

Non Destructive Testing - Computed Radiography (CR) in Welded Joints

Procedure

This Standard replaces and cancels its previous revision.

The CONTEC - Authoring Subcommittee provides guidance on the interpretation of this Standard when questions arise regarding its contents. The Department of PETROBRAS that uses this Standard is responsible for adopting and applying the sections, subsections and enumerates thereof.

Technical Requirement: A provision established as the most adequate and which shall be used strictly in accordance with this Standard. If a decision is taken not to follow the requirement ("non-conformity" to this Standard) it shall be based on well-founded economic and management reasons, and be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by imperative nature.

Recommended Practice: A provision that may be adopted under the conditions of this Standard, but which admits (and draws attention to) the possibility of there being a more adequate alternative (not written in this Standard) to the particular application. The alternative adopted shall be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by verbs of a nonmandatory nature. It is indicated by the expression: **[Recommended Practice]**.

Copies of the registered "non-conformities" to this Standard that may contribute to the improvement thereof shall be submitted to the CONTEC - Authoring Subcommittee.

Proposed revisions to this Standard shall be submitted to the CONTEC - Authoring Subcommittee, indicating the alphanumeric identification and revision of the Standard, the section, subsection and enumerate to be revised, the proposed text, and technical/economic justification for revision. The proposals are evaluated during the work for alteration of this Standard.

"This Standard is exclusive property of Petróleo Brasileiro S. A. - PETROBRAS, internal application and PETROBRAS Subsidiaries and shall be used by its suppliers of goods and services under contracts or similar under the conditions established in Bidding, Contract, Agreement or similar.

The use of this Standard by other companies / organizations / government agencies and individuals is the sole responsibility of the users.."

CONTEC

Comissão de Normalização
Técnica

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Non Destructive Testings

Introduction

PETROBRAS Technical Standards are prepared by Working Groups - WG (consisting specialized of Technical Collaborators from Company and its Subsidiaries), are commented by Company Units and its Subsidiaries, are approved by the Authoring Subcommittees - SCs (consisting of technicians from the same specialty, representing the various Company Units and its Subsidiaries), and ratified by the Executive Nucleus (consisting of representatives of the Company Units and its Subsidiaries). A PETROBRAS Technical Standard is subject to revision at any time by its Authoring Subcommittee and shall be reviewed every 5 years to be revalidated, revised or cancelled. PETROBRAS Technical Standards are prepared in accordance with PETROBRAS Technical Standard N-1. For complete information about PETROBRAS Technical Standards see PETROBRAS Technical Standards Catalog.

Foreword

This Standard is the English version (issued in 07/2015) of PETROBRAS N-2821 REV. C 12/2014. In case of doubt, the Portuguese version, which is the valid document for all intents and purposes, shall be used.

1 Scope

1.1 This standard specifies the requirements for the realization of non-destructive testing of computed radiography for the inspection of welded joints by means of X-rays and gamma rays, using the techniques of Single-Wall Single Image (SWSI), Double-wall Simple Image (DWSI) and Double-Wall Double Image (DWDI).

1.2 This Standard applies to proceedings initiated after the date of its issue.

1.3 This standard contains Technical Requirements and Best Practices.

2 Normative References

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

INMETRO [VIM:2012](#) - Vocabulário Internacional de Metrologia: Conceitos Fundamentais e Gerais e Termos Associados (Edição Luso-Brasileira);

PETROBRAS [N-1738](#) - Descontinuidades em Juntas Soldadas, Fundidos, Forjados e Laminados;

ABNT [NBR 15783:2012](#) - Ensaios não Destrutivos - Radiografia Industrial - Medição de Espessura em Serviço de Tubulações e Acessórios com Uso de Radiografia Computadorizada;

ABNT [NBR 15790-1:2012](#) - Ensaios não Destrutivos - Radiografia Industrial - Inspeção de Soldas por Radiografia Computadorizada. Técnica de Parede Dupla Vista Dupla;

ABNT [NBR NM 314:2007](#) - Ensaios não Destrutivos - Radiografia Industrial - Terminologia;

ABNT [NBR NM ISO 9712:2014](#) - Ensaio não Destrutivo - Qualificação e Certificação de Pessoal;

ISO [9712:2012](#) - Non-Destructive Testing - Qualification and Certification of Personnel;

ISO [16371-1](#) - Non-destructive Testing - Industrial Computed Radiography with Storage Phosphor Imaging Plates - Part 1: Classification of Systems;

ISO [19232-1:2013](#) - Non-destructive Testing - Image Quality of Radiographs - Part 1: Determination of the Image Quality Value Using Wire-Type Image Quality Indicators;

ISO [19232-4:2013](#) - Non-destructive Testing - Image Quality of Radiographs - Part 4: Experimental Evaluation of Image Quality Values and Image Quality Tables;

ISO [19232-5:2013](#) - Non-destructive testing - Image quality of radiographs - Part 5: Determination of the image unsharpness value using duplex wire type image quality indicators;

ISO/IEC [17024:2012](#) - Conformity Assessment - General Requirements for Bodies Operating Certification of Persons;

ISO [17636-2:2013](#) - Non-Destructive Testing of Welds - Radiographic Testing - Part 2: X- and Gamma-ray Techniques with Digital Detectors;

API [STD 1104:2013](#) - Welding of Pipelines and Related Facilities;

ASME [BPVC Section V:2013](#) - Boiler and Pressure Vessel Code - Nondestructive Examination;

ASTM [E 94: 2004](#) - Standard Guide for Radiographic Examination;

ASTM [E 747:2010](#) - Standard Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology;

ASTM [E 2002:2009](#) - Standard Practice for Determining Total Image Unsharpness in Radiology;

ASTM [E 2445:2005](#) - Standard Practice for Qualification and Long-Term Stability of Computed Radiology Systems;

ASTM [E 2446:2005](#) - Standard Practice for Classification of Computed Radiology Systems;

AWS [D1.1/D1.1M:2010](#) - Structural Welding Code - Steel;

BSI [BS EN 14784-1:2005](#) - Non-Destructive Testing - Industrial Computed Radiography with Storage Phosphor Imaging Plates - Part 1: Classification of Systems;

BSI [BS EN 14784-2:2005](#) - 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;

DNV-OS-[F101:2013](#) - Submarine Pipeline Systems;

DNV-OS-[C401:2013](#) - Fabrication and Testing of Offshore Structures.

NOTE For documents referred in this Standard and for which only the Portuguese version is available, the PETROBRAS department that uses this Standard should be consulted for any information required for the specific application.

3 Terms and Definitions

For the purposes of this document the terms and definitions of INMETRO [VIM: 2012](#), [N-1738](#), ABNT [NBR NM 314: 2007](#), ABNT [NBR 15783: 2012](#) and ABNT [NBR 15790-1: 2012](#) and the following are applicable.

3.1 addition

insertion a new paragraph or a text in a paragraph

3.2 modification

replacement of a whole paragraph or modification of part of it

3.3 suppression

exclusion of the paragraph or part of it

3.4 base standard

design, manufacturing, construction and assembly standards for the inspected equipment and complementary standards cited by those

4 General Conditions

4.1 The radiographic test shall be performed as established in the standards and its specifications of design, manufacturing, construction and assembly related to the inspected unit except for the modifications, additions and suppressions mentioned in the specific conditions.

4.2 When a standard referenced in Section 2 is not mentioned in Section 5 it must be fully applied in its items related to the Non-destructive testing using radiography.

4.3 For all design, manufacturing, construction and assembly standards is required the addition of 5.1 and 5.2 in order to complement them as for the requirements specified therein for carrying out the testing.

4.4 The contractor shall provide, at no cost to PETROBRAS, at least one original media of the installation program, updated version and compatible with the platform of operating systems used by the Company with the relevant licenses and activation keys for image processing software and visualization of digital radiographies together with the manuals for use of these programs.

4.5 It is recommended in order to improve the quality of the results, the maximum focus of the source is equal to 1 mm. This recommendation ceases when the penetrable thicknesses are greater than 40 mm of steel. **[Recommended Practice]**

5 Specific Conditions

5.1 Personnel Qualification

5.1.1 For services performed in Brazil, the certification of personnel for the radiographic test must be obtained through the Brazilian System of Qualification and Certification (SNQC) of Personnel in Non-Destructive Testing (END), by means of a body accredited by INMETRO according to ABNT [NBR NM ISO 9712: 2014](#).

5.1.2 While there is no implementation of SNQC specific for CR, the professionals shall be certified by SNQC-END referring to the conventional radiography. In case of professionals from levels 1 and 2 who shall work in digital radiography techniques, must be certified for X-rays or gamma rays by SNQC-END added to the provisions in 5.1.3.

5.1.3 In addition, the professionals involved with computed radiography (CR) shall be specific trained on the computed radiography system used, with certification issued by the professional level 3 of the service provider.

5.1.4 After establishing the deadline in documentation for the implementation of SNQC specific for computed radiography, all professionals must be certified according to this system and the provisions in 5.1.2 and 5.1.3 become invalid.

5.1.5 For services performed abroad, the qualification and certification must be as established in 5.1.2 and 5.1.3 or by independent international entities, accredited by the national bodies of their respective countries, integrally meeting the requirements of the ISO / [IEC 17024:2012](#) and that operate in total accordance with [ISO 9712: 2012](#).

NOTE Self-certification systems for inspectors from Levels 1, 2 or 3, wherein the certification methodology is established or applied by the employer itself according to its own criteria, are not accepted by PETROBRAS.

5.2 Procedure Qualification

5.2.1 The procedure shall be qualified and certified by Inspector Level 3.

5.2.2 Objective evidences of the procedure qualification shall be maintained to allow its confirmation to PETROBRAS, at any time when requested.

5.3 Acceptance Criteria discontinuities

The acceptance criteria shall be established by the design specification.

5.4 Modification, Addition and Deletion of the ASME BPVC Section V: 2013 - Article 2

5.4.1 T-221.1 - Written Procedure - Modify

Radiographic Testing shall be conducted in accordance with a written procedure, which shall include at least the requirements listed in Table 1.

Table 1 - Procedure Items and Essential Variables

Requirements	Essential variable	Non essential variable
Issuer's name, number and review indication		X
Objective		X
Reference standards for the procedure elaboration and qualification	X	
Type of radiation (specifying radioactive isotope or maximum voltage of X-ray instrument) and filters	X	
Type of material, thickness and diameter range	X (see Note 1)	
Maximum dimensions of the source or focus X-ray devices	X (see Note 2)	
Computed radiography system		
1 Manufacturer and scanner model:	X	
a) pixel size (in μm);	X	
b) focal spot size (in μm);	X	
c) dynamic range;	X	
d) basic spatial resolution (in μm);	X	
2- Manufacturer and Imaging plate trademark;	X	
3 - Manufacturer and monitor model:		X
a) monitor features: luminance, luminance ratio, resolution, pixel size and dynamic range;	X (ver Nota 3)	
b) useful screen size;		X
4 - image viewing program:		
a) image processing system;	X	
b) version of the image processing system.		X
Sequence of image processing steps:		
a) image contrast enhancement operations;		X
b) image filters;		X
c) magnification (zoom).		

Table 1 - Procedure items and Essential Variables (Continued)

Requirements	Essential variable	Non essential variable
Storage:		
a) image identification;		X
b) file format;		X
c) media (including precautions to avoid loss of data).		X
Intensifying screens mentioning their type, quantity and thickness	X	
Condition applied to the surfaces to be tested and preparation method		X
Radiographic technique and indicative scheme of exposure arrangement	X	
Execution Tables	X	
Systematic procedure for radiographies identification		X
Minimum source to object distance	X (see Note 4)	
Image Quality Indicators (IQI): type, material and location	X	
chassis arrangement		X
Handling of phosphor imaging plates		X
Radioprotection		X
Systematic of Result Records		X
Form for results records report		X
Schedule to check CR system long term stability		X
NOTE 1 Except for the same group of material (see SE-747).		
NOTE 2 Except when decreased.		
NOTE 3 The replacement of the monitor does not constitute an alteration in essential variable provided the minimum normative requirements for monitors (T-235.1 of this standard) are met.		
NOTE 4 Except when increased.		

5.4.2 T-221.1.1 - Revision and / or requalification of Written Procedure - Add

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

5.4.3 T-221.2 - Procedure Demonstration - Modify

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

- a) clearly defined image quality indicator;
- 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.

5.4.4 T-221.3 - Validation Procedure - Add

Additionally to the established in 5.4.3, the procedure must be validated in comparison with conventional radiography, according to the minimum quantity defined in Table 2 and with satisfactory results, according to the criteria described in a) to j) of 5.4.5 added the T-221.3 .1. The validation process must be followed by the PETROBRAS' technical representative.

Table 2 - Combination of Nominal Diameter / Thickness

Thickness (mm)	$\varnothing \leq 1\ 1/2''$	$1\ 1/2'' < \varnothing \leq 3''$	$3'' < \varnothing \leq 10''$	$\varnothing > 10''$	Plates
$e \leq 4,0$	29 defects	29 defects	29 defects	29 defects	29 defects
$4,0 < e \leq 6,0$	29 defects	29 defects	29 defects	29 defects	29 defects
$6,0 < e \leq 8,0$	29 defects	29 defects	29 defects	29 defects	29 defects
$8,0 < e \leq 12,7$	29 defects	29 defects	29 defects	29 defects	29 defects
$12,7 < e \leq 25,0$	-	29 defects	29 defects	29 defects	29 defects
$e > 25,0$	-	29 defects	29 defects	29 defects	29 defects

5.4.5 T-221.3.1 - Criteria for Validation - Add

- a) in order to validate the thicknesses ranges specified in the procedure, test samples shall be prepared presenting typical planar defects inherent to the welding process used. The weld joints must be inspected using computed and conventional radiography. If the results are satisfactory and, at least, equivalent in terms of detectability, see h) and i), the inspection may be performed with CR. If the results are not equivalent or unsatisfactory, the CR inspection can not be performed;
- b) the validation process must be approved by a professional level 3 of PETROBRAS or its representatives;
- c) the qualified procedure must be accompanied by all of documents which prove its qualification and validation (radiographies, reports, etc.);
- d) all documentation must be accompanied by the form of "Computed Radiography Procedure Validation Documentation Record" which records the information required by the contractor to prove the validation, as follows:
 - name, signature and registration number of the SNQC-END professional level 3 of the contractor, who is responsible for monitoring the validation process;
 - signature of the professional level 3 of PETROBRAS or its representatives, who is responsible for approval the validation process;
 - number and review of the procedure of radiographic testing used, conventional and CR, in the comparative radiographies;
 - range of diameter/thickness validated;
 - equipment(s)/ work(s) where the radiographies were shot;
 - welded joint code examined by both techniques (conventional and CR);
 - number of radiography appraisal reports performed by conventional and CR techniques;
 - comparative reports of pairs of conventional and computed radiographs by the professional level 3 of the contractor who is responsible for supervise the validation process;
 - date of date of form issuance;
- e) a form template of "Computed Radiography Procedure Validation Documentation Record" is available in Annex A;
- f) once validated for a given range of diameter / thickness to be inspected in one (or more) work or service is not needed further validation when implementing the inspection using CR in another work or service;
- g) the qualification and validation of the inspection procedure may be accepted for inspections in other works or other services if agreed between the parties;

- h) In order to verify that the computed radiography technique is equivalent / satisfactory in comparison with conventional radiography, all discontinuities detected by conventional radiography must be detected by CR under conditions that simulate those of executions, ie conditions comparable to those of field and factory. Otherwise, the computed radiography may not be used;
- i) increase of sampling: if any result of CR technique is not equivalent or is unsatisfactory compared to conventional radiography, computed radiography inspection may not be performed. It is allowed to make adjustments in exposure parameters and / or energy, followed by an increase in the sampling, where two additional welded joints, keeping the same combination of diameter and thickness, must be radiographed by both techniques. PETROBRAS or its representatives must indicate which additional joints shall be shot. If the results are satisfactory, according to the criteria established in h) the inspection with computed radiography can be performed and the procedure shall be revised to include the modifications adopted. If any result is unsatisfactory, the inspection with computed radiography shall not be performed for that combination of diameter and thickness evaluated which shall be inspected with conventional radiography;
- j) in addition to the equivalence in detectability compared to conventional radiography, the quality requirements expressed in T-276.4, with the addition of 5.4.27 requirements of this standard shall be integrally met by computed radiography.

5.4.6 T-222 - Surface Preparation - Add

For austenitic stainless steels, duplex or superduplex, nickel alloys, aluminum alloys or other materials required, the tools for preparing the surface of those materials shall be used only for the same materials and shall meet the following requirements:

- a) be made of stainless steel (austenitic, duplex and superduplex) or coated with this material;
- b) cutting and grinding disks shall have a core made of nylon or a similar material.

5.4.7 T-224 - System of Identification - Modify

5.4.7.1 The information provided by this system of identification shall necessarily appear as radiographic images, whether obtained by X-rays or gamma-rays. In any case, this information shall not hide the area of interest.

5.4.7.2 At least, the following information shall appear in the radiographic image:

- a) number of equipment, piping or part ;
- b) joint number, in case of welded joints;
- c) thickness;
- d) material or optionally in the case of piping, its class;
- e) film identification number;
- f) date of execution of the service;
- g) identification of the professional level 1;
- h) as appropriate, the following information:
 - NR - radiography of partially repaired weld;
 - NE - radiography of weld after grinding;
 - NT - radiography of fully redone weld;
 - NX - reshot radiography due to an execution error;
 - RX - reshot radiography to defect confirmation;
 - AM - sampling increase due to the previous radiographies have shown defect;
 - EX - reshot radiography for defect delimitation size.

5.4.7.3 The radiographic images on electronic media shall be, at least, related to radiographic report containing the following information:

- a) codes of reports referring to the recorded images;
- b) identification of the contractor.

5.4.7.4 It is recommended to use the protocol Digital Imaging and Communication in Non-Destructive Evaluation (DICONDE) for image storage. **[Recommended Practice]**

5.4.7.5 Digital radiographs shall be identified by an exclusive code, not duplicate, but generated by the user, allowing traceability with the corresponding equipment or piping.

5.4.8 T-225 - Monitoring Density Limitations of Radiographs - Suppress

Integrally Suppressed.

5.4.9 T-231- Film - Modify

Modify the title to "Imaging Plates".

5.4.10 T-231.1 - Selection - Modify

5.4.10.1 The radiographs shall be performed using Imaging Plates (IPs) developed for the industrial area.

5.4.10.2 The length of the IP in radiographic test shall be, at least, 150 mm.

5.4.10.3 The service provider shall ensure the traceability of imaging plates used in order to provide unmistakable identification of detector quality (type and model). This identification shall appear in the radiographic image.

5.4.10.4 Damaged IPs which generate artifacts in the image as scratches, bright spots or any others that may induce misinterpretations or impair the quality of the radiography shall not be used.

5.4.11 T-231.2 - Processing - Modify

5.4.11.1 Modify the title to "Image Processing".

5.4.11.2 The conversion of the latent imaging into visible image on the scanner shall be performed according to the applied system manufacturer's guidelines.

5.4.11.3 The ambient temperature where the scanner and the plates are placed must not exceed 25°C.

5.4.11.4 It is recommended that the IP, scanner and computer software for acquisition and image processing applied are from the same manufacturer. **[Recommended Practice]**