

CONTECComissão de Normalização
Técnica**SC-27**

Welding

Non-Destructive Testing - Thermography**1st Amendment**

This is the 1st amendment to PETROBRAS N-2472 REV. D, and it is used to alter the text of the Standard in the part(s) indicated below:

NOTE 1 The new(s) page(s) with the performed amendment(s) is (are) placed in its corresponding position(s).

NOTE 2 The amended pages, indicated the date of the amendment, are placed at the end of this standard, in chronological order, and shall not be used.

CONTENTS OF THE 1st AMENDMENT - 09/2013

- Section 2:

Exclusion of the ABNT NBR 13377:1995.

- Subsection 5.2.9:

Exclusion of the ABNT NBR 13377:1995.

Non-Destructive Testing - Thermography

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.

"The present Standard is the exclusive property of PETRÓLEO BRASILEIRO S.A. - PETROBRAS, for internal use in the Company, and any reproduction for external use or disclosure, without previous and express authorization from the owner, will imply an unlawful act pursuant to the relevant legislation through which the applicable responsibilities shall be imputed. External circulation shall be regulated by a specific clause of Secrecy and Confidentiality pursuant to the terms of intellectual and industrial property law."

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 08/2012) of PETROBRAS N-2472 REV. D 04/2011. 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 lays down the conditions required for the non-destructive testing through the thermography technique.

1.2 This Standard applies to the inspection of mechanical and electrical systems and of process equipment through thermography, obtaining thermograms and recording of temperatures.

1.3 The non-destructive testing, object of this Standard, is applicable as of its issuing date.

1.4 This Standard contains Technical Requirements and Recommended 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:2008](#) - Vocabulário Internacional de Metrologia (Primeira Edição Brasileira do VIM 2008) (International Vocabulary of Metrology (First Brazilian Edition of VIM 2008));

Norma Regulamentadora nº 10 ([NR-10](#)) - Segurança em Instalações e Serviços em Eletricidade (Safety in Electrical Installations and Services);

PETROBRAS [N-2830](#) - Critérios de Segurança para Ambientes e Serviços em Painéis e Equipamentos Elétricos com Potencial de Arco Elétrico (Safety Criteria for Environments and Services in Electric Panels and Equipment with Electric Arc potential);

ABNT [NBR 8221:2003](#) - Equipamento de Proteção Individual - Capacete de Segurança para Uso na Indústria (Personal Protective Equipment – Industrial Safety Helmet);

ABNT [NBR 13712:1996](#) - Luvas de Proteção (Protective Gloves);

ABNT [NBR 15424:2010](#) - Ensaios Não Destrutivos - Termografia – Terminologia (Non-destructive Testing – Thermography – Terminology);

ABNT [NBR 15572:2008](#) - Ensaios Não Destrutivos - Termografia - Guia para Inspeção de Equipamentos Elétricos e Mecânicos (Non-destructive Testing – Thermography – Guide for inspection of Electrical and Mechanical Equipment);

ABNT [NBR 15718:2009](#) - Ensaios Não Destrutivos - Termografia - Guia para Verificação de Termovisores (Non-destructive Testing – Thermography – Guideline to Check Thermal Imager);

ABNT [NBR 15763:2009](#) - Ensaios Não Destrutivos - Termografia - Critérios de Definição de Periodicidade de Inspeção em Sistemas Elétricos de Potência ((Non-destructive Testing – Thermography – Criteria for Inspection Periodicity Definition in Electrical Power Systems);

ABNT [NBR 15866:2010](#) - Ensaios Não Destrutivos - Termografia - Metodologia de Avaliação de Temperatura de Trabalho de Equipamentos em Sistemas Elétricos (Non-destructive Testing – Thermography – Methodology of Working Temperature Evaluation for Equipment in Electric Systems);

API [530:2008](#) - Calculation of Heater-Tube Thickness in Petroleum Refineries;

ASTM [D 737:2008](#) - Standard Test Method for Air Permeability of Textile Fabrics;

ASTM [D 6413:2008](#) - Standard Test Method for Flame Resistance of Textiles (Vertical Test);

ASTM [E 1933:2005](#) - Standard Test Methods for Measuring and Compensating for Emissivity Using Infrared Imaging Radiometers;

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 following terms and definitions and the INMETRO [VIM:2008](#) are applicable.

3.1

addition

addition of a new paragraph or a text to a paragraph

3.2

modification

replacement of an entire paragraph or modification of part of it

3.3

suppression

deletion of the paragraph or part of it

3.4

base standard

Design, manufacturing, construction and assembly standards related to the inspected equipment and complementary standards mentioned by those

4 General Conditions

4.1 The thermography cameras checking has as base ABNT [NBR 15718:2009](#) standard, except for the modifications and suppressions mentioned in Section 5, of specific conditions.

4.2 For electrical and mechanical systems, the thermographic testing shall be performed as mentioned in ABNT [NBR 15572:2008](#), [NBR 15763:2009](#), and [NBR 15866:2010](#), except for modifications, additions and suppressions mentioned in Section 5, of specific conditions.

4.3 When a base standard referenced in Section 2 is not mentioned in Section 5, of specific conditions, it shall be integrally applied.

4.4 For the base standards referenced in Section 2, there is the need of addition of the numbers 5.1 to 5.3 of this Standard, aiming to complement them.

4.5 For process equipment, the thermographic testing shall be performed as in Section 6 of this Standard.

4.6 The emissivity values are available in the manuals of the thermography cameras. If the emissivity of the material to be inspected is not in the annex or in the literature, or if the temperatures are different, emissivity shall be experimentally determined. Indicators, which emissivity in the inspection points is known, can be used. For inspection of fired heaters internals, contact thermometers can be used, as in methods described on ASTM [E 1933:2005](#).

5 Specific Conditions for Thermographic Inspection in Electrical and Mechanical Systems

5.1 Modifications, Additions and Suppressions in ABNT NBR 15718:2009

5.1.1 Item 4 - Thermal Imager Calibration - Modify

5.1.1.1 Item 4.1 shall be deemed mandatory.

5.1.1.2 Item 4.2 shall be deemed mandatory.

5.1.1.3 Item 4.3 shall be deemed mandatory.

5.1.1.4 Item 4.4 shall be suppressed.

5.2 Modifications, Additions and Suppressions in ABNT [NBR 15572:2008](#)

5.2.1 Item 3.1 - Qualified Assistant - Modify

Authorized Assistant: qualified professional, according to [NR-10](#), and authorized by the end user to perform the tasks required by the thermography inspector, and knowledgeable about the operation and the history of the equipment to be inspected and about the end user's rules and safety practices.

5.2.2 Items 4.2, 4.3.2, 5.1, 5.3, 5.4, 5.5, 5.9, 5.10, 6.1 b) and 6.1 o) - Modify

Qualified assistant for authorized assistant.

5.2.3 Item 4.2 - Authorized Assistant - Modify

The authorized assistant assumes responsibilities relative to the ABNT [NBR 15572:2008](#) items 5.1, 5.3 to 5.5, 5.9 and 5.10.

5.2.4 Item 4 - Personal Responsibilities - Add

5.2.4.1 Minimum Requirements for Hiring Thermography Services

If hiring is necessary, consider the following practices:

- test must be executed by an inspector with a specific course in the electrical field, recognized by the Ministry of Education and Culture in Brazil (Ministério da Educação e Cultura);
- test must be executed by an inspector trained in the thermography technique with proven capacity, and must have a minimum duration of 32 hours under supervision of a professional thermography inspector with proven experience;
- thermography inspector with 3 years minimum experience in the technique applied to mechanical and/or electrical equipment;
- thermography inspector with [NR-10](#) course, in compliance with the type of inspection to be performed;
- submission of procedure which meets the specific conditions of the service to be performed and in compliance with PETROBRAS requirements.

5.2.4.2 Qualification of Procedures and Training of Personnel

5.2.4.2.1 Inspection Procedures

Procedures prepared by a duly qualified thermography inspector shall be used.

5.2.4.2.2 Thermography Inspector

- shall be able to perform the testing, interpret the resulting data and be duly trained in the technique;
- shall be knowledgeable about the operation of the thermographic camera used and its limitations for the type of inspection required;
- shall be knowledgeable to understand the observed thermal radiation patterns and to know how to contemplate the effects of the environmental conditions and of operation of the equipment in the results found.

5.2.4.2.3 Thermography Testing Inspector

Shall be a technician or engineer with technical knowledge in thermography testing, competent to prepare contracts, perform testing critical analysis and supervise the contract.

5.2.5 Item 5 - Procedure - Modify

5.2.5.1 Measuring System

Selection of thermographic cameras to perform the testing:

- preferably use a portable and light ergonomic camera with a fixed detection system (Focal Plane Array detector - FPA), avoiding mechanical and mobile parts used in the scanning detection system;
- b) 8-14 μ m (long waves) thermographic camera spectral range;
- c) both spatial resolution and measurement resolution shall be in accordance with the distances and dimensions of the targets to be inspected; in most situations, the standard 24° x 18° lens and, for inspection of components at great distances, a telescopic 12° x 9° lens are enough;
- d) maximum thermal sensitivity of 80 mK or 0.08°C;
- e) temperature measurement minimum range from -10 °C to 500 °C.

5.2.5.2 Instruments and Materials Needed to Perform the Testing

- thermographic camera appropriate to the type of inspection to be performed;

NOTE The instrument shall be checked and calibrated;

- digital electronic measuring tape with laser targeting, for long distance inspections;
- calibrated thermometer, hygrometer and anemometer to determine the environmental conditions;
- digital photographic camera;
- high-powered flashlight (for night inspections);
- a/c clamp meter category III or IV;
- radio for interpersonal communication, as in item 10.7.9 of [NR-10](#);
- inventory (with relevant information on the most recent inspection), with equipment mapped according to a safe and efficient sequential logic route of inspection;
- tool set for opening equipment, when necessary;

NOTE It is interesting to record a registry with the type of tool to be used to open each panel/equipment, for every substation has a different type of closure;

- Personal Protective Equipment (PPE) needed to perform the service.

NOTE If only mechanical equipment is inspected, there is no need of compliance with the [NR-10](#) requirements.

5.2.5.3 Preparation to Perform the Testing

5.2.5.3.1 Appointment of an authorized assistant to follow the thermography inspector in the inspection services, as in the [NR-10](#) requirements.

5.2.5.3.2 If inspection is performed by their own employees, the authorized assistant can be the thermography inspector, at the discretion of the company. However, this does not exempt compliance with the requirement of [NR-10](#)'s item 10.7.3, through which there is a minimum requirement of two people to perform the testing.

5.2.5.3.3 The thermography inspector and/or authorized assistant shall be knowledgeable about generic information on the installations and equipment to be inspected, such as:

- the type of electric power source (DC or AC voltage, single-phase or three-phase);
- area classification;
- information on risk zone and controlled zone.

5.2.5.3.4 It is important that the thermography inspector has a temperature reference (black body or some other reference with known temperature and emissivity) in order to enable the initial checking of the thermographic camera within the temperature ranges which are the most used in its work.

5.2.5.4 Testing Performance Procedure

5.2.5.4.1 Adjust the parameters of the thermographic camera prior to starting inspection. This adjustment shall be changed every time there are changes to parameters such as emissivity, distance to the object, air humidity, ambient temperature, atmospheric temperature and reflected temperature.

5.2.5.4.2 Enable for a short shutter period when recording temperature values and for medium when simply viewing the inspection scene. For thermal imagers without this function, manually perform the Non Uniformity Corrections (NUC) every 30 minutes of operation when measuring temperature.

5.2.5.4.3 Wait whatever time is necessary for the thermometry instruments (thermographic camera, radiometer, etc.) to get acclimated to the temperature change (refrigerated room/storage - industrial area).

5.2.5.4.4 Compensate the presence of external optics (infrared window) recording its spectral transmittance to infrared and temperature or, for cameras without this feature, record as target emissivity the result of the component emissivity multiplied by the optical transmittance. When this parameter is not safely informed by the product supplier, it shall be obtained by the thermography inspector through testing with thermal references of known temperature and emissivity, and preferably, in the temperature range expected for the equipment to be inspected.

NOTE It is important that the optics spectral transmittance is known, and that its value is reliable relatively to which infrared camera is used.

5.2.5.4.5 Define scale of the thermography camera according to the temperature of the equipment to be inspected. The automatic adjustment function can be used, when available.

5.2.5.4.6 The inspection cannot be performed from behind bulkheads or glass.

5.2.5.4.7 Use (acrylic or zinc oxide) white paint to improve the emissivity of connectors and of other components of electrical equipment with manufacture based on copper, aluminum or steel. If this is not feasible, the thermography inspector can measure the temperatures in the areas of the components where there are holes, oxidation, corrosion or dirt, taking advantage of the natural emissivity increase in these areas. If it is not possible to identify every emissivity involved in inspection, adopt 0.75 as the standard emissivity value for all components of the electrical equipment in the qualitative analysis.

5.2.5.4.8 For equipment put in operation, or subject to a wide variation of loads, you shall register the temperature of the equipment being inspected after a minimum of 2 hours of loading (operation), in order for the system to reach thermal stability.

5.2.5.4.9 Avoid inspecting components operating with electric current under 50% of the rated value. When operation of electrical systems with load over 50% is not possible, thermography can still be executed. For cases without abnormalities, record that thermography was executed under low load and that, consequently, the result was inconclusive. Repeat the same procedure as when the testing is not executed.

5.2.5.4.10 In open environments

Avoid diurnal thermographic inspections, so as not to let sun reflex or charging influence them. When this is inevitable, pay attention to:

- initiate inspections until, at most, 2 hours after sunrise or in cloudy days;
- respecting the premise previously recommended, prioritize the hottest days, so as to observe the worst conditions to which the equipment and systems will be subject;
- observe the same object under several different positions to compensate for sun reflection effects.

5.2.5.4.11 Do not perform inspections with wind speed over 20 km/h (approximately 6 m/s).

5.2.5.4.12 Do not perform inspections under rain, drizzle or mist. Wait at least 1 hour to start work after rain stops.

5.2.5.4.13 Do not perform inspections with relative air humidity over 90 %.

5.2.5.4.14 Preferably, the angle between the thermal imager and the inspected location shall be the most perpendicular possible, so as to avoid emissivity reduction because of inappropriate observation angles (higher than 60° relative to the normal, line perpendicular to the plane of the target-object).

5.2.5.4.15 Use the appropriate lens (standard or telescopic, depending on the need) to the distances and dimensions of the locations to be inspected.

5.2.5.4.16 Do not place the thermographic camera near high electromagnetic field-generating electrical equipment in order to prevent interference in the formation of the image.

5.2.5.4.17 The authorized assistant shall assist the thermography inspector with his notes and in the observation of his movement around the area, since the inspector must be focused in thermographic analysis.

5.2.5.5 Procedure in the Occurrence of Opening of Energized Electrical Panels

5.2.5.5.1 Inspection in electrical panels shall be in accordance with [NR-10](#), observe PPE and free zone for positioning of the thermography inspector.

5.2.5.5.2 The authorized assistant shall perform visual inspection, checking possible abnormalities within the panel, such as loose parts, damaged components, and presence of strange objects or animals. Now the thermography inspector will place himself in the free zone, out of the way of the authorized assistant's escape route.

5.2.5.5.3 If you need to perform any complementary electrical measurements or general notes about the equipment, this shall be the authorized assistant's responsibility.

5.2.5.5.4 When the inspection is over, the thermography inspector must distance himself from the panel and the authorized assistant must close it.

5.2.5.5.5 If the thermography inspector and the authorized assistant are the same person, he shall handle the panels with nothing in his hands, i.e., not holding the thermographic camera or any other instrument.

5.2.5.6 Identification, Evaluation and Management of Thermal Abnormalities

When locating a place with probable thermal abnormality:

- a) obtain the best possible image, respecting the safety limit distances, adjusting frame, focus, distance and angle to obtain the temperature reading;
- b) in order to obtain greater measurement accuracy, repeat the procedure and consider the average temperature value;
- c) record the electric current of the circuit or equipment being tested and check if there has been a wide variation in the load curve during the one hour period prior to the testing. If so, wait for thermal balance;
- d) if it is not possible to measure the current, consider the load as 90% for determination of load correction; an alternative, if feasible, is to set the loading of the system to the maximum condition provided in the project, with no need of load correction; for control loops, command loops and DC loops, do not correct load;