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**Nondestructive testing of pressure equipment -
Part 14: X-ray computed radiographic testing**

承压设备无损检测

第 14 部分：X 射线计算机辅助成像检测

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Table of Contents

Foreword.....	3
1 Scope.....	5
2 Normative references.....	5
3 Terms and definitions	6
4 General requirements	9
5 Testing technology and its selection.....	14
6 Testing result evaluation and quality grading	30
7 Testing records and reports.....	31
Annex A (informative) Test method for minimum grey value	33
Annex B (normative) Determination of spatial resolution	35
Annex C (normative) Determination of normalized signal-to-noise ratio	38

Foreword

This Standard, NB/T 47013 “Nondestructive testing of pressure equipment”, consists of the following 14 parts:

- Part 1: General requirements;
- Part 2: Radiographic testing;
- Part 3: Ultrasound testing;
- Part 4: Magnetic particle testing;
- Part 5: Penetrant testing;
- Part 6: Eddy current testing;
- Part 7: Visual examination;
- Part 8: Leak testing;
- Part 9: Acoustic emission testing;
- Part 10: Ultrasonic time of flight diffraction technique;
- Part 11: Standard practice for X-ray digital radiography;
- Part 12: Magnetic flux leakage testing;
- Part 13: Pulsed eddy current testing;
- Part 14: X-ray computed radiographic testing.

This Part is Part 14 of NB/T 47013: X-ray computed radiographic testing.

This Part is drafted according to the rules given in GB/T 1.1-2009 “Directives for standardization - Part 1: The structure and drafting of standards”.

This Part is proposed by and shall be under the jurisdiction of China Standardization Technical Committee National on Boilers and Pressure Vessels (SAC/TC 262).

Drafting organizations of this Part: China Special Equipment Inspection and Research Institute, Special Equipment Safety Supervision and Inspection Institute of Jiangsu Province, China Nuclear Power Engineering Co., Ltd., Fong's National Engineering (Shenzhen) Co., Ltd., Shanghai Crown Domain Testing Technology Co., Ltd., De Hua Materials Testing Co., Ltd., Emerson Process Management Flow Technologies Co., Ltd., Beijing Hangxing Technology Development Co., Ltd., General Electric Inspection

Nondestructive testing of pressure equipment

- Part 14: X-ray computed radiographic testing

1 Scope

1.1 This Part of NB/T 47013 specifies the technical and quality grading requirements for fusion-welded joints of pressure-bearing metal parts of pressure equipment using X-ray computed radiographic testing below 450 kV (hereinafter referred to as “CR testing”).

1.2 This Part applies to the CR testing for fusion-welded joints of steel, copper and copper alloys, aluminum and aluminum alloys, titanium and titanium alloys, nickel and nickel alloys. The type of welded joints is butt joint weld (hereinafter referred to as “butt weld”) of a plate or tube.

1.3 The CR testing for the welded joints of other materials, supports and structural parts of pressure equipment may refer to this Part.

2 Normative references

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

GB 11533 Standard for logarithmic visual acuity charts

GB/T 12604.2 Non-destructive testing - Terminology - Terms used in radiographic testing

GB 18871 Basic standards for protection against ionizing radiation and for the safety of radiation sources

GB/T 21356 Non-destructive testing - Qualification and long-term stability of computed radiology systems

GB/T 23901.5 Non-destructive testing - Image quality of radiographs - Part 5: Image quality indicators (duplex wire type) - Determination of image unsharpness value

GBZ117 Radiological Protection Standards for Industrial X-ray Detection

The quality certificate of the IP shall include at least the main performance parameters such as type and specification, dynamic range, excitation response time, chemical composition of IP. Users shall use and store (IP) at the manufacturer's recommended temperature and humidity conditions and avoid unnecessary exposure. For workpiece under test with smaller thickness, it shall choose IP with slower photographic speed; For workpiece under test with larger thickness, it may choose IP with faster photographic speed.

4.2.2.2 Scanner

The quality certificate of the laser scanner shall include at least the main performance parameters such as specification, scanning size, input voltage, scanning resolution, laser beam focal spot size and scanning step speed, and the functions and performances of the laser scanner shall meet at least the following requirements:

- a) the scanner shall have scanning and erasing functions. The grey value of residual latent image after erasing shall not be higher than 5 % of the maximum grey value of the system;
- b) the scanning laser power shall meet the requirements of signal acquisition;
- c) the PMT voltage or gain, scanning resolution of the scanner shall be adjustable;
- d) the laser beam shall be free from chatter and free from artifacts and missing scan lines.

4.2.2.3 Display

The following minimum requirements shall be met:

- a) the minimum brightness is 250 cd/m²;
- b) the display is at least of 256 grey level;
- c) the minimum light intensity ratio is 1: 250;
- d) display at least 1M pixels, and the pixel size is less than 0.3 mm.

4.2.2.4 System-specific software

It shall include at least the following functions:

- a) measurement functions: including grey level measurement, spatial resolution measurement, signal-to-noise ratio measurement, geometric dimension measurement, etc.;
- b) adjustment functions: including grey level transformation, contrast adjustment,

4.3.5 In the CR testing of pressure equipment, if some conditions of testing cannot meet the requirements of AB-level testing technology, it is agreed by both parties to the contract that under the premise of taking effective compensation measures (such as increasing the exposure or selecting a system with higher signal-to-noise ratio), A-level testing technology may be used, but it shall also use other non-destructive testing methods for supplementary testing.

4.4 Testing process documents

4.4.1 Test process documents include process instructions and operating instructions.

4.4.2 In addition to meeting the requirements of NB/T 47013.1, the process specification shall also specify the specific scope or requirements of the following relevant factors. If the relevant factors change beyond the provisions, the process specification shall be redeveloped or revised:

- a) applicable structure, material type and thickness;
- b) ray source energy range and focus size;
- c) testing technology level;
- d) trans-illumination method;
- e) type and model of IP;
- f) model of wire-type image quality indicator and duplex-wire-type image quality indicator;
- g) type and thickness of metal screen;
- h) model and parameter settings of scanner;
- i) digital image display.

4.4.3 The operating instructions shall be developed according to the contents of the process specification and the testing requirements of the tested workpieces. The content of the operating instructions shall, in addition to meeting the requirements of NB/T 47013.1, at least include:

- a) testing equipment: ray source (focus size), IP, metal screen (type and thickness), image quality indicator (type and model), backscatter shield lead plate, mark, scanner and observation equipment;
- b) testing technology and process: testing technology, trans-illumination method (the relative position between the ray source AND the tested workpiece and IP), parameter selection (ray source, IP, exposure conditions), image quality indicator,

5.6.4.2 If the method of using cassette to directly trans-illuminate is used, it shall also ensure that the digital image quality of the entire effective evaluation area meet the requirements of 5.16.

5.6.5 Double-wall double-image trans-illumination of small-diameter tubes

For annular butt welds of small-diameter tubes, it may use double-wall double-image trans-illumination layout.

5.6.5.1 Trans-illumination layout

When the following two conditions are met at the same time, it shall use tilt trans-illumination method to obtain elliptical images:

- a) T (wall thickness) ≤ 8 mm;
- b) g (weld width) $\leq D_0/4$.

When obtaining ellipse images, the opening width (the maximum distance between the upper and lower welds) of the image shall be controlled at about 1 times the weld width.

When the above conditions cannot be met or elliptical imaging is difficult, it use vertical trans-illumination method to overlap imaging.

5.6.5.2 Number of trans-illumination

The number of trans-illumination of 100 % testing for annular butt welds of small-diameter tubes: when using tilt trans-illumination method to obtain elliptical images, and when $T/D_0 \leq 0.12$, trans-illuminate twice at an interval of 90° ; when $T/D_0 > 0.12$, trans-illuminate three times at an interval of 120° or 60° . When using vertical trans-illumination overlap imaging, generally it shall trans-illuminate three times at an interval of 120° or 60° .

When trans-illuminating in accordance with the above provisions, the overlap of adjacent digital images' valid evaluation area shall ensure coverage of the entire volume range of the testing area. If the minimum number of exposure cannot meet the requirement of 100 % coverage, it shall increase the number of exposure.

5.6.5.3 Special cases

If it is not allowed to carry out multiple trans-illuminations at the interval specified in 5.6.5.2 due to structural reasons, as agreed by both parties to the contract, the trans-illumination interval angle specified in 5.6.5.2 may no longer be enforced, but measures shall be taken to maximize the detectable scope of the defect, meanwhile it shall ensure that the image quality meet the requirements of this Part within the evaluation range. Relevant situations shall be explained in the test report.

shall not exceed 50 % of the specified value.

5.7.3 When using ray source to expose in the tested workpiece circumferentially by eccentric trans-illumination method, the value of f can be reduced as long as the quality of the obtained digital image meets the requirements of 5.16, but the reduction value shall not exceed 50 % of the specified value.

5.7.4 If the relevant regulations, standards, design technical documents or both parties to the contract have specified the maximum geometric unsharpness (U_g), in actual trans-illumination, the geometric unsharpness (U_g) value shall be calculated according to Annex H of NB/T 47013.2-2015.

5.8 Distance from IP to the tested workpiece

IP shall be close to the tested workpiece during exposure, unless there are special provisions or trans-illumination layouts that may make the tested area to get better digital images.

5.9 Exposure

The exposure shall ensure that the normalized signal-to-noise ratio of the digital image meets the standard requirements. The appropriate exposure may be determined by the minimum grey level test in accordance with Annex A.

5.10 Unwanted ray and scattered ray shielding

5.10.1 It should use appropriate measures such as metal screens, surrounding shielding lead plates, collimators, etc. to shield the scattered rays and unwanted rays, limiting the scope of the exposure field.

5.10.2 For testing process developed for the first time, and when the testing conditions and environment change, the inspection to the backscatter protection shall be carried out.

The inspection method for backscatter protection is by attaching to the back of the cassette a "B" type mark. Generally, the height of B type is 13 mm, and the thickness is 1.6 mm. And then carry out trans-illumination and scanning according to the provisions of the testing process. If the "B" image with the grey below the grey of the surrounding background appears on the digital image (negative film), the backscatter protection is not enough, so it shall increase the thickness of the backscatter protection lead. If the "B" image or the "B" image with the grey below the grey of the surrounding background does not appear on the digital image (negative film), then backscatter protection meets the requirements.

In the case of minor backscatter or the back metal screen is sufficient to shield the backscatter, backscatter shield lead plates or metal screens may not be used.

5.13.1 The marks of trans-illumination position consist of identification mark and positioning mark. The marks are generally composed of appropriate-size numbers, alphabetic letters, symbols, etc. made of lead (or other suitable heavy metal). The marks of digital image shall be clearly displayed without affecting digital image evaluation. The marked material and thickness shall be selected according to the thickness of the tested workpiece, so as to ensure that the marked image is not blurred.

5.13.2 Identification marks generally include: product number, weld number, part number and date of trans-illumination. The trans-illumination after rework shall have rework mark, and the trans-illumination with expanded testing proportion shall have expanded testing mark.

5.13.3 Positioning marks generally include center marks, lap marks, testing area marks, etc. The center mark indicates the center position of the trans-illumination position section and the direction of the section number, generally represented by a cross arrow “”. The lap mark is the trans-illumination section mark for continuous testing, which may be represented by the symbol “↑” or by any other methods (e.g. number, etc.) that shows the lapped condition. Any method for testing area marking that can clearly identify the testing area range is applicable.

5.13.4 When the inside and outside reinforcement of the weld are ground, and the location and width of the testing area cannot be determined from the digital image, it shall use appropriate positioning marks (e.g. lead strips) to identify.

5.13.5 Positioning marks shall be placed on the tested workpiece, and the placement shall comply with the provisions of Annex J of NB/T 47013.2-2015. All marked images shall not overlap, and shall not interfere with the image within the valid evaluation range. When it is necessary to place the positioning mark, which is supposed to be placed on the ray source side, on the IP side due to structural reasons or difficult to implement, the actual evaluation range shall be indicated in the test records and reports.

5.13.6 Identification marks are allowed to be placed on the ray source side or the IP side. All marked images shall not overlap, and shall not interfere with the image within the valid evaluation range.

5.13.7 In order to be able to accurately identify the digital image position, permanent marks or locations on the tested workpiece are taken as reference points; when permanent marks cannot be made due to the nature of materials and conditions of use, other methods (e.g. cloth map) shall be used to determine the digital image location.

5.14 Selection scanner parameters

5.14.1 The selection of scanner photomultiplier tube voltage or gain shall be matched with the exposure, to make the grey value of the digital image in the appropriate range (10 % ~ 80 %).

7 Testing records and reports

7.1 It shall record the relevant information and data during the testing process in detail according to the actual situation of the field operation. CR testing shall, in addition to meeting the requirements of NB/T 47013.1, include at least the following:

- a) commissioning organization or manufacturing organization;
- b) tested workpieces: name, testing location, weld groove type, welding method;
- c) testing equipment: ray source (focal spot size), IP, metal screen (type, quantity and thickness), image quality indicator (type and model), filter plate, backscatter shield lead plate, scanning and observation equipment;
- d) process verification of operating instructions (if necessary);
- e) testing process parameters: testing technology level, trans-illumination method, trans-illumination parameters (F , f , b , tube voltage, tube current, exposure time), scanning parameters;
- f) digital image quality: contrast sensitivity, resolution, normalized signal-to-noise ratio, grey values (if necessary), defect location and nature;
- g) schematic diagram of trans-illumination layout;
- h) test results and quality grading;
- i) prepare and audit personnel and their qualifications;
- j) other things that need to be explained or recorded.

7.2 The test reports shall be issued basing on the test records. CR testing report shall, in addition to meeting the requirements of NB/T 47013.1, include at least the following:

- a) commissioning organization or manufacturing organization;
- b) tested workpieces: name, testing location, weld groove type, welding method;
- c) testing equipment: ray source (focal spot size), IP, metal screen (type, quantity and thickness), image quality indicator (type and model), filter plate, backscatter shield lead plate, scanning and observation equipment;
- d) testing process parameters: testing technology level, trans-illumination method, trans-illumination parameters (F , f , b , tube voltage, tube current, exposure time), scanning parameters;
- e) digital image quality: contrast sensitivity, resolution, normalized signal-to-noise

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