Nondestructive Examination Services for Equipment Used in the Petroleum and Natural Gas Industry

API STANDARD 20D
FIRST EDITION, SEPTEMBER 2013

AMERICAN PETROLEUM INSTITUTE

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Nondestructive Examination Services for Equipment Used in the Petroleum and Natural Gas Industry

1 Scope

1.1 Purpose

This standard specifies requirements for the design, development, and qualification of nondestructive examination (NDE) methods used in the manufacturer of equipment for the petroleum and natural gas industries.

1.2 Applicability

This is applicable to suppliers providing NDE services for equipment used in the oil and natural gas industries. The requirements of this standard apply to magnetic particle, liquid penetrant, radiography, and ultrasonic methods of NDE.

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 (including any amendments) applies.

API Specification Q1, *Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry*

API Specification Q2, *Specification for Quality Management System Requirements for Service Supply Organizations for the Petroleum and Natural Gas Industries*

ASME *Boiler and Pressure Vessel Code (BPVC)* [1], *Section V*: *Nondestructive Examination*

ASNT SNT-TC-1A [2], *Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing*

ASTM E428 [3], *Standard Practice for Fabrication and Control of Metal, Other Than Aluminum, Reference Blocks Used in Ultrasonic Testing*

ASTM E1114, *Standard Test Method for Determining the Size of Iridium-192 Industrial Radiographic Sources*

ASTM E1165, *Standard Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging*

ASTM E1316, *Standard Terminology for Nondestructive Examinations*

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1 ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.

2 American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.

3 ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM E1417, *Standard Practice for Liquid Penetrant Testing*

EN 473 [4], *Non-destructive testing—Qualification and certification of NDT Personnel—General Principles*

EN 12679, *Non-destructive testing—Determination of the size of industrial radiographic sources—Radiographic method*

ISO 9712 [5], *Non-destructive testing—Qualification and certification of NDT personnel*

3 Terms and Definitions

For purposes of this standard, the following terms, definitions, and acronyms apply.

Definitions relating to NDE, which appear in ASTM E1316, shall apply to the terms used in this standard.

3.1
acceptance criteria
Defined limits placed on characteristics of materials, processes, products, or services.

3.2
calibration
Comparison and adjustments to a standard of known accuracy.

3.3
check
A process performed to maintain confidence in the calibration status of reference, primary, transfer, or working standards and reference materials, carried out according to defined procedures and schedules.

3.4
fluorescent method magnetic particle inspection
The inspection process employing magnetic materials that have been coated with a material that fluoresces when activated by light of suitable wavelength.

3.5
immersion method ultrasonic examination
The examination method in which the search unit and the test part are submerged in a fluid, usually water, which acts as the coupling medium.

3.6
linear indication
An indication whose length is equal to or greater than three times its width.

3.7
liquid penetrant examination
PT
A NDE method for detecting surface-breaking flaws by bleedout of a colored or fluorescent dye from the flaw.

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4 European Committee for Standardization, Avenue Marnix 17, B-1000 Brussels, Belgium, www.cen.eu.

5 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

3.8
magnetic particle examination
MT
A NDE method for detecting discontinuities on or near the surface in suitably magnetized materials, which employs finely divided magnetic particles that tend to congregate in regions of the magnetic nonuniformity (i.e. along cracks, over inclusions, voids, etc.).

3.9
nondestructive examination
NDE
A method used to check the soundness of a material or a part without impairing or destroying the serviceability of the part.

3.10
procedure qualification
The process whereby a written NDE procedure is qualified in accordance with the requirements of this standard.

3.11
radiographic quality level
An expression of the quality of a radiograph in terms of an image quality indicator (penetrameter).

3.12
radiographic recording media
When used in this standard, recording media may be radiographic film or digital technology.

3.13
radiography
RT
A NDE method wherein a source of X-rays or gamma rays is utilized to indicate the subsurface condition of opaque materials.

3.14
rounded indication
An indication that is circular or elliptical with its length less than three times its width.

3.15
shear wave ultrasonic examination
A type of wave in which the particle motion is perpendicular to the direction of propagation.

3.16
straight beam ultrasonic examination
A vibrating pulse wave train traveling normal to the scan surface.

3.17
traceability
The ability to verify the history, location, or application of an item by means of documented recorded identification.

3.18
ultrasonic examination
UT
A NDE method of testing materials by transmitting high frequency sound waves through them.

3.19
verification
The adjustment of an NDE instrument using an appropriate reference standard to obtain or establish a known and reproducible response. This is usually done prior to an examination but can be carried out anytime there is concern about the examination or instrument response.

3.20
visible method magnetic particle examination
Magnetic particle inspection in which the particles are applied in a form where particles are visible in ambient light.

3.21
wet method magnetic particle examination
The magnetic particle inspection method employing ferromagnetic particles suspended in a liquid bath.

4 Responsibilities and Duties

It is the responsibility of the NDE service supplier to ensure that it:

— performs all examinations in accordance with specified standards or quality control criteria, or both;

— performs only examinations for which it is adequately equipped and staffed;

— performs only examinations for which its employees are adequately qualified;

— ensures equipment is calibrated and personnel are certified in accordance with applicable specifications;

— ensures all equipment is properly maintained;

— informs the purchaser of any discrepancy or limitation imposed on the testing accuracy by such factors as surface finish, form, shape, or procedure;

— calls to the attention of the purchaser at once any irregularity or deficiency noted in the documents;

— submits promptly to the purchaser formal reports of all examinations that indicates compliance or noncompliance of the material. The NDE service supplier should be prepared to substantiate examination results when required; and

— develops and qualifies procedures.

5 Personnel Qualification Requirements

Personnel performing NDE shall be qualified in accordance with the manufacturer's documented training program that is based on the requirements specified in ISO 9712, EN 473, or SNT-TC-1A. When SNT-TC-1A is used as the basis for qualification and certification, the content of the document shall be considered requirements and not considered a recommended practice as the title implies.

6 Design

The NDE service supplier shall have a system of written procedures for each NDE service performed. NDE procedures shall comply with the requirements of this standard and those of all applicable nationally or

internationally recognized standards. The procedures shall include a description of the methods used for NDE and the methods used for data recording, data processing, data reporting, and for certification of the results.

The development of an NDE procedure shall comply with the design controls of API Q1 or API Q2, as appropriate. Individual(s) other than the person or persons who developed the procedure shall approve the final procedure. At least one individual approving the procedure shall be qualified and certified at Level III in accordance with the requirements of Section 5. Design and development changes, including changes to procedures, shall require the same controls as the original design and development and the design documentation.

7 NDE Equipment and Calibration

7.1 Inventory

The NDE service supplier shall have an inventory listing of all available equipment with the following information noted:

— name of the manufacturer,

— equipment model and serial number,

— characteristics subject to calibration,

— range of operation and range of calibration,

— reference to nationally or internationally recognized standards used for calibration,

— frequency of calibration,

— allowable tolerances or maximum sensitivity.

7.2 Calibration

Equipment used to inspect, test, or examine material or other equipment shall be identified, controlled, calibrated, and adjusted at specified intervals in accordance with documented manufacturer instructions, and consistent with nationally or internationally recognized standards specified by the manufacturer, to maintain the accuracy required by this standard. Records of calibration shall be maintained.

8 Quality Control Records Requirements

8.1 General

The quality control records required by this standard are necessary to substantiate that all services provided to meet this standard do conform to the specified requirements.

The NDE service supplier shall establish and maintain documented procedures to control the documents and data required by this standard.

Records to be maintained by manufacturer:

— NDE process records,

— NDE procedure,

— NDE procedure qualification record,

— NDE personnel qualification records.

8.2 Records Retention

Records required by this standard shall be maintained for five years after the date a procedure or qualification record is no longer used. Documents and data may be in any type of media (hard copy or electronic) and shall be

— signed and dated;

— maintained to demonstrate conformance to specified requirements;

— legible;

— retained and readily retrievable;

— stored in an environment to prevent damage, deterioration, or loss; and

— available and auditable by the user/purchaser.

9 NDE Processes, Equipment, and Qualification Requirements

9.1 General

NDE processes and equipment shall be documented and qualified in accordance with the criteria defined for each method in this standard.

9.2 Magnetic Particle Examination (MT)

9.2.1 General

MT shall be performed using dry visible particle, wet visible particle, or wet fluorescent particle method. One or more of the following five magnetization techniques shall be used:

— prod technique,

— longitudinal magnetization technique,

— circular magnetization technique,

— yoke technique,

— multidirectional magnetization technique.

9.2.2 Calibration and Verification Requirements

MT equipment shall be calibrated and verified for performance and accuracy before first use and at intervals thereafter as indicated in Table 1 or Table 2, whenever malfunction is suspected or whenever electrical maintenance that might affect equipment accuracy is performed.

Table 1—Required Verification Intervals for Magnetic Particle Examination

Item	Maximum Time Between Verification [a]
Lighting: [b]	
Visible light intensity	Weekly
Ambient light intensity	Weekly
Black light intensity	Daily
System performance [b]	Daily
Wet particle concentration	8 hours or every shift change
Wet particle contamination [b]	1 week
Water break test	Daily

[a] When the inspection system is in operation.

[b] The maximum time between verifications may be extended when substantiated by actual technical/reliability data.

Table 2—Required Calibration Intervals for Magnetic Particle Examination

Equipment Calibration Check [a]	Maximum Time Between Calibration
Ammeter accuracy	6 months
Timer control	6 months
Quick break	6 months
Yoke dead weight check	6 months
Black and white light meters	6 months
Gaussmeter accuracy	6 months

[a] The maximum time between calibrations may be extended when substantiated by actual technical/reliability data.

9.2.3 Procedures

MT shall be performed in accordance with a written procedure, which shall as a minimum contain the requirements listed in Table 3.

9.2.4 Procedure Qualification

Each procedure shall be supported with a documented qualification record to demonstrate the effectiveness of the procedure. One or more of the following may be used to demonstrate discontinuity detection:

— actual production parts with known discontinuities of the type, location, and size needed for verification;

— representative reference parts containing discontinuities of the type, location, and size specified in the acceptance criteria and examined in accordance with a written procedure;

— Ketos ring.

NOTE Artificial discontinuities may be fabricated to meet a particular need or may be commercially available magnetic field indicators or shims.

Records of the qualification results shall be maintained and retained.

9.2.5 Procedure Requalification

A change of a requirement in Table 3 identified as an essential variable shall require requalification of the written procedure. A change of a requirement identified as a nonessential variable does not require requalification of the written procedure. All changes of essential or nonessential variables from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

Table 3—Requirements of a Magnetic Particle Examination Procedure

Requirement	Essential Variable	Nonessential Variable
The minimum detectable indication type (linear or rounded) and size (length or diameter or aligned)	X	
Magnetizing technique	X	
Magnetizing current type or amperage outside range qualified	X	
Surface preparation	X	
Magnetic particles (fluorescent/visible, particle size, wet/dry)	X	
Method of particle application	X	
Method of excess particle removal	X	
Minimum light intensity (visible/black)	X	
Existing coatings, greater than the thickness qualified	X	
Nonmagnetic surface contrast enhancement, when utilized	X	
Examination part surface temperature outside of the temperature range recommended by the manufacturer of the particles or as qualified	X	
Shape or size of the examination object		X
Equipment of the same type		X
Temperature (within those specified by manufacturer or as previously qualified)		X

9.2.6 Records of Qualification

9.2.6.1 Technique Sketch

A technique sketch shall be prepared for each different geometry examined showing the part geometry, cable arrangement and connections, magnetizing current for each circuit, and the areas of examination where adequate field strengths are obtained.

9.2.6.2 Recording of Indications

Rejectable indications shall be recorded. As a minimum, the type of indications (linear or rounded), location, and extent (length or diameter or aligned) shall be recorded.

9.2.6.3 Examination Report

Following the completion of MT, an examination report shall be prepared, which shall include the following as a minimum:

a) material identification (description, grade, material traceability);

b) identification of the procedure used including revision;

c) quantity of parts examined, description of and thickness of material;

d) surface condition (i.e. as forged, as cast, abrasive blasted, machined);

e) magnetic particle equipment and type of magnetizing current;

f) bath strength, as applicable;

g) amperage/amp turns used;

h) magnetic particles (visible or fluorescent, wet or dry);

i) ambient light intensity;

j) black light intensity, as applicable;

k) map or record of indications;

l) results of examination;

m) MT technician's name, signature, and certification level;

n) date of examination.

Multiple entries of the same test will be itemized and may appear on one (1) report. Reports for unacceptable parts shall include a sketch or description indicating locations of defects. All recorded results shall be identified, filed, and made available for review. Where a signature is a requirement of this standard, the signature may be electronic.

9.3 Liquid Penetrant Examination (PT)

9.3.1 General

PT shall be performed using either a color contrast (visible) penetrant or a fluorescent type penetrant with one of the following three penetrant processes:

a) water washable,

b) post-emulsifying,

c) solvent removable.

The visible and fluorescent penetrants used in combination with these three penetrant methods result in six PT processes. Each of the various processes has been designed for specific uses such as critical service items, volume of parts, portability, or localized areas of examination. The process selected will depend accordingly on the service requirements.

9.3.2 Calibration and Verification Requirements

PT equipment shall be calibrated and verified for performance and accuracy at intervals indicated in Table 4.

Table 4—Required Calibration and Verification for Liquid Penetrant Examination

Check [a]	Maximum Interval
Penetrants and emulsifiers	Monthly for contamination
Dryers	Monthly for thermostat accuracy
Light meters, fluorescent (black), and visible light	6 months
[a] The maximum interval may be extended when substantiated by actual technical/reliability data.	

9.3.3 Procedures

PT shall be performed in accordance with a written procedure, which shall as a minimum contain the requirements listed in Table 5.

9.3.4 Procedure Qualification

Each procedure shall be supported with a documented qualification record to demonstrate the effectiveness of the procedure. One or more of the following may be used to demonstrate discontinuity detection:

— actual production parts with known discontinuities of the type, location, and size needed for verification;

— representative reference parts containing discontinuities of the type, location, and size specified in the acceptance criteria and examined in accordance with a written procedure;

— comparator blocks or other test panels (e.g. TAM panels, crack panels).

9.3.5 Procedure Requalification

A change of a requirement in Table 5 identified as an essential variable shall require requalification of the written procedure. A change of a requirement identified as a nonessential variable does not require requalification of the written procedure. All changes of essential or nonessential variables from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

9.3.6 Equipment and Facilities

9.3.6.1 General

Equipment used in the penetrant examination process shall be constructed and arranged to permit a uniform and controlled operation. The equipment shall meet all applicable national and local safety requirements as well as the requirements specified herein.

9.3.6.2 Viewing Areas

Lighting shall comply with the requirements of the applicable standards referenced within the procedure being qualified.

Table 5—Requirements of a Liquid Penetrant Examination Procedure

Requirement	Essential Variable	Nonessential Variable
The minimum detectable indication type (linear or rounded) and size (length or diameter or aligned)	X	
Identification of and any change in type or family group of penetrant materials including developers, emulsifiers, etc.	X	
Surface preparation (finishing and cleaning, including type of cleaning solvent)	X	
Method of applying penetrant	X	
Method of removing excess surface penetrant	X	
Hydrophilic or lipophilic emulsifier concentration and dwell time in dip tanks and agitation time for hydrophilic emulsifiers	X	
Hydrophilic emulsifier concentration in spray applications	X	
Method of applying developer	X	
Minimum and maximum time periods between steps and drying aids	X	
Decrease in penetrant dwell time	X	
Increase in developer dwell time (interpretation time)	X	
Minimum light intensity	X	
Surface temperature outside 40 °F to 125 °F (5 °C to 52 °C) or as previously qualified	X	
Performance demonstration, when required	X	
Personnel qualification requirements		X
Materials, shapes, or sizes to be examined and the extent of examination		X
Post-examination cleaning technique		X

9.3.7 Process Validation

The penetrant system's overall performance shall be checked as specified in Table 6. The check shall be performed by processing a known defect standard (comparator block) conforming to 9.3.4 through the system using in-use penetrant, emulsifier (if used), and developer and appropriate processing parameters. The resulting indications will then be compared to the indications obtained using unused penetrant, emulsifier (if used), and developer. This comparison may be made with records of previously obtained indications or with a similar known defect standard processed with unused material. When the sensitivity or performance of the in-use materials falls below the performance of the unused materials, the in-use materials shall be checked in accordance with ASTM E1417 prior to conducting any further penetrant examinations. Unacceptable materials shall be discarded or otherwise corrected in accordance with the manufacturer's instruction.

9.3.8 Records of Examination

9.3.8.1 Recording of Indications

Rejectable indications shall be recorded. As a minimum, the type of indications (linear or rounded), location, and extent (length or diameter or aligned) shall be recorded.

Table 6—Required Performance Tests and Frequency for Liquid Penetrant Systems

Tests	Frequency
Penetrant contamination [a]	Daily
Penetrant brightness	Quarterly
Water content—water-based penetrant (Method A)	Weekly
Water content—non-water-based penetrant (Method A)	Monthly
Lipophilic emulsifier water content [b]	Monthly
Hydrophilic emulsifier concentration [b]	Weekly
Dry developer condition [b]	Daily
Aqueous developer contamination—soluble and suspendable	Daily
Aqueous developer concentration—soluble and suspendable	Weekly
Penetrant system performance [c]	Daily
Water-washable penetrant removability	As required per ASTM E1417
Emulsifier removability	As required per ASTM E1417
Comparative penetrant sensitivity	As required per ASTM E1417
Black light intensity	Daily
Black light integrity weekly	Weekly
Special UV lighting	Daily
Visible light intensity	Weekly
Light meter calibration [b]	Semiannually
Inspection area cleanliness [a]	Daily
Inspection area ambient light intensity	Quarterly
Water wash pressure check [a]	Start of each working shift
Water pressure gage calibration [b]	Semiannually
Water wash temperature check [a]	Start of each working shift
Water temperature gage calibration [b]	Semiannually
Drying oven calibration [b]	Quarterly

[a] Need not be recorded.

[b] The maximum time between verifications or checks may be extended when substantiated by technical data.

[c] Not required for solvent-removable examinations.

9.3.8.2 Examination Report

Following the completion of PT, an examination report shall be prepared, which shall include the following as a minimum:

— material identification (description, material traceability);

— identification of the procedure used including revision;

— quantity of parts examined, description of material;

— condition and stage of manufacture (i.e. as forged, as cast, abrasive blasted, machined);

— type and method of liquid penetrant used;

— black light intensity, when applicable;

— results of examination;

— PT technician's printed name, signature, and certification level;

— date of examination.

Multiple entries of the same test shall be itemized and may appear on one (1) report. Separate reports are required for acceptable and rejectable results. Reports for unacceptable parts shall include a sketch showing locations of defects. All recorded results shall be identified, filed, and made available for review. Where a signature is a requirement of this standard, the signature may be electronic.

9.4 Ultrasonic Examination (UT)

9.4.1 General

UT uses high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, and more.

9.4.2 Procedures

UT shall be performed in accordance with a written procedure, which shall as a minimum contain the requirements listed in Table 7.

9.4.3 Procedure Qualification

Each procedure shall be supported with a documented qualification record to demonstrate the effectiveness of the procedure. One or more of the following may be used to demonstrate discontinuity detection:

— actual production parts with known discontinuities of the type, location, and size needed for verification;

— representative reference parts containing discontinuities of the type, location, and size specified in the acceptance criteria and examined in accordance with a written procedure;

— calibration block in accordance with 9.4.7.4.1.

9.4.4 Procedure Requalification

A change of a requirement in Table 8 identified as an essential variable shall require requalification of the written procedure. A change of a requirement identified as a nonessential variable does not require requalification of the written procedure. All changes of essential or nonessential variables from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

9.4.5 Calibration and Verification Requirements

UT equipment shall be calibrated and verified for performance and accuracy as indicated in Table 7.

Table 7—Calibration and Verification Requirements for Ultrasonic Examination Equipment

Calibration Requirement	Verification Requirement
Instrument linearity checks	The requirements of 7.2 shall be met at intervals not to exceed three months for analog type instruments and one year for digital type instruments, or prior to first use thereafter.
Screen height linearity	Evaluate in accordance with ASME *BPVC*, Section V, Article 4, Appendix I.
Amplitude control linearity	Evaluate in accordance with ASME *BPVC*, Section V, Article 4, Appendix II.

9.4.6 Techniques

UT may be performed using the following contact and/or immersion techniques:

— straight beam,

— angle beam (shear wave).

9.4.7 Equipment

9.4.7.1 Instrument

A pulse-echo type of ultrasonic instrument shall be used. The instrument shall be capable of operation at frequencies over the range of at least 1 MHz to 5 MHz and shall be equipped with a stepped gain control in units of 2.0 dB or less. The reject control shall be in the “off” position for all examinations. The instrument, when required because of the technique being used, shall have both send and receive jacks for operation of dual search units or a single search unit with send and receive transducers.

9.4.7.2 Search Units

The nominal frequency shall be from 1 MHz to 5 MHz unless variables such as production material grain structure require the use of other frequencies to assure adequate penetration or better resolution. Search units with contoured contact wedges may be used to aid ultrasonic coupling.

9.4.7.3 Couplant

The couplant, including additives, shall not be detrimental to the material being examined.

9.4.7.4 Calibration Blocks

9.4.7.4.1 General

Calibration blocks shall conform to a recognized industry, national, or international standard relevant to the scope of work performed by the NDE service supplier such as ASTM E428 or ASME *BPVC,* Section V. Calibration blocks shall be serialized and certified to applicable standards.

9.4.7.4.2 Material Requirements

The material from which the block is fabricated shall be of the same product form, material specification, or equivalent and shall be acoustically similar in velocity and attenuation to the material being examined. The finish on the scanning surface of the block shall be representative of the scanning surface finish on the material to be examined. Whenever practical, the application of a transfer correction, as addressed in the written procedure, is applied to the scanning surface when its surface is not representative of the reference standard surface.

9.4.8 Calibration (Setup for Examination)

9.4.8.1 General

Calibrations shall include the complete ultrasonic system and shall be performed prior to use of the system in the thickness range under examination in accordance with the NDE service supplier's written specification.

9.4.8.2 Calibration Surface

Calibrations shall be performed from the surface (clad or unclad; convex or concave) corresponding to the surface of the material for which the examination will be performed.

9.4.8.3 Couplant

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

9.4.8.4 Contact Wedges

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

9.4.8.5 Instrument Controls

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.

9.4.8.6 Temperature

For contact examination, the temperature differential between the calibration block and examination surfaces shall be within 25 °F (14 °C). For immersion examination, the couplant temperature for calibration shall be within 25 °F (14 °C) of the couplant temperature for examination.

9.4.8.7 Calibration Confirmation

When any of the examination variables specified in Table 8 are changed, a calibration check shall be made to verify distance range points and sensitivity setting.

9.4.8.8 Calibration Checks

A calibration check in accordance with specified requirements shall be performed at the completion of each examination or series of similar examinations and when examination personnel (except for automated equipment) are changed.

NOTE Interim calibration checks between the required initial calibration and the final calibration check may be performed. The decision to perform interim calibration checks should be based on ultrasonic instrument stability (analog vs digital), the risk of having to conduct reexaminations, and the benefit of not performing interim calibration checks.

9.4.9 Records

9.4.9.1 Recording Indications

Nonrejectable indications shall be recorded, when specified.

Rejectable indications shall be recorded. As a minimum, the type of indication (i.e. crack, lamination, inclusion, etc.), location, and extent (i.e. length) shall be recorded.

Table 8—Requirements of an Ultrasonic Examination Procedure

Requirement	Essential Variable	Nonessential Variable
Material types and configurations to be examined, including thickness dimensions and product form (casting, forging, plate, etc.) [a]	X	
Weld configurations to be examined, including thickness dimensions and base material product form (pipe, plate, etc.) [a]	X	
Personnel qualification requirements		X
Personnel performance requirements, when required	X	
The surfaces from which the examination shall be performed	X	
Surface condition (examination surface, calibration block)		X
Couplant: brand name or type		X
Technique(s) (straight beam, angle 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	
Automatic alarm and/or recording equipment, when applicable		X
Scanning (manual vs automatic)	X	
Method for sizing indications	X	
Method for discriminating geometric indications from flaw indications [b]	X	
Computer enhanced data acquisition, when used	X	
Records, including minimum calibration data to be recorded (e.g. instrument settings)		X
Scan overlap (decrease only)	X	

[a] Applies to procedures for the examination of materials.

[b] Applies to procedures for the examination of welds.

9.4.9.2 Examination Records

For each UT, the following information shall be recorded:

a) procedure identification and revision;

b) ultrasonic instrument identification (including manufacturer’s serial number);

c) search unit(s) identification (including manufacturer’s serial number, frequency, and size);

d) beam angle(s) used;

e) couplant used, brand name or type;

f) search unit cable(s) used, type and length;

g) special equipment, when used (search units, wedges, shoes, automatic scanning equipment, recording equipment, etc.);

h) computerized program identification and revision, when used;

i) calibration block identification;

j) simulation block(s) and electronic simulator(s) identification, when used;

k) instrument reference level gain and, if used, damping and reject setting(s);

l) calibration data [including reference reflector(s), indication amplitude(s), and distance reading(s)];

m) data correlating simulation block(s) and electronic simulator(s), when used, with initial calibration;

n) identification of material or volume scanned;

o) surface(s) from which examination was conducted, including surface condition;

p) map or record of rejectable indications detected or areas cleared;

q) areas of restricted access or inaccessible areas;

r) examination personnel identity and qualification level;

s) date of examination.

NOTE Items b) through m) may be included in a separate calibration record provided the calibration record identification is included in the examination record.

9.4.9.3 Examination Report

A report of the examinations shall be made. The report shall include those records indicated in 9.4.9.1 and 9.4.9.2.

9.5 Radiographic Examination (RT)

9.5.1 General

RT involves the use of penetrating gamma or X-radiation to examine materials and welds for discontinuities. An X-ray generator or radioactive isotope is used as a source of radiation. Radiation is directed through a part and onto film or other imaging media. The resulting radiograph shows the dimensional features of the part with possible discontinuities indicated as density changes on the film.

9.5.2 Calibration and Verification Requirements

Radiographic examination equipment shall be calibrated and verified for performance and accuracy at intervals indicated in Table 9.

Table 9—Calibration and Verification Requirements for Radiographic Examination Equipment

Calibration Requirement	Verification Requirement
Verification of source size	The equipment manufacturer's or supplier's publications, such as technical manuals, decay curves, or written statements documenting the actual or maximum source size or focal spot, shall be acceptable as source size verification.
Determination of source size	a) *X-ray Machines*—For X-ray machines operating at 500 kV and less, the focal spot size may be determined by the Pinhole Method 1 or in accordance with ASTM E1165. b) *Gamma Sources*—Gamma source size shall be determined in accordance to ASTM-E1114 (for Iridium-192), EN 12679 (for IR-192, Co-60 and Se-75), manufacturer's certification, or other appropriate written standards.

9.5.3 Facility Requirements

Radiographic exposure areas shall be clean and equipped so that acceptable radiographs may be produced in accordance with the requirements of this standard.

Darkroom facilities, including equipment and materials, shall be capable of producing uniform radiographs free of blemishes or artifacts, which might interfere with interpretation in the area of interest.

The film viewing room or enclosure shall be an area with subdued lighting to preclude objectionable reflective shadows or glare on the radiograph that interfere with the interpretation process.

The NDE service supplier shall develop a workable examination technique recorded as a written procedure that is capable of consistently producing the desired results and radiographic quality level. All written procedures shall be approved by an individual qualified and certified as a Level III for radiography in accordance with Section 5.

The written procedure shall contain, as a minimum, the following information, either directly or by reference to the applicable requirements:

a) material type (e.g. casting, plate, pipe, weld) and thickness range;

b) isotope or maximum X-ray voltage to be used;

c) source-to-object distance;

d) distance from source side of object to film;

e) source: diagonal size or focal spot size, and serial number;

f) recording media (details of digital technique or film brand and designation);

g) screens used;

h) image quality indicators;

i) film density or pixel intensity;

j) quality level and sensitivity.

NOTE When a standard hole-type penetrameter is used, quality level is stated as a-bT, where a is the penetrameter thickness, expressed as a percentage of the maximum thickness of the specimen, and b is the diameter of the smallest discernible hole, expressed as a multiple of penetrameter thickness, T.

EXAMPLE The 2-2T quality level means that the penetrameter thickness equals 2 % of maximum specimen thickness, and the smallest discernible penetrameter hole has a diameter equal to twice the penetrameter thickness.

9.5.4 Process Validation

Demonstration of the density and image quality indicator image requirements of the written procedure on production or technique radiographs shall be considered satisfactory evidence of process validation.

9.5.5 Equipment and Materials

9.5.5.1 General

The radiation source shall be capable of producing sufficient energy and intensity to examine materials in accordance with required specifications.

9.5.5.2 X-ray

X-ray equipment should contain voltage and amperage controls (when applicable) and meters, a timer to time the length of the exposure, or other approved controls, and provisions for positioning the tube head and the part being X-rayed (when applicable). The suitability of these exposure parameters shall be demonstrated by attainment of the required radiographic quality level.

9.5.5.3 Gamma Ray

Gamma rays are produced by radioactive materials, such as Cobalt-60, Iridium-192, and Selenium-75. Different isotopes emit gamma rays in a specific energy range. Isotope sources that are used shall be capable of demonstrating the required radiographic quality level.

9.5.5.4 Intensifying Screens

Intensifying screens may be used when performing radiographic examination in accordance with this standard. Fluorescent intensifying screens shall not be used.

9.5.5.5 Image Quality Indicator

Image quality indicators shall be either the hole type or the wire type manufactured in accordance with recognized industry standards.

9.5.5.6 Densitometers

Densitometers, when used, shall be capable of measuring the light transmitted through a radiograph with a film density up to 4.0 with a density unit resolution of 0.02. When film densities greater than 4.0 are permitted, a densitometer capable of measuring densities up to the maximum density permitted is required.

9.5.6 Process Control Checks

Devices used in the performance of radiographic examination shall be checked in accordance with Table 10.

Table 10—Process Control Checks for Radiographic Examinations

Check	Frequency
Discontinuity image measuring device	When procured
Image quality indicators	Certified when procured Check (condition) prior to use
Automatic processing: Processor performance daily Base fog daily Developer temperature prior to use Replenishment rate Transport speed	 Daily Daily Prior to use When solutions are changed During maintenance or repair
Manual processing: Processing performance daily Base plus fog monthly Developer temperature prior to use	 Daily Monthly Prior to use
Densitometer: Verification check Calibration check	 Each shift 90 days
Light meters	Annual
Viewer light intensity	When procured
Thermometer calibration	6 months
Ambient visible light	6 months
Step wedge calibration	Annual

9.5.7 Quality of Radiographs

All radiographs shall be free from mechanical, chemical, or other blemishes to the extent that they do not mask and are not confused with the image of any discontinuity in the area of interest of the object being radiographed.

9.5.8 System of Identification

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 NDE service supplier's symbol or name and the date of the radiograph shall be plainly and permanently included on the radiograph. This identification system does not necessarily require that the information appear as radiographic images. In any case, this information shall not obscure the area of interest.

9.5.9 Records

9.5.9.1 Radiographic Technique Record

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

a) identification as required by 9.5.8;

b) marker placement, if essential for interpretation;

c) number of radiographs (exposures);

d) X-ray voltage or isotope type used;

e) source: diagonal size or focal spot size, and serial number;

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

g) source-to-object distance;

h) distance from source side of object to film;

i) film or digital imaging plates manufacturer and manufacturer's type/designation;

j) number of film in each film holder/cassette;

k) single- or double-wall exposure;

l) single- or double-wall viewing.

9.5.9.2 Radiograph Review Report

The NDE service supplier shall prepare a radiograph review report. As a minimum, the following information shall be provided:

a) a listing of each radiograph location;

b) the information required in 9.5.9.1 by inclusion or by reference;

c) evaluation and disposition of the material(s) or weld(s) examined;

d) identification (name) of the NDE service supplier's representative who performed the final acceptance of the radiographs;

e) date of manufacturer's evaluation.

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