-5.

I-3.19.2 SIZE

NOTE: The hole type IQI shall not be used.

I-3.19.3 WELDS JOINING DISSIMILAR MATERIALS OR WELDS WITH DISSIMILAR FILLER METAL

When the weld metal is from a group of materials that having different radiation attenuation from the base material, the IQI material selection shall be based on the weld metal and from an alloy material group or grade with less radiation absorption than the material being radiographed.

I-3.20 IMAGE QUALITY REQUIRED

I-3.20.1 The measurements and acceptable values of the basic spatial resolution (SR_b) and normalized signal-to-noise ratio (SNR_N) shall be in accordance with ISO 17636-2.

I-3.20.2 The radiographies shall present the image of wire IQI for contrast evaluation according to the design and the duplex wire IQI for the basic spatial resolution evaluation, the latter when required.

I-3.20.3 The digital radiographies shall reach the average value of SNR_N enough high to provide detectability equal to the conventional radiography's one. Is mandatory to increase it if the digital radiography does not detect the same flaws as the conventional. It shall be verified during the validation process of the written procedure.

I-3.21 QUALITY OF RADIOGRAPHS

All radiographies shall be free of marks or spots in its extension that may mask the results or be mistaken for any discontinuity indication in the interest area of the radiographed object. Such marks include, for example:

a) Artifacts

b) Scanning flaws

c) Scratches, fingerprints, dirtiness or dents

d) False indications due to damaged screens

I-3.22 SYSTEM OF IDENTIFICATION

I-3.22.1 It is required that the information provided by this identification system necessarily appears as radiographic images, obtained with X-ray or Gamma rays. In any case, this information shall not obscure the interest area.

I-3.22.2 At least, the following information shall be appear in the radiographic image:

a) Equipment, piping or part number

b) Joint number, in case of welded joint

c) Thickness

d) Material or, optionally in case of piping, its class

e) Date of execution of the service

f) According to the case, the following inscriptions:

- NR – radiography of partially repaired weld
- NE – radiography of weld after its grinding
- NT – radiography of weld completely remade
- NX – repetition of radiography by mistake of performance
- RX – repetition of radiography for flaw confirmation
- AM - radiography taken for increasing sampling due to the presentation of flaw by the previous radiography
- EX - radiography taken to delimitate the flaw

I-3.22.3 The radiographic images in electronic media shall be at least related to the radiographic report containing the following information:

a) Codes of reports referring to the recorded images

b) Identification of the CONTRACTOR

I-3.23 LONG TERM STABILITY OF THE DIGITAL RADIOGRAPHY SYSTEM

I-3.23.1 The systems of computed radiography and direct radiography must be analyzed for their long-term stability by assessing the quantities reported in ASTM E2445 and ASTM E2737, respectively. These rules establish the acceptance limits for each case.

I-3.23.2 It is recommended that the evaluations be carried out in a specialized third party laboratory or by the CONTRACTOR itself, upon proof of accomplishment and issuance of a report accepted by the CONTRACTOR.

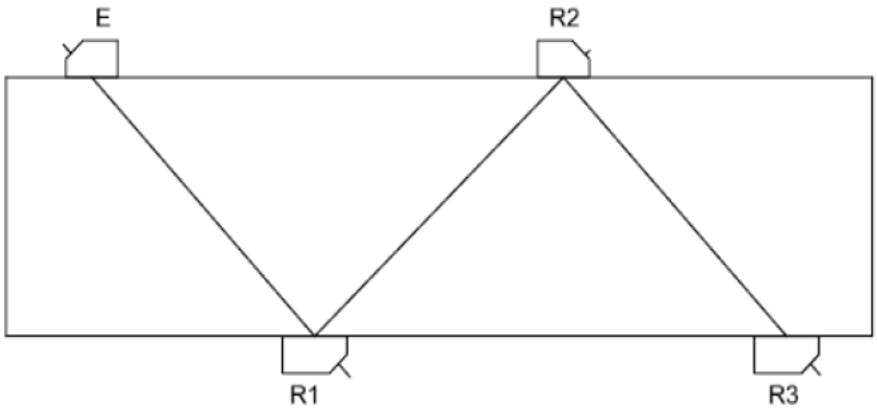
I-3.23.3 Quality assurance requires periodic tests of the CR or DDA system to ensure the proper performance of the system. The time interval depends on the degree of usage of the system and shall be defined by the user with consideration of the CR or DDA system manufacturer's information. It is recommended to apply ISO 10012 to manage and define the periodicity of calibrations.

I-3.23.4 For new computed radiography systems, the manufacturer of this system shall provide the certificate of stability assessment in accordance with ISO 16371-1, ISO 16371-2, ASTM E2445 and ASTM E2446. For new DDA systems, the manufacturer of this system shall provide the certificate of stability assessment in accordance with ASTM E2597 and ASTM E2736. However, after 1 year of this evaluation, the CR and DDA systems shall be evaluated according to the aforementioned Standards.

I-3.24 MODIFICATION, ADDITION AND SUPPRESSION API STD 1104, AWS D1.1/D1.1M, DNV-OS-F101, DNV-OS-C401 AND ASTM E94.

For the application of the digital radiography technique, the requirements of ISO 17636-2 complemented by this specification shall be followed.

APPENDIX II - CORRECTION DUE TO TRANSFER LOSSES



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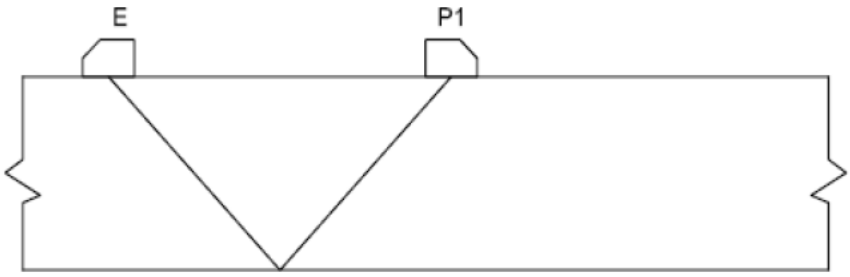

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