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

API STANDARD 20D

BALLOT - 6556

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1 Scope

1.1 Purpose

This standard specifies requirements for the qualification of Nondestructive Examination (NDE) services of the suppliers by defining the requirements for establishing procedures and qualification/ validation of procedures used in the manufacturing, servicing, and/or service 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, eddy current, conventional as well as advanced radiography, and conventional as well as advanced ultrasonic methods of NDE.

2 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any addenda) 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 [2] SNT-TC-1A, Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

ASNT ACCP-CP-1, ASNT Central Certification Program

ASTM [3] 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.

ASTM E709 2021 Edition, Standard Guide for Magnetic Particle Testing

[1] ASME International, Two Park Avenue, New York, New York 10016-5990, www.asme.org.
[2] ASNT 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, P.O. Box C700, West Conshohocken, Pennsylvania 19428-2949, www.astm.org.

EN[2] 12679, Non-destructive testing—Determination of the Size of Industrial Radiographic Sources—Radiographic Method.

ISO[3] 9001, Quality Management System Requirements

ISO 9712, Non-destructive testing—Qualification and certification of NDT personnel

ISO 17025, General requirements for competence of testing and calibration.

ISO 17020, General requirements for competence of testing and calibration

3 Terms, Definitions, Acronyms, Symbols, and Units

For purposes of this standard, the following terms, definitions, and acronyms apply. Definitions in ASTM E1316 shall apply unless otherwise stated below.

3.1 calibration
Process of comparison to a standard of known accuracy, comparison of results against TMMDE (testing, measuring, monitoring, and detection equipment) acceptance criteria, and, if applicable, making needed adjustment(s).
NOTE Calibration of non-adjustable equipment can be referred to as verification.

3.2 complex geometry
Components whose configuration does not permit 100% coverage of the area of interest or provide challenges to identify surface or volumetric indications.

3.3 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.
NOTE The term NDE may be known as NDT or NDI in other standards.

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

3.5 quantitative quality indicator
QQI
A flawed shim used to establish proper field direction and field strength during magnetic particle examination.

3.6 TAM Panel
Penetrant system testing and monitoring panel used as a quick and efficient means for determining the continued serviceability of liquid penetrant inspection systems.

[2] European Committee for Standardization, Rue de la Science 23, B-1040 Brussels, Belgium, www.cen.eu.

[3] International Organization for Standardization, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

3.7 traceability
The ability to verify the history, location, or application of an item by means of documented recorded identification.
NOTE When considering a product or a service, traceability can relate to the origin of materials and parts, the processing history, or the distribution and location of the product or service after delivery.

3.8 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 performed any time there is concern about the examination or instrument response.

3.9 artificial Intelligence
The theory and development of computer systems that normally require human intelligence.
EXAMPLE Visual perception, speech recognition, decision making, etc.

3.10 reader sheet
A reader sheets contains evaluation of each radiographic view/location that includes information on acceptable and rejectable indications in accordance with the specified acceptance criteria.

4 Quality Management System (QMS)

The NDE service provider shall establish, document, implement, and maintain at all times a Quality Management System (QMS) conforming to API Specification Q1, API Specification Q2, ISO 17020, ISO 17025, or ISO 9001. In addition, the NDE service provider shall conform to the applicable requirements of this standard.

5 Facility Requirements

The NDE Service provider shall have the following on-site capabilities, at a minimum:

a) A facility to store and maintain equipment and associated consumables that protects from damage and deterioration.
b) Appropriate handling and lifting equipment.
c) Inspection and test equipment applicable to each method and location (e.g. field work).
d) Safety program to address staff, public, and environmental concerns with NDE methods.

6 Responsibilities and Duties

The NDE service supplier shall:

a) Develop and qualify NDE procedures.
b) Maintain and calibrate equipment in accordance with service supplier's written procedure and this standard.
c) Perform examinations in accordance with developed and qualified/validated procedures.
d) Perform examinations for which its employees are qualified and certified.
e) Inform the purchaser of discrepancy or limitation imposed on the testing accuracy by such factors as surface finish, form, shape, or procedure.
f) Inform the purchaser of irregularity or deficiency noted in the purchaser's documents.
g) Submit the results of the examination in a written report to the purchaser.

7 Personnel Requirements

Personnel performing NDE shall be certified in accordance with the service supplier's documented qualification and certification program. The service supplier documented qualification and certification program shall be in conformance with the requirements specified in ISO 9712, ASNT-ACCP-CP-1 (ASNT-9712) or ASNT 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.

8 Procedure Requirements

8.1 The NDE service supplier shall have a system of written procedures for each NDE service performed in accordance with this procedure and shall be in conformance with the applicable nationally and internationally recognized codes, standards, specifications, and contractual requirements.

8.2 All NDE procedures shall be qualified / validated as detailed in Section 10, before applying to production.

8.3 At least one individual approving the procedure shall be qualified and certified at Level III in that method. (See Section 7).

8.4 While the use of Artificial Intelligence (AI) is gaining in application, limitations in technical (NDE) qualification and interpretation of anomalies (application of knowledge) the use of AI shall be restricted to the following, when approved within procedure:

a) Performing scanning routines
b) Identifying anomalies based on detection levels preset by a level 2 or higher.

8.5 Activities where AI is not permitted include:

a) Setting of detection levels
b) Evaluation of anomalies detected
c) Making accept / reject decisions on the examined product.

9 NDE Equipment and Calibration

9.1 Inventory

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

a) Name of the manufacturer.
b) Equipment model and serial number.
c) Characteristics subject to calibration.
d) Range of operation and range of calibration.
e) Reference to nationally or internationally recognized standards used for calibration.
f) Frequency of calibration.
g) Allowable tolerances or maximum sensitivity.

9.2 Calibration

9.2.1 Equipment used to inspect, test, or examine material or other equipment shall have a unique identification, and be controlled, calibrated, and adjusted at specified intervals in accordance with documented manufacturer instructions and shall be in accordance with nationally or internationally recognized standards specified by the manufacturer, or as required by this standard, whichever is more stringent.

9.2.2 The accuracy of the equipment shall as a minimum meet the manufacturer's requirements.

9.2.3 Records of calibration shall be maintained in accordance with section 11.0.

9.2.4 Calibration intervals for measuring and test equipment shall be established based on repeatability, amount of usage, environment, and past history for that type of instrument. The maximum time between calibrations may be extended when substantiated by actual technical/reliability data.

9.2.5 The initial calibration interval shall be as specified in relevant sections of 10.0, until a recorded calibration history for that instrument can be established. Intervals may then be lengthened or shortened. The calibration interval cannot be increased by more than twice the previous interval and shall not exceed more than one year.

NOTE The calibration intervals may not exceed contractual requirements.

10 NDE Process Requirements

10.1 General

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

For those NDE methods/techniques which are not specifically addressed in this standard, (e.g. Acoustic Emission), the requirements of sections 1 through 9, requirements of section 10.11 for Miscellaneous methods and section 11 shall be followed to claim conformance to this specification.

10.2 Magnetic Particle Examination (MT)

10.2.1 General

MT uses a magnetic field to attract magnetic particles to a leakage flux established by the discontinuities that are at or near the surface in the ferro magnetic materials.

10.2.2 Procedures

The NDE service supplier shall develop a written procedure that conforms to the standards and specifications relevant to the scope of work, which shall as a minimum contain or reference the requirements listed below. The written procedure shall establish a single value, or range of values, for each requirement identified as an essential variable in Table 1.

a) Examination material types, shapes, sizes, product form and the extent of examination.

b) Personnel qualification requirements and performance demonstration requirements.
c) Procedure validation and revalidation requirements.
d) Part Surface condition, preparation, and pre-cleaning requirements.
e) Calibration and verification requirements, System performance verification.
f) Temperature range of the magnetic particles and the examination part surface temperature.
g) Magnetizing techniques/ methods.
h) Type of Magnetic particle equipment.
i) Type of Magnetizing currents.
j) Means of establishing part magnetization and direction of magnetic field.
k) Technique sheet for complex geometries, where applicable.
l) Magnetic field strength (ampere-turns, Amperage range, duration of application).
m) Method of confirming the magnetic field strength and direction.
n) Type of magnetic particles (fluorescent/visible/dual, particle size, wet/dry), bath concentration.
o) Type of coatings and thickness of coatings on which examination can be done.
p) Type of nonmagnetic surface contrast enhancement and coating thickness.
q) Method of magnetic particle application and controls.
r) Method of excess particle removal.
s) Minimum required light intensity (visible/ambient/ UV-A light).
t) Interpretation and evaluation of indications and acceptance/rejection criteria.
u) Methods of identification of areas inspected and marking of indications.
v) Demagnetizing technique and acceptable levels of residual magnetic field.
w) Post-examination cleaning requirements and methods.
x) Documentation requirements and type of records

10.2.3 Procedure Qualification (Validation)

Essential variables listed in Table 1 shall be used for procedure qualification/validation.

Each procedure shall be supported with a documented qualification/validation record to demonstrate the effectiveness of the procedure. One or more of the following shall be used for qualification/validation of the procedure.

a) QQI (per AS 5371)

b) actual production parts with known discontinuities of the type, location, and size needed for verification.

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

NOTE Artificial discontinuities may be fabricated to meet a particular need.

Table 1—Essential Variables of a Magnetic Particle Examination Procedure

Item	Requirement
a	Magnetizing technique
b	Magnetizing current type or amperage outside range qualified
c	Surface preparation
d	Magnetic particles (fluorescent/visible, color, particle size, wet/dry)
e	Method of particle application
f	Method of excess particle removal
g	Minimum light intensity (visible/ UV-A/ Ambient)
h	Existing coatings, greater than the thickness qualified
i	Nonmagnetic surface contrast enhancement, when used
j	Examination part surface temperature outside of the temperature range recommended by the manufacturer of the particles or as qualified
k	Performance demonstration, when required.

10.2.4 Procedure Re-qualification (Re-validation)

A change of a requirement identified as an essential variable in Table 1 shall require requalification/revalidation of the written procedure. All changes from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

10.2.5 Calibration and Verification Requirements

MT equipment shall be calibrated and verified for performance and accuracy at the intervals specified in Table 2 and Table 3 below.

Table 2—Required Calibration Intervals for Magnetic Particle Examination

Equipment Calibration	Maximum Time Between Calibration [a] [b]
Ammeter accuracy	Semi-annually
Timer control	Semi-annually
Quick break	Semi-annually
Yoke dead weight check	Semi-annually
UV-A and white light meters	Semi-annually
Gaussmeter accuracy	Semi-annually

[a] The maximum time between calibrations may be extended when substantiated by actual technical/reliability data. (refer to section 9.2)
[b] Shall be additionally calibrated whenever a malfunction is suspected; or whenever electrical maintenance that might affect equipment accuracy is performed.

Table 3—Required Verification Intervals for Magnetic Particle Examination

Item	Maximum Time Between Verification [a]
Lighting	
Visible light intensity	Prior to use
Ambient light intensity	Prior to use
UV-A lamp intensity	Prior to use
Battery-powered UV-A light intensity check.	Prior to and after each use
UV-A lamp integrity [b]	Prior to use
Yoke dead weight check	Prior to use
System performance [c]	Daily or Prior to use
Wet Particle [d]	
Wet particle concentration	8 hours or every shift change
Wet particle contamination [b]	1 week
Water break test	Daily
Expiration Date [e]	Verify before use

[a] When the inspection system is in operation.
[b] Need not be recorded.
[c] Shall be performed in accordance with ASTM E709 Section 20.8.
[d] Applies to wet particles that are provided as not ready for use and require mixing to a concentration, and are recovered, or reused, or both.
[e] Consumables shall not be used after the expiration date. Consumables shall meet the requirements of procedure.

10.2.6 Techniques

Qualification/ validation shall be performed on all techniques detailed in the written procedure used for inspection of products being supplied.

10.2.7 Magnetic Particle Examination Equipment

The magnetic particle testing equipment, such as magnetizing equipment, light meters, UV lamps/ lights, magnetic field indicators, and magnetic powders, shall meet the requirements specified in the MT procedure.

10.2.8 Technique verification

Before starting inspection, magnetic field strength and field direction shall be verified using field indicators as defined in the MT procedure.

10.2.9 Records of Qualification and Examination

10.2.9.1 Recording of Indications

Non-rejectable indications shall be recorded when specified.

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

10.2.9.2 Qualification/Re-qualification and Examination Records

10.2.9.2.1 Qualification/Re-qualification records.

Records of the qualification/ requalification results shall be maintained and retained per this section.

10.2.9.2.2 Examination Records

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

a) Material identification (description, grade, material traceability), the thickness of the material.
b) Identification of the procedure used and acceptance criteria used, including revision.
c) Quantity of parts examined.
d) Surface condition (i.e., as forged, as cast, abrasive-blasted, machined)
e) Magnetic particle equipment, including serial number and type of magnetizing current.
f) Amperage/amperage-turns used.
g) Magnetic particles type (visible or fluorescent, wet, or dry); including manufacturing batch number and grade, wet bath concentration (when used).
h) Lighting equipment and light intensity.
i) UV-A lamp, including serial number and intensity, when used.
j) Residual field after demagnetization,(not applicable for AC yoke).
k) Map or record of indications.
l) Traceability of equipment used for measuring the indications.
m) Results of examination.
n) MT technician's signature, printed full name, and certification level
o) 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.

10.3 Liquid Penetrant Examination (PT)

10.3.1 General

PT uses capillary action to detect discontinuities which are open to the surface in non-porous materials.

10.3.2 Procedures

The NDE service supplier shall develop a written procedure that conforms to the standards and specifications relevant to scope of work, which shall as a minimum contain or reference the requirements listed below. The written procedure shall establish a single value, or range of values, for each requirement identified as an essential variable in Table 4.

a) Examination material types, shapes, sizes, product form and the extent of examination.
b) Personnel qualification requirements and performance demonstration requirements.
c) Procedure validation and revalidation requirements.
d) Part surface condition, preparation, and pre-cleaning requirements.
e) Calibration and verification requirements, System performance verification.
f) Temperature range of the penetrant materials and the examination part surface temperature.
g) Penetrant testing techniques/methods.
h) Type of penetrant materials (classification, brands, and designations).
i) Minimum time limit for drying after preparation.
j) Method of applying penetrant.

k) Minimum and maximum times for penetrant dwell time.
l) Method of removing excess surface penetrant and controls.
m) Type of Emulsifiers and their concentration in spray applications
n) Minimum and maximum dwell times for emulsifiers (hydrophilic or lipophilic) in dip tanks, agitation times
o) Minimum and maximum time limits for penetrant removal with lipophilic emulsifier.
p) Maximum time limits for penetrant removal with hydrophilic emulsifier during pre-rinse/ immersion/ water-emulsifier spray, water immersion or spray post rinse.
q) Maximum time limits for drying after penetrant removal for solvent removable penetrants, water - washable and post emulsifiable penetrants.
r) Method of applying developer
s) Maximum time limit for developer applications
t) Minimum and maximum time limits for developing dwell time and interpretation time.
u) Minimum required light intensity (visible/ ambient / UV-A light).
v) Interpretation and evaluation of indications and acceptance/rejection criteria.
w) Methods of identification of areas inspected and marking of indications.
x) Post-examination cleaning methods.
y) Documentation requirements and type of records.

10.3.3 Procedure Qualification (Validation)

Essential variables listed in Table 4 shall be used for procedure validation.

Each procedure shall be supported with a documented validation record to demonstrate the effectiveness of the procedure. One or more of the following shall be used for qualification/validation of the procedure:

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

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

c) test panels with a known defect sizes. (e.g., TAM panels, crack panels).

NOTE Artificial discontinuities may be fabricated to meet a particular need.

Table 4—Essential Variables of a Liquid Penetrant Examination Procedure

Item	Requirement
a	Identification of and any change in type or manufacturer or family group of penetrant materials, including developers, emulsifiers, etc.
b	Surface preparation (finishing and cleaning, including type of cleaning solvent)
c	Method of applying penetrant
d	Method of removing excess surface penetrant and controls (water pressure, water temperature etc,,)
e	Hydrophilic or lipophilic emulsifier concentration and dwell time in dip tanks and agitation time for hydrophilic emulsifiers
f	Hydrophilic emulsifier concentration in spray applications
g	Method of applying developer
h	Minimum and maximum time periods between steps and drying aids
i	Decrease in penetrant dwell time

j	Increase in developer dwell time (interpretation time)
k	Minimum light intensity
l	Surface temperature outside 40 °F to 125 °F (5 °C to 52 °C) or as previously qualified
m	Performance demonstration, when required

10.3.4 Procedure Re-qualification (Re-validation)

A change in a requirement identified as an essential variable in Table 4 shall require revalidation of the written procedure. All changes from those specified within the written procedure shall require revision of or an addendum to the written procedure.

10.3.5 Calibration and Verification Requirements

PT equipment shall be calibrated and verified for performance and accuracy at intervals indicated in Table 5 and Table 6.

Table 5—Required Calibration Intervals for Liquid Penetrant Examination

Equipment Calibration	Maximum Time Between Calibration [a] [b]
Water and air pressure gauge calibration	Semi-annually
Water temperature gauge calibration	Semi-annually
Drying oven calibration	Semi-annually
UV-A Radiometer and Photometer	Semi-annually

[a] The maximum time between calibrations may be extended when substantiated by actual technical/reliability data. (refer to section 9.2)
[b] Shall be additionally calibrated, whenever malfunction is suspected; or whenever electrical maintenance that might affect equipment accuracy is performed.

Table 6—Required verification intervals for Liquid Penetrant Systems

Tests	Maximum Time Between Verification
Penetrants [a]	
Penetrant contamination [b]	Daily
Penetrant brightness	Semi-annually
Water content—water-based penetrant (Method A)	Weekly
Water content—non-water-based penetrant (Method A)	Monthly
Emulsifier	
Lipophilic emulsifier water content	Monthly
Hydrophilic emulsifier concentration	Weekly
Developer	
Dry developer condition	Daily
Aqueous developer contamination—soluble and suspendable [a b]	Daily
Aqueous developer concentration—soluble and suspendable [a]	Weekly
Penetrant system performance [c d]	Daily
Water wash pressure check [b]	Prior to use
Water wash temperature check [b]	Prior to use
Air Pressure Gauge Check [b]	Prior to use
Inspection area cleanliness [b]	Daily
Lighting	
Visible light intensity	Prior to use
Ambient light intensity	Prior to use
UV-A lamp integrity [b]	Prior to use
UV-A lamp intensity	Prior to use
Battery powered UV-A lamp intensity.	Prior to and after each use
Special UV-A lighting	Prior to use
Expiration date [e]	Verify before use

[a] Applies to penetrant materials that are provided as not ready for use and require mixing to a concentration, and are recovered, or reused, or both.
[b] Need not be recorded.
[c] Not required for solvent-removable examinations.
[d] Shall be done per section 10.3.8 and photographic evidence shall be maintained
[e] Consumables shall not be used after expiration date.

10.3.6 Techniques

Qualification/ validation shall be performed on all techniques detailed in the written procedure used for inspection of products being supplied.

10.3.7 Penetrant Examination Equipment

Penetrant testing equipment, such as chemicals, light meters, UV lamps/ Lights, stationary equipment, thermometers, and pressure gauges, shall meet the requirements specified in the PT procedure.

10.3.8 Process Verification

The in-use penetrant system's overall performance shall be checked as specified in Table 5 by processing a known defect standard (e.g., comparator block) using in-use penetrant, emulsifier (if used), developer and required processing parameters. Unacceptable materials shall be discarded or otherwise corrected in accordance with the manufacturer's instruction.

10.3.9 Records of Qualification and Examination

10.3.9.1 Recording of Indications

Non rejectable indications shall be recorded, when specified.

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

10.3.9.2 Qualification/Re-qualification and Examination Records

10.3.9.2.1 Qualification/Re-qualification records.

Records of the qualification/re-qualification results shall be maintained and retained per this section.

10.3.9.2.2 Examination Records

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

a) Material identification (description, grade, material traceability), thickness when appropriate to the acceptance criteria,
b) Identification of the procedure used; acceptance criteria used including revision.
c) Quantity of parts examined,
d) Surface condition (i.e., as forged, as cast, abrasive-blasted, machined).
e) Type(visible or fluorescent) and liquid penetrant materials used (including manufacturing name, batch number and designation).
f) Dwell Times (i.e., penetrant, emulsifier (when used), developer)
g) Lighting equipment and light intensity.
h) UV-A lamp including serial number and intensity, when used.
i) Map or record of indications.
j) Traceability of equipment used for measuring the indications.
k) Results of examination.
l) PT technician's printed full name and certification level.
m) 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.

10.4 Ultrasonic Examination (UT)

10.4.1 General

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

10.4.2 Procedures

The NDE service supplier shall develop a written procedure that conforms to the standards and specifications relevant to scope of work, which shall as a minimum contain or reference the requirements listed below. The written procedure shall establish a single value, or range of values, for each requirement identified as essential variable in Table 7.

a) Examination material types, shapes, sizes, product form, and the extent of examination.

b) Personnel qualification requirements and personnel performance demonstration requirements.
c) Procedure validation and revalidation requirements.
d) Calibration(calibration blocks and techniques) and verification requirements.
e) Part Surface condition, preparation and precleaning requirements.
f) Calibration block surface condition
g) Examination part surface temperature and calibration block temperature requirements.
h) Surfaces from which the examination to be performed and stage of inspection.
i) Ultrasonic testing techniques / method (straight beam, angle beam, contact, and/or immersion).
j) Type of Ultrasonic instrument(s) and requirements.
k) Type of Angle(s) and mode(s) of wave propagation in the material.
l) Type of Search unit type(s), frequency (ies), and element size(s), shape(s) requirements.
m) Type of Special search units, wedges, shoes, or saddles, when used.
n) Type of Couplant brand or type.
o) Automatic alarm and/or recording equipment, when used.
p) Computer-enhanced data acquisition, when used.
q) Standardization requirements, Primary reference reflector and level, scanning gain.
r) Scanning methods (manual or automatic), maximum scanning speed and Scan overlap.
s) Scanning directions and extent of scanning.
t) Method for sizing indications, discriminating geometric indications from flaw indications.
u) Interpretation and evaluation of indications and acceptance/rejection criteria.
v) Methods of identification of areas inspected and marking of indications.
w) Post-examination cleaning technique
x) Documentation requirements and type of records.

10.4.3 Procedure Qualification (Validation)

Essential variables listed in Table 7 shall be used for procedure qualification/validation.

Each procedure shall be supported with a documented qualification/validation record to demonstrate the effectiveness of the procedure. One or more of the following shall be used for qualification /validation of the procedure.

a) actual production parts with known discontinuities of the type, location, and size needed for verification.

b) representative reference parts containing discontinuities of the type, location, and size specified in the acceptance criteria.

c) calibration block with ~~a~~ reference reflector(s) equivalent to or smaller than the defect size required to be detected.

d) Representative reference part(s) of known dimensions used for verifying the accuracy of the Ultrasonic system for Ultrasonic thickness measurements.

NOTE Artificial discontinuities may be fabricated to meet a particular need.

Table 7—Essential Variables of an Ultrasonic Examination Procedure

Item	Requirement
a	Material types and configurations to be examined, including thickness dimensions and product form (casting, forging, plate, etc.)
b	Weld configurations to be examined, including thickness dimensions and base material product form (pipe, plate, etc.)
c	Personnel performance requirements, when required
d	The surfaces from which the examination shall be performed
e	Technique(s) (straight beam, angle beam, contact, and/or immersion)
f	Angle(s) and mode(s) of wave propagation in the material
g	Search unit type(s), frequency(ies), and element size(s), shape(s)
h	Special search units, wedges, shoes, or saddles, when used
i	Ultrasonic instrument(s)
j	Calibration (calibration block[s] and technique[s])
k	Directions and extent of scanning
l	Scanning (manual vs automatic)
m	Method for sizing indications
n	Method for discriminating geometric indications from flaw indications
o	Computer-enhanced data acquisition, when used
p	Scan overlap (decrease only)

10.4.4 Procedure Re-qualification (Re-validation)

A change of a requirement identified as an essential variable in Table 7 shall require requalification of the written procedure. All changes of requirements from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

10.4.5 Calibration and Verification Requirements

UT equipment shall be calibrated and verified for performance and accuracy as indicated in Table 8 and Table 9.

Table 8—Calibration Requirements for Ultrasonic Examination Equipment

Equipment Calibration	Maximum Time Between Calibration and method [a]
Instrument linearity checks indicated below	Not to exceed three months for analog type instruments and one year for digital type instruments, or prior to first use thereafter
a. Screen height linearity	Evaluate in accordance with ASME BPVC, Section V, Article 4, Appendix I.
b. Amplitude control linearity	Evaluate in accordance with ASME BPVC, Section V, Article 4, Appendix II.
c. Horizontal screen linearity	Per manufacturer's standards.
[a] Shall be additionally calibrated, whenever malfunction is suspected; or whenever electrical maintenance that might affect equipment accuracy is performed.	

Table 9—Verification Requirements for Ultrasonic Examination Equipment

Tests	Maximum Time Between Verification
Calibration verification [a]	The calibration for each technique method shall be completed for distance range calibration and sensitivity calibration, as applicable for the scope of work Prior to start of examination.
	A calibration check on at least one of the reflectors in the basic calibration block or a check using a simulator shall be performed.
	• When any of the examination variables specified in Table 7 are changed
	• at the completion of each examination or series of similar examinations.
	• 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.	
[a] Intervals: The calibration check intervals not to exceed one shift or prior to first use thereafter.	

10.4.6 Techniques

Qualification/ validation shall be performed on all techniques detailed in the written procedure used for inspection of products being supplied.

10.4.7 Ultrasonic Examination Equipment

The ultrasonic testing equipment, probes, wedges, couplant reference standards and calibration blocks shall meet the requirements specified in the UT procedure.

10.4.8 Calibration Blocks (Reference standards)

10.4.8.1 General

Calibration blocks shall conform to a recognized national, international, or industry standard relevant to the scope of work performed by the NDE service supplier. Non-standard calibration blocks shall be approved by customer and NDE Level III.

10.4.8.2 Material Requirements

10.4.8.2.1 The material from which the block is fabricated shall be of the same product form and material specification or 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.

10.4.8.2.2 The application of a transfer correction, as addressed in the written procedure, shall be applied to the scanning surface when its surface is not representative of the reference standard surface. By agreement with the purchaser, the transfer correction may also be applied for acoustical property differences, when the calibration block is not of the same material, product form or has not received the same heat treatment as the product being examined, provided it meets all other calibration block requirements in this standard.

10.4.8.2.3 The calibration blocks for Ultrasonic examinations of high alloy steel weld deposits such as nickel alloys and dissimilar metal welds shall contain a representative weld with reference reflectors in the weld deposit and heat affected zone.

10.4.9 Calibration (Standardization for Examination)

10.4.9.1 Equipment, probes, cables, wedges including couplant to be used during the examination shall be used for calibration.

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

10.4.9.3 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.

10.4.9.4 For standardization of ultrasonic energy transmission through coarse grain materials and/or dissimilar welds, reference blocks with representative welds shall be used to verify adequate sensitivity and signal to noise ratio through the welds, Heat effected zone areas and adjacent parent materials.

10.4.10 Records of Qualification and Examination

10.4.10.1 Recording of Indications

Non rejectable 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.

10.4.10.2 Qualification/ Re-qualification and Examination Records

10.4.10.2.1 Qualification / Re-qualification Records

Records of the qualification results shall be maintained and retained per this section

10.4.10.2.2 Examination Records

Following the completion of UT, a report shall be prepared, which includes the following as a minimum.

a) Material identification (description, grade, material traceability). thickness of material.
b) Identification of the procedure used, acceptance criteria used, including revision.
c) Part Surface condition (i.e., as forged, as cast, abrasive-blasted, machined).
d) Ultrasonic instrument (including manufacturer's serial number).
e) Search unit(s) identification (including manufacturer's serial number, type, frequency, and size).
f) Beam angle(s) used.
g) Couplant used (brand name or type).
h) Search unit cable(s) used (type and length).
i) Special equipment, when used (search units, wedges, shoes, automatic scanning equipment, recording equipment, etc.).
j) Computerized program identification and revision, when used.
k) Calibration block identification.
l) Simulation block(s) and electronic simulator(s) identification, when used.
m) Instrument reference level gain and, if used, damping and reject setting(s).
n) Calibration data, (including reference reflector(s), indication amplitude(s), and distance reading(s)).

o) Data correlating simulation block(s) and electronic simulator(s), when used, with initial calibration.
p) Identification of material or volume scanned.
q) Surface(s) from which examination was conducted.
r) Map or record of rejectable indications detected, or areas cleared.
s) Areas of restricted access or inaccessible areas.
t) Results of examination.
u) UT technician's printed full name and certification level.
v) Date of examination.

NOTE Items a through o may be included in a separate calibration record, provided the calibration record identification is included in the examination record.

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.

10.5 Phased Array Ultrasonic Testing (PAUT)

10.5.1 General

PAUT is an NDE technique used to perform material examinations for the detection and sizing of discontinuities.

PAUT systems are normally based around a specialized ultrasonic transducer that contains many individual elements (typically from 16 to 256) in a single housing that can be pulsed separately in a programmed pattern using a software in the equipment.

PAUT systems can change the focus depth dynamically, steer the ultrasonic energy, change the pitch of elements, program triggering of elements, sequential triggering of multiple elements using numerous focal laws, display results in real time with sectional, plan, side views.

10.5.2 Procedures

The NDE service supplier shall develop a written procedure that conforms to the standards and specifications relevant to scope of work, which shall as a minimum contain or reference the requirements listed below. The written procedure shall establish a single value, or range of values, for each requirement identified as essential variable in Table 10.

a) Examination material types, shapes, sizes, product form and the extent of examination
b) Personnel qualification requirements and performance demonstration requirements.
c) Procedure validation and revalidation requirements.
d) Part Surface condition, preparation, and precleaning requirements.
e) Calibration block surface condition
f) Calibration and verification requirements.
g) Examination part surface temperature and calibration block temperature requirements
h) Surfaces from which the examination to be performed and stage of inspection.
i) PAUT testing techniques/method.
j) Type of PAUT Instrument(s) and software requirements.
k) Instrument setting (Virtual aperture size, focus length, focal plane, Filters and smoothing, Digitizing frequency, and Net digitizing frequency, Pulser requirements, Pulse repetition frequency, E-scan, S scan, compound E scan requirements, Instrument dynamic range setting, Maximum range setting.
l) Type of Angle(s) and mode(s) of wave propagation in the material.

m) Type of Search unit type(s), frequency (ies), and element size(s), shape(s) requirements.
n) Type of Special search units, wedges, shoes, or saddles, when used.
o) Type of Couplant brand or type.
p) Automatic alarm and/or recording equipment, when applicable.
q) Computer-enhanced data acquisition, when used.
r) Calibration block(s) requirements.
s) Calibration and Standardization method and reflectors (wedge delay, sensitivity, TCG), Primary reference reflector and level, scanning gain levels.
t) Scanner and encoder requirements.
u) Scanning methods (manual or automatic), maximum scanning speed and Scan overlap.
v) Scanning directions and extent of scanning.
w) Method for sizing indications, discriminating geometric indications from flaw indications.
x) Interpretation and evaluation of indications and Acceptance/rejection criteria.
y) Methods of identification of areas inspected and marking of indications.
z) Documentation requirements and type of records.

10.5.3 Procedure Qualification (Validation)

Essential variables listed in Table 10 shall be used for procedure qualification/validation.

Each procedure shall be supported with a documented qualification/validation record to demonstrate the effectiveness of the procedure. One or more of the following shall be used for qualification/validation of the procedure.

a) actual production parts with known discontinuities of the type, location, and size needed for verification.

b) representative reference parts containing discontinuities of the type, location, and size specified in the acceptance criteria.

c) calibration block with reference reflector(s) equivalent to or smaller than the defect size required to be detected.

NOTE Artificial discontinuities may be fabricated to meet a particular need.

Table 10 - Essential Variables of a PAUT Examination Procedure

Item	**Requirement**	Raster scan	Linear scan
a	Configurations examined, including joint design, thickness, and material product form(s)	x	x
b	Surfaces from which the examination is performed	x	x
c	Surface condition (examination surface, calibration block)	x	x
d	Part axis reference system and marking	x	x
e	Personnel qualification requirements	x	x
f	Personnel performance demonstration (if required)	x	x
g	Primary reference reflector and level	x	x
h	Calibration block(s) and technique(s)	x	x
i	Standardization method and reflectors (wedge delay, sensitivity, TCG)	x	x
j	Computerized data acquisition	x	x
k	Wedge type, wedge material, Wedge cut/natural refracted angle, and Wedge height	x	x

l	Wedge contouring and/or stabilizing features	x	x
m	Scanner type and fixturing	x	x
n	Search unit mechanical fixturing device (manufacturer and model), adhering and guiding mechanism, Search unit separation, if applicable	x	x
o	Instrument manufacturer and model, including all related operating modules	x	x
p	Instrument software and revision	x	x
q	Use of separate data analysis software and revision	x	x
r	Special phased array probes, curved/shaped wedges, shoes, or saddles, when used	x	x
s	Search unit type (linear, dual linear, dual matrix, tandem, etc.)	x	x
t	Search unit detail (frequency, element size, number pitch, gap dimensions, element shape)	x	x
u	Technique(s) (straight beam, angle beam, contact, and/or immersion)	x	x
v	Angle(s) and mode(s) of wave propagation in the material	x	x
w	Directions and extent of scanning	x	x
x	Scan increment (decrease in overlap amount)	x	x
y	Scanning technique (line vs. raster) , (automated vs. semiautomated),	x	x
z	Scanning (manual vs. encoded)	x	x
aa	Use of scan gain over primary reference level	x	x
ab	Virtual aperture size (i.e., number of elements, effective height, and element width)	x	x
ac	Focus length and plane (identify plane projection, depth, or sound path, etc.)	x	x
ad	For E-scan: Range of element numbers used (i.e., 1‑126, 10‑50, etc. Element incremental change (i.e., 1, 2, etc.) Rastering angle Aperture start and stop numbers	 x x x x	 x x x x
ae	For S-scan: Aperture element numbers (first and last) Decrease in angular range used (i.e., 40 deg to 50 deg, 50 deg to 70 deg, etc.) Maximum angle incremental change (i.e., 1/2 deg, 1 deg, etc.)	 x x x	 x x x
af	For compound E-scan and S-scan: all E-scan and S-scan variables apply	x	x
ag	Digitizing frequency, Net digitizing frequency (points quantity and other data compression)	x	x
ah	Instrument dynamic range setting, Maximum range setting	x	x
ai	Pulser voltage, Pulsar type and width, Pulse repetition frequency	x	x
aj	Filters and smoothing	x	x
ak	Method for discriminating geometric from flaw indications	x	x
al	Flaw characterization methodology	x	x
am	Method for measuring flaw length	x	x

10.5.4 Procedure Re-qualification (Re-validation)

A change of a requirement outside of validated single value, or range of values, for each requirement identified as essential variable in Table 10 shall require requalification of the written procedure. All changes of requirements from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

10.5.5 Calibration and Verification Requirements

PAUT equipment shall be calibrated and verified for performance and accuracy as indicated in Table 11 and Table 12.

Table 11—Calibration Requirements for PAUT Examination Equipment

Equipment Calibration	Maximum Time Between Calibration and method [a]
Instrument linearity checks indicated below	Not to exceed three months for analog type instruments and one year for digital type instruments, or prior to first use thereafter
a. Screen height linearity	Evaluate in accordance with ASME BPVC, Section V, Article 4, Appendix I.
b. Amplitude control linearity	Evaluate in accordance with ASME BPVC, Section V, Article 4, Appendix II.
c. Horizontal screen linearity	Per manufacturer's standards.
[a] Shall be additionally calibrated, whenever malfunction is suspected; or whenever electrical maintenance that might affect equipment accuracy is performed.	

Table 12—Verification Requirements for PAUT Examination Equipment

Tests	Maximum Time Between Verification [a]
Dead Element check [b] Wedge delay, where applicable [b] Encoder check, where applicable [b]	Daily or Prior to use Daily or Prior to use Daily or Prior to use
Calibration verification	The calibration for each technique method shall be completed for distance range calibration and sensitivity calibration, as applicable for the scope of work prior to start of examination [b]
	A calibration checks on at least one of the reflectors in the basic calibration block or a check using a simulator shall be performed.
	• When any of the examination variables specified in Table 7 are changed [b]
	• At the completion of each examination or series of similar examinations [b]
	• 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.	
[a] Intervals: The calibration check intervals not to exceed one shift or prior to first use thereafter. [b] to be recorded	

10.5.6 Techniques

Qualification/ validation shall be performed on all techniques detailed in the written procedure used for inspection of products being supplied.

10.5.7 PAUT Examination Equipment

The PAUT equipment, probes, wedges, couplant, reference standards and calibration blocks shall meet the requirements specified in the PAUT procedure.

10.5.8 Calibration Blocks (Reference standards)

10.5.8.1 General

Calibration blocks shall conform to a recognized national, international, or industry standard relevant to the scope of work performed by the NDE service supplier. Non-standard calibration blocks shall be approved by customer and NDE Level III.

10.5.8.2 Material Requirements

10.5.8.2.1 The material from which the block is fabricated shall be of the same product form and material specification or 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.

10.5.8.2.2 The application of a transfer correction, as addressed in the written procedure, shall be applied to the scanning surface when its surface is not representative of the reference standard surface. By agreement with the purchaser, the transfer correction may also be applied for acoustical property differences, when the calibration block is not of the same material, product form or has not received the same heat treatment as the product being examined, provided it meets all other calibration block requirements in this standard.

10.5.8.2.3 The calibration blocks for ultrasonic examinations of high alloy steel weld deposits such as nickel alloys and dissimilar metal welds shall contain a representative weld with reference reflectors in the weld deposit and heat affected zone.

10.5.9 Calibration (Standardization for examination)

The standardization of the PAUT system shall as a minimum include the following:

a) Transducer dead element checks: The number of dead elements on each active aperture shall be a maximum of 1 out of 16 and dead elements are not allowed to be adjacent. For active apertures using less than 16 elements, no dead element is allowed, unless adequate performance is demonstrated**.**

b) Calibration of all focal laws defined in the scan plan to provide accurate distance measurement and distance amplitude correction (DAC) or Time corrected gain (TCG) over the sound path to be employed during the examination(s). This shall include applicable compensation for wedge sound path variations and wedge attenuation effects.

c) For encoded data collection, the encoder shall be calibrated by moving the encoder a minimum distance of 20 in. (500 mm) or full circumference of the pipe when circumferential scanning of pipes is performed. The display distance shall be within 1% of the actual distance moved. If performing X-Y raster scanning using automated or semi-automated systems using encoders, both encoders must be calibrated.

d) Only focal laws used in the standardization process shall be used during the examination(s).

e) All individual beams used in the examination shall be calibrated to provide measurement of distance and amplitude correction over the sound path employed in the examination.

10.5.10 Scan plan

A scan plan shall be developed. The scan plan/ technique sheet, in combination with the written procedure, shall address all requirements of Table 10. Note that scan plans developed with beam plotting software, do not always include all the requirements from Table 10, hence additional technique sheet may be required.

All focal Law(s) defined in the scan plan(s) intended for use during the examination shall also be used for calibration.

Any changes to scan plan(s) and focal law parameters require a recalibration.

10.5.11 Examination Requirements

Scanning speed shall be such that data drop-out is less than 2 data lines/in. (25 mm) of the linear scan length and that there are no adjacent data line skips.

f automated and semi-automated scanning is used the following shall be applicable.

a) For E-scan techniques, overlap between adjacent active apertures (i.e., aperture incremental change) shall be a minimum of 50% of the effective aperture height.

b) For S-scan techniques, the angular sweep incremental change shall be a maximum of 1 deg or sufficient to assure 50% beam overlap.

c) When multiple linear scans are required to cover the required volume overlap between adjacent linear scans shall be a minimum of 10% of the effective aperture height for E-scans or beam width for S-scans.

10.5.12 Records of Qualification and Examination

10.5.12.1 Recording Indications

Non rejectable 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.

10.5.12.2 Qualification/ Re-qualification and Examination Records

10.5.12.2.1 Qualification/Re-qualification Records

Records of the qualification/ Requalification results shall be maintained and retained per this section.

10.5.12.2.2 Examination Records

Following the completion of PAUT, report shall be prepared, which include the following as a minimum.

a) Material identification (description, grade, material traceability). thickness of material.
b) Identification of the procedure used, acceptance criteria used, including revision.
c) Part Surface condition (i.e., as forged, as cast, abrasive-blasted, machined).
d) PAUT instrument (including manufacturer's serial number), Software version.
e) Search unit(s) identification (including manufacturer's serial number, frequency, and size). Search unit type, element size and number, and pitch and gap dimensions
f) Beam angle(s) used.
g) Search unit cable(s) used (type and length).
h) Special equipment, when used (search units, wedges, shoes, automatic scanning equipment, recording equipment, etc.).
i) Wedge details
j) Couplant used (brand name or type).
k) Computerized program identification and revision, when used.
l) Calibration block identification.
m) Simulation block(s) and electronic simulator(s) identification, when used.

n) Instrument settings to include, as a minimum, excitation, pulse type, duration and voltage settings, digitization rate (e.g., nominal rate as affected by compression and points quantity), rectification, pulse repetition rate, range start and stop, band pass filters, smoothing, focal type, and length.
o) Instrument reference level gain and, if used, damping and reject setting(s).
p) Calibration data, (including reference reflector(s), indication amplitude(s), and distance reading(s)).
q) Data correlating simulation block(s) and electronic simulator(s), when used, with initial calibration.
r) Identification of material or volume scanned.
s) Scan plan variables, Focal law parameters, including, as applicable, angle, Element numbers used, range of elements, element incremental change, angular range, and angle incremental change.
t) Surface(s) from which examination was conducted, including surface condition.
u) Map or record of rejectable indications detected, or areas cleared.
v) Areas of restricted access or inaccessible areas.
w) Results of examination.
x) PAUT technician's printed full name and certification level.
y) 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.

10.6 Radiographic Examination (RT)

10.6.1 General

RT involves the use of penetrating gamma or X-radiation to examine materials and welds for discontinuities. The radiograph shows the features of the part, with detectable discontinuities or density differences.

10.6.2. Procedures

The NDE service supplier shall develop a written procedure that conforms to the standards and specifications relevant to scope of work, which shall as a minimum contain or reference the requirements listed below.

a) Examination material types, shapes, sizes, product form and extent of examination.
b) Personnel qualification requirements.
c) Procedure validation and revalidation requirements.
d) Calibration and verification requirements.
e) Part Surface condition, preparation requirements.
f) RT Techniques(s) and methods
g) Isotope type or maximum X-ray voltage to be used.
h) Source details (max diagonal size or focal spot size allowed)
i) Radiation filters/ masking requirements.
j) Geometric unsharpness limits, Source to object distance, source to film distance
k) Recording media (film class/brand and designation).
l) Type of Screens and thickness.
m) Image quality indicators (type, material, size, placement, and number of IQIs).
n) Optical density range requirements
o) Image quality/sensitivity requirements
p) Film processing method and requirements.
q) Film review requirements.
r) Interpretation and evaluation of indications and acceptance/rejection criteria.
s) Methods of identification of areas inspected and marking of indications.
t) Documentation requirements and type of records.

10.6.3 Procedure Qualification (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.

10.6.4 Procedure Re-qualification (Re-validation)

10.6.4.1 A change in any of the requirements specified in written procedures shall require requalification of the written procedure.

10.6.4.2 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 procedure re-qualification /re-validation.

10.6.4.3 All changes of requirements from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

10.6.5 Calibration and Verification Requirements

RT equipment shall be calibrated and verified for performance and accuracy as indicated in Table 13 and Table 14.

Table 13—Calibration Requirements for RT Equipment

Equipment Calibration	Maximum Time Between Calibration
Densitometer	Quarterly
Light meters	Annually
Thermometer calibration	Semi-Annually
Step wedge calibration	Annually

Table 14—Verification Requirements for RT Equipment

Tests	Maximum Time Between Verification and Method
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	When manufacturer's or supplier's publications are not available, source size may be determined as follows. a) X-ray Machines—For X-ray machines operating at 1000 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.
Discontinuity image measuring device	When procured. Check (condition) prior to use
Image quality indicators	When procured. Check (condition) prior to use
Automatic processing Processor performance including base fog Temperature	 Daily Prior to use
Manual processing: Processing performance including base fog Temperature Replenishment frequency	 Daily Prior to use As defined in the procedure
Densitometer: Verification check	 Beginning of Each shift, every 8 hours or after change of apertures
Viewer light intensity	When procured, and annually

10.6.6 Techniques

Qualification/validation shall be performed on all techniques detailed in the written procedure used for inspection of products being supplied.

10.6.7 Radiographic Examination Equipment

The RT equipment, Radiation sources, IQI, Densitometers, Viewers, film, screens, and processing equipment shall meet the requirements specified in the RT procedure**.**

10.6.8 Radiographic Image Sensitivity

10.6.8.1 Image quality indicators shall be either the hole-type or step and hole type, or wire-type manufactured in accordance with recognized industry standards.

10.6.8.2 Source Side IQI shall be used where practical. If the IQI cannot be placed on the source side for a single-wall techniques a comparison exposure with one IQI placed on the source side and another one on the film side shall be performed under the same conditions to establish the film quality.

10.6.8.3 The radiograph shall display the designated hole-type IQI image (including applicable material group identification notches) and the essential hole, or the essential wire of a wire-type IQI together with the IQI identifying numbers and letters as defined in the procedure.

11.6.9 Optical Density

The transmitted film density through the radiographic image of the body of the designated hole-type IQI adjacent to the essential hole or adjacent to the essential wire of a wire-type IQI and the area of interest shall not exceed the limits as defined in the procedure.

10.6.10 Records of Qualification and Examination

10.6.10.1 Technique sheet

A technique sheet shall be prepared for each geometry to be examined indicating the RT technique and details per section 10.6.10.3.2 a to l.

10.6.10.2 Recording of Indications

Non rejectable indications shall be recorded, when specified.

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

10.6.10.3 Qualification / Re-qualification Records and Examination Records

10.6.10.3.1 Qualification / Re-qualification Records

Records of the qualification/ requalification results shall be maintained and retained per this section.

10.6.10.3.2 Examination Records

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

a) Base material type and thickness, weld thickness, weld reinforcement thickness, as applicable.
b) Identification and X-ray voltage or isotope type used.
c) Source diagonal size or focal spot size, and serial number.
d) Dimensional map of Marker placement,
e) Film manufacturer and manufacturer's type/designation.
f) Screens used.
g) Number of film in each film holder/cassette.
h) Number of radiographs (exposures).
i) Source-to-object distance and distance from source side of object to film.
j) Single- or double-wall exposure
k) Single- or double-wall viewing details.
l) Film processing (Manual/ Automatic) parameters.
m) Listing of each radiograph location.
n) Reader sheet information (Disposition of each image (acceptable or rejectable, if rejectable cause for rejection (slag, crack, porosity and so forth)
o) Evaluation and disposition of material(s) or weld(s) examined.
p) Identification (name) of the Manufacturer's representative who performed the final acceptance of the radiographs.
q) RT technician's printed full name, and certification level.
r) Date of manufacturer's evaluation.

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.

10.7 Digital Radiographic Examination (DR)

10.7.1 General

DR involves the use of penetrating gamma or X-radiation to examine materials and welds for discontinuities using digital detector systems (DDS). The digital image shows the features of the part, with detectable discontinuities as a gray scale differences.

10.7.2 Procedures

The NDE service supplier shall develop a written procedure that conforms to the standards and specifications relevant to scope of work, which shall as a minimum contain or reference the requirements listed below.

a) Examination material types, shapes, sizes, product form and extent of examination
b) Personnel qualification requirements.
c) Procedure validation and revalidation requirements.
d) Calibration and verification requirements.
e) Part Surface condition, preparation requirements.
f) DR Techniques(s) and methods
g) Isotope type or maximum X-ray voltage to be used.
h) Radiation filters/ masking requirements.
i) Source details max diagonal size or focal spot size allowed.
j) Geometric unsharpness limits, Motion unsharpness limits, Source to object distance, object to detector distance
k) Recording media (digital detector class/brand and designation).
l) Image quality indicators (type, placement, size, and number of IQIs).
m) Image display parameters.
n) Methods for performing detector offset correction and detector gain correction, frequency of performing detector pixel correction.
o) Method of controlling beam width
p) Minimum and maximum Pixel intensity/ gray scale range or image brightness values
q) Method of developing bad pixel map, Method of updating bad pixel maps.
r) Detector/ Source alignment validation.
s) Frame averaging requirements.
t) Storage media.
u) Interpretation and evaluation of indications and Acceptance/rejection criteria.
v) Methods of identification of areas inspected and marking of indications.
w) Documentation requirements and type of records.

10.7.3 Procedure Qualification (Validation)

10.7.3.1 General

Demonstration of the image brightness / gray scale values and image quality indicator requirements of the written procedure on the digital radiograph, at the minimum and maximum material thicknesses stated in the procedure

using the demonstration block(s) per section 10.7.3.1, shall be considered satisfactory evidence of process validation.

10.7.3.2 Demonstration blocks

Using a minimum of two demonstration blocks, representing the minimum and maximum thicknesses of the procedure thickness range, shall be required for procedure qualification.

a. **Gray scale values:** The radiographic image of the demonstration block shall be viewed and evaluated without the aid of postprocessing filters. Image analysis shall be performed through window and level (brightness and contrast) variation only. The pixel intensity values in the region of interest shall fall within the minimum/maximum values described in the procedure. The pixel intensity values will be based on actual assigned image bitmap values, not digital drive levels.
b. **Sensitivity validation:** At minimum, both IQIs (essential wire and designated hole) shall be visible while the embedded notch is discernable. This shall be accomplished in raw data, without the aid of processing algorithms or filters.
c. **Records:** The raw, unfiltered images of the procedure demonstration shall be maintained and available for review. The images shall be clearly identified and traceable to the procedure for which they are used for qualification.

10.7.4 Procedure Re-qualification (Re-validation)

A change in any of the requirements specified in written procedures shall require requalification of the written procedure.

Demonstration of the gray values and image quality indicator requirements of the written procedure using demonstration block as defined in section 10.7.3.1 covering the minimum and maximum thickness specified in the procedure shall be considered satisfactory evidence of procedure re-qualification /re-validation.

All changes of requirements from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

10.7.5 Verification Requirements

DR equipment shall be verified for performance and accuracy at intervals indicated in Table 15.

Table 15—Verification Requirements for DR Equipment

Tests	Maximum Time Between Verification and Method
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	When manufacturer's or supplier's publications are not available, source size may be determined as follows. a) X-ray Machines—For X-ray machines operating at 1000 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.
Image quality indicators	When procured. Check (condition) prior to use

Gray scale calibration of the monitor	As defined in the procedure
Detector Offset Correction	Prior to use As defined in the procedure
Detector Gain Correction	Prior to use As defined in the procedure
Bad Pixel Map verification	Prior to use At the completion of examination or after 24 hrs. of continuous use.
Encoders check	Prior to use
Measuring Scale Comparator	Prior to use

10.7.6 Techniques

Qualification/ validation shall be performed on all techniques detailed in the written procedure used for inspection of products being supplied.

10.7.7 DR Equipment

All equipment, materials and parameters range used for validation of procedure/ technique shall only be used for the production.

10.7.8 Image Brightness/ Gray Scale Values

The image brightness through the body of the hole-type IQI or adjacent to the designated wire of the wire-type IQI, shall be judged to be equal to or greater than the image brightness in the area of interest for a negative image format. If verified by measurement, pixel intensity variations up to 30% are permitted in the determination of “equal to.” Localized pixel averaging may be used in determining pixel intensity variations, provided the number of pixels averaged does not exceed the total number that would fit inside the area of a circle 0.125 in. (3 mm) in diameter. This image brightness requirement is reversed for a positive image format.

The pixel intensity values in the region of interest shall fall within the minimum/maximum values described in the procedure. The pixel intensity values will be based on actual assigned image bitmap values, not digital drive levels.

10.7.9 Digital Image Sensitivity

The digital image display the designated hole-type IQI image and the essential hole, or the essential wire of a wire-type IQI together with the IQI identifying numbers and letters. For wire-type IQIs, the essential wire shall be visible within the area of interest representing the thickness used for determining the essential wire, inclusive of the allowable brightness variations.

10.7.10 Records of Qualification and Examination.

10.7.10.1 Acquisition of data requirements,

The acquisition parameters used to acquire the radiographic image shall be verifiable, either embedded in the image data or in the associated header metadata information or recorded on the radiographic detail sheet.

10.7.10.2 Recording of Indications

Non rejectable indications shall be recorded, when specified.

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

10.7.10.3 Qualification/ Re-qualification and Examination Records

10.7.10.3.1 Qualification/Re-qualification Records

Records of the qualification/requalification results shall be maintained and retained per this section.

10.7.10.3.2 Examination Records

Following the completion of DR, a report shall be prepared, which includes the following as a minimum:

a) Base material type and thickness, weld thickness, weld reinforcement thickness, as applicable.
b) Identification and X-ray voltage or isotope type used.
c) Source diagonal size or focal spot size, and serial number.
d) The dimensional map (if used) of marker placement,
e) Detector manufacturer and manufacturer's type/designation and serial number
f) Imaging software version and revision
g) Image acquisition(digitizing) equipment and manufacturer model and serial number
h) The min./max. travel speed of the detector, source of radiation, and/or test object
i) Source-to-object distance and distance from source side of object to detector.
j) Single- or double-wall exposure details
k) Single- or double-wall viewing details.
l) Numerical values of the final image processing parameters, to include filters, window (contrast), and level (brightness) for each view.
m) Bad pixel maps
n) Computer monitor resolution.
o) Listing of each radiograph location.
p) Image interpretation record (Disposition of each image (acceptable or rejectable, if rejectable cause for rejection (slag, crack, porosity and so forth)
q) Evaluation and disposition of the material(s) or weld(s) examined.
r) RT technician's printed full name, and certification level.
s) Date of manufacturer's evaluation.

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.

10.8 Computed Radiographic Examination (CR)

10.8.1 General

CR involves the use of penetrating gamma or X-radiation to examine materials and welds for discontinuities using phosphor imaging plates. The digital image shows the features of the part, with detectable discontinuities as gray scale differences.

10.8.2 Procedures

The NDE service supplier shall develop a written procedure that conforms to the standards and specifications relevant to scope of work, which shall as a minimum contain or reference the requirements listed below.

a) Examination material types, shapes, sizes, product form and extent of examination.
b) Personnel qualification requirements.
c) Procedure validation and revalidation requirements.
d) Calibration and verification requirements.
e) Part Surface condition, preparation requirements
f) CR Techniques(s) and methods.
g) Isotope type or maximum X-ray voltage to be used.
h) Radiation filters/ masking requirements
i) Source details max diagonal size or focal spot size allowed.
j) Geometric unsharpness limits, minimum Source to object distance, object to imaging plate distance.
k) Recording media (Imaging plate manufacturer rand and designation).
l) Image quality indicators (Type, placement, and number of IQIs)
m) Image display parameters.
n) Screens used.
o) Details of Storage media.
p) Image scanning and processing equipment manufacturer and model.
q) Minimum and maximum Pixel intensity/ gray scale range or image brightness values
r) Image scanning parameters (i.e., gain, laser, resolution), detailed, as applicable, for material thicknesses across the thickness range.
s) Interpretation and evaluation of indications and Acceptance/rejection criteria.
t) Methods of identification of areas inspected and marking of indications.
u) Documentation requirements and type of records.

10.8.3 Procedure Qualification (Validation)

10.8.3.1 General

Demonstration of the image brightness/gray scale values and image quality indicator requirements of the written procedure on the digital radiograph, at the minimum and maximum material thicknesses stated in the procedure using demonstration block(s) per section 10.8.3.2, shall be considered satisfactory evidence of process validation.

10.8.3.2 Demonstration Blocks

Using a minimum of two demonstration blocks, representing the minimum and maximum thicknesses of the procedure thickness range, shall be required for procedure qualification.

a) **Gray scale values :**The radiographic image of the demonstration block shall be viewed and evaluated without the aid of postprocessing filters. Image analysis shall be performed through window and level (brightness and contrast) variation only. The pixel intensity values in the region of interest shall fall within the minimum/maximum values described in the procedure. The pixel intensity values will be based on actual assigned image bitmap values, not digital drive levels.
b) **Sensitivity validation:** As a minimum, both IQIs (essential wire and designated hole) shall be visible while the embedded notch is discernable. This shall be accomplished in raw data, without the aid of processing algorithms or filters.
c) **Records:-** The raw, unfiltered images of the procedure demonstration shall be maintained and available for review. The images shall be clearly identified and traceable to the procedure for which they are used for qualification.

10.8.4 Procedure Re-qualification (Re-validation)

10.8.4.1 A change in any of the requirements specified in written procedures shall require requalification of the written procedure.

10.8.4.2 Demonstration of the gray values and image quality indicator requirements of the written procedure using demonstration block as defined in section 10.8.3.2 covering the minimum and maximum thickness specified in the procedure shall be considered satisfactory evidence of procedure re-qualification /re-validation.

10.8.4.3 All changes of requirements from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

10.8.5 Verification Requirements

CR equipment shall be verified for performance and accuracy at intervals indicated in Table 16.

Table 16—Verification Requirements for CR Examination Equipment

Tests	Maximum Time Between Verification and Method
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	When manufacturer's or supplier's publications are not available, source size may be determined as follows. a) X-ray Machines—For X-ray machines operating at 1000 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.
Image quality indicators	When procured. Check (condition) prior to use
Montier Gray scale calibration	As defined in the procedure
Digital Comparator	As defined in the procedure

10.8.6 Techniques

Qualification/ validation shall be performed on all techniques detailed in the written procedure used for inspection of products being supplied.

10.8.7 CR Equipment

All equipment, materials and parameters range used for validation of procedure/ technique shall only be used for the production.

10.8.8 Image Brightness/ Gray Scale Values

The image brightness through the body of the hole-type IQI or adjacent to the designated wire of the wire-type IQI, shall be judged to be equal to or greater than the image brightness in the area of interest for a negative image format. If verified by measurement, pixel intensity variations up to 30% are permitted in the determination of “equal to.” Localized pixel averaging may be used in determining pixel intensity variations, provided the number of pixels averaged does not exceed the total number that would fit inside the area of a circle 0.125 in. (3 mm) in diameter. This image brightness requirement is reversed for a positive image format.

The pixel intensity values in the region of interest shall fall within the minimum/maximum values described in the procedure. The pixel intensity values will be based on actual assigned image bitmap values, not digital drive levels.

10.8.9 Digital Image sensitivity

The digital image shall display the designated hole-type IQI image and the essential hole, or the essential wire of a wire-type IQI together with the IQI identifying numbers and letters.

For wire-type IQIs, the essential wire shall be visible within the area of interest representing the thickness used for determining the essential wire, inclusive of the allowable brightness variations.

10.8.10 Records of Qualification and Examination.

10.8.10.1 Acquisition of data requirements.

The acquisition parameters used to acquire the radiographic image shall be verifiable, either embedded in the image data or in the associated header metadata information or recorded on the radiographic detail sheet.

10.8.10.2 Recording of Indications

Non rejectable indications shall be recorded, when specified.

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

10.8.10.3 Qualification/ Re-qualification and Examination Records

10.8.10.3.1 Qualification / Re-qualification Records

Records of the qualification/ requalification results shall be maintained and retained per this section.

10.8.10.3.2 Examination Records

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

a) Base material type and thickness, weld thickness, weld reinforcement thickness, as applicable.
b) Identification and X-ray voltage or isotope type used.
c) Procedure identification and revision level
d) Source diagonal size or focal spot size, and serial number.
e) Dimensional map of Marker placement
f) Imaging plate manufacturer and manufacturer's type/designation and serial number
g) Imaging software version and revision
h) Image acquisition (digitizing) equipment and manufacturer model and serial number
i) Source-to-object distance and distance from source side of object to imaging plate.
j) Single- or double-wall exposures
k) Single- or double-wall viewing details.
l) Number of exposures
m) Numerical values of the final image processing parameters, to include filters, window (contrast), and level (brightness) for each view.
n) Computer monitor resolution.
o) Listing of each radiograph location.
p) Image interpretation record (Disposition of each image (acceptable or rejectable, if rejectable cause for rejection (slag, crack, porosity and so forth)
q) Evaluation and disposition of the material(s) or weld(s) examined.
r) Identification (name) of the Manufacturer's representative who performed the final acceptance of the digital images.
s) RT technician's signature printed full name, and certification level.
t) Date of manufacturer's evaluation.

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.

10.9 Computed Tomography (CT)

10.9.1 General

CT captures radiographic projections of an object at various rotational angles, which are mathematically reconstructed to produce a three-dimensional volume data set or one or more two-dimensional cross sectional images.

10.9.2. Procedures

The NDE service supplier shall develop a written procedure that conforms to the standards and specifications relevant to scope of work, which shall as a minimum contain or reference the requirements listed below. The written procedure shall establish a single value, or range of values, for each requirement identified as an essential variable in Table 17.

a) Examination material types, shapes, sizes, product form and extent of examination.
b) Personnel qualification requirements.
c) Procedure validation and revalidation requirements.
d) Calibration and verification requirements.
e) Part Surface condition, preparation requirements.
f) Type of Radiation sources (X-ray tube voltage range, X-ray tube current or pulse rate range, Radiation source filtration requirements, collimation),

g) System manufacturer and model
h) Maximum Focal spot sizes of the Radiography sources
i) Acquisition and reconstruction software version
j) Indirect or direct conversion
k) Type of image quality verification to be used.
l) Pixel matrix size
m) Binning.
n) Pixel pitch.
o) Scintillator type
p) Detector gain correction, Detector offset correction and Detector correction frequency.
q) Image reconstruction techniques.
r) Methods of Bad pixel reporting/mapping.
s) Source to center of rotation distance and Source to detector distance.
t) Geometric magnification, Geometric unsharpness limits
u) Piercing point/central ray.
v) Field of view (FOV).
w) Center of rotation calibration
x) Scan/projection type (continuous, step and shoot, etc.)
y) Scan/projection method (centered, offset, 360 deg or 180 deg)
z) Frame averaging.
aa) Reconstruction type, volume, algorithm, matrix/voxel size, Reconstruction filters and beam hardening corrections.
bb) Minimum image display requirements
cc) Environmental conditions for maintaining image quality.
dd) Vibration control
ee) Steps to control Scatter radiation.
ff) Interpretation and evaluation of indications and Acceptance/rejection criteria
gg) Methods of identification of areas inspected and marking of indications.
hh) Documentation requirements and type of records.

10.9.3 Procedure Qualification (Validation)

Essential variables listed in Table 17 shall be used for procedure qualification/validation.

Demonstration of the gray scale values and image quality indicator image requirements of the written procedure on production or technique digital radiographic images shall be considered satisfactory evidence of process validation.

Table 17 - Essential Variables of CT examination procedure

Item	**Requirement**
a	Component configurations to be examined, including thickness dimensions and base material composition
b	Focal spot size
c	Radiation source
d	X-ray tube voltage, X-ray tube current or pulse rate
e	Radiation source filtration, collimation
f	Personnel qualification requirements
g	System manufacturer and model
h	Acquisition and reconstruction software version
i	Indirect or direct conversion
j	Type of image quality verification to be used
k	Pixel matrix size
l	Binning
m	Examination volume
n	Pixel pitch
o	Scintillator type
p	Detector gain correction, offset correction and correction frequency
q	Image reconstruction techniques
r	Bad pixel reporting/mapping
s	Source to center of rotation distance, Source to detector distance
t	Geometric magnification
u	Piercing point/central ray
v	Field of view (FOV)
w	Center of rotation calibration
x	Scan/projection type (continuous, step and shoot, etc.)
z	Scan/projection method (centered, offset, 360 deg or 180 deg)
aa	Frame averaging
ab	Reconstruction type, volume, algorithm, matrix/ Voxel size, filters and beam hardening corrections
ac	Minimum image display requirements

10.9.4 Procedure Re-qualification (Re-validation)

10.9.4.1 A change in any of the requirements specified in written procedures shall require requalification of the written procedure.

10.9.4.2 Demonstration of the gray scale values and image quality indicator image requirements of the written procedure on production or technique digital radiographic images shall be considered satisfactory evidence of process re-validation.

10.9.4.3 All changes of requirements from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

10.9.4.4 Software revisions do not require the procedure to be redemonstrated, provided there have been no changes that would influence the reconstructed image as displayed, recorded, or automatically processed.

10.9.5 Verification Requirements

CT examination equipment shall be verified for performance and accuracy at intervals indicated in Table 18.

Table 18—Verification Requirements for CT Examination Equipment

Tests	Maximum Time Between Verification and Method
Verification of source size	The equipment manufacturer's or supplier's publications, such as technical manuals, or written statements documenting the actual or maximum source size or focal spot, shall be acceptable as source size verification.
Determination of source size	When manufacturer's or supplier's publications are not available, source size may be determined as follows. a) X-ray Machines—For X-ray machines operating at 1000 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.
Gray scale calibration of the monitor	As defined in the procedure
Detector off set Correction	Prior to use As defined in the procedure
Detector Gain Correction	Prior to use As defined in the procedure
Bad Pixel Maps	Prior to use At the completion of examination or after 24 hrs. of continuous use.

10.9.6 Techniques

Qualification/ validation shall be performed on all techniques detailed in the written procedure used for inspection of products being supplied.

10.9.7 CT Equipment

Equipment, materials, Radiation sources, Software, computer hardware, Representative quality Indicators(RQIs) and parameters range used for validation of procedure/ technique shall only be used for the production.

Computer hardware shall have the memory and processing capabilities to acquire and reconstruct the required examination volume.

10.9.8 Image Acquisition Plan

An image acquisition plan shall be developed prior to examination that demonstrates that the required volume is completely examined.

10.9.9 Image Quality Verification

Image quality shall be demonstrated using an actual or similar part of comparable geometry and attenuation characteristics to the test specimen that has known measurable features, representing examples of relevant discontinuities.

The part shall have minimum detectable indication size as required by referencing code requirements.

10.9.10 Records of Qualification and Examination.

10.9.10.1 Technique sheet

A technique sheet shall be prepared for each geometry to be examined indicating the CT technique and details per section 10.9.10.3.2 a to dd.

10.9.10.2 Recording of Indications

Non rejectable indications shall be recorded, when specified.

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

10.9.10.3 Qualification/ Re-qualification and Examination Records

10.9.10.3.1 Qualification / Re-qualification records.

Records of the qualification/ requalification results shall be maintained and retained per this section.

10.9.10.3.2 Examination Records

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

a) Base material type and thickness, weld thickness, weld reinforcement thickness, as applicable
b) Identification and X-ray voltage or isotope type used.
c) Source diagonal size or focal spot size, and serial number
d) Source type, Voltage, Current or pulse rate
e) Beam filtration and Beam collimation
f) Number of projections
g) Detector electronic gain
h) Detector gain and offset data, e.g., number of frames, how often.
i) Bad pixel correction protocols
j) Scan type, i.e., continuous or step and shoot
k) Acquisition type, e.g., helical, axial, or axial-offset, and region of interest
l) Exposure time per frame, i.e., frame time, including read-out time.
m) Net exposure time if radiation source is off during readout time.
n) Number of frames averaged.
o) Number of frames skipped between frames.
p) Geometric information, i.e., source to detector distance (SDD), source to center of rotation distance (SOD), magnification, effective voxel size.
q) Component orientation
r) Detector architecture, i.e., 2048 × 2048
s) Detector manufacturer, type, model number, and serial number
t) Acquisition software and version number
u) Reconstruction software and version number
v) Review software and version number
w) Type of reconstruction, e.g., filtered back projection (FBP)
x) Reconstruction volume to create.
y) Filters used in the reconstruction.

z) Beam hardening corrections used.
aa) Other reconstruction corrections
bb) display settings to review the reconstructions.
cc) Post-processing tools, e.g., digital filters, other corrections
dd) Analysis tools, e.g., porosity, nominal/actual comparison
ee) Listing of each scan/examination
ff) Image interpretation record (Disposition of each image (acceptable or rejectable, if rejectable cause for rejection (slag, crack, porosity and so forth)
gg) Evaluation and disposition of the materials or welds examined.
hh) Identification (name) of the Manufacturer's representative who performed the final acceptance of the examinations date of Manufacturer's evaluation.

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.

10.10 Eddy Current Testing (ET)

10.10.1 General

ET uses eddy currents and detects the changes in the flow caused by the variations in the specimen due to changes in the material characteristics or presence of imperfections.

10.10.2 Procedures

The NDE service supplier shall develop a written procedure that conforms to the standards and specifications relevant to scope of work, which shall as a minimum contain or reference the requirements listed below, as applicable to the technique being used. The written procedure shall establish a single value, or range of values, for each requirement identified as essential variable in Table 19.

a) Examination material types, shapes, sizes, product form and the extent of examination.
b) Personnel qualification requirements and performance demonstration requirements.
c) Procedure validation and revalidation requirements.
d) Part Surface condition, preparation, and precleaning requirements.
e) Calibration block surface condition
f) Calibration and verification requirements.
g) Examination of part surface temperature and calibration block temperature requirements.
h) Surfaces from which the examination to be performed and stage of inspection.
i) Eddy Current testing techniques/methods.
j) Eddy current testing instrument(s), types and requirements
k) Type of eddy current testing Probes, frequency (ies),size(s), and shape(s) requirements.
l) Lengths of probe and probe extension cables
m) Type of scanners, as applicable.
n) Encoder requirements and calibration.
o) Method of Data acquisition (analog/digital),
p) Method of Data analysis (analog/ digital/ hybrid)
q) Eddy Current testing data acquisition software and data recording equipment requirements
r) Eddy Current analysis software and analyzing requirements.
s) Calibration reference standards and method of calibration.
t) Standardization requirements, Primary reference reflector and level, scanning gain.
u) Mode of inspection (Absolute/ absolute),
v) Examination frequency range, drive voltage range and gain settings
w) Modes of Scanning (manual, mechanized probe driver, remote controlled fixture)

x) Maximum scanning speed during data acquisition and during analysis
y) Probe Scanning direction and fixture location verification requirements.
z) Minimum digitization rates and data recording requirements.
aa) Frequencies for data evaluation
bb) Interpretation and evaluation of indications and acceptance/rejection criteria.
cc) Methods of identification of areas inspected and marking of indications.
dd) Documentation requirements and type of records

10.10.3 Procedure Qualification (Validation)

Essential variables listed in Table 19 shall be used as applicable based on type of technique or method being used for procedure qualification/validation.

Each procedure shall be supported with a documented qualification/validation record to demonstrate the effectiveness of the procedure. One or more of the following shall be used for qualification/ validation of the procedure.

a) actual production parts with known discontinuities of the type, location, and size needed for verification.

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

c) calibration or reference standard containing notches and/or drilled holes equivalent to or smaller than the defect size required to be detected by the examination technique.

NOTE Artificial discontinuities may be fabricated to meet a particular need.

Table 19—Essential variables of a Eddy current testing Procedure

Item	Requirement
a	Tube material, Diameter, and wall thickness
b	Mode of inspection – Differential or absolute
c	Probe Manufacturer, pat number, and description
d	Length of probe cable and extension cables
e	Probe type and size
f	Examination frequencies, drive voltage and gain setting
g	ET equipment manufacturer and model,
h	Acquisition software version and revision, Analysis software
i	Minimum fill factor, if applicable
j	Scanning direction during push or pull of probe while data recording
k	Scanning mode – manual, mechanized probe driver, remote controlled fixture
l	Fixture location verification
m	Minimum digitization rate
n	Maximum scanning speed during data recording
o	Calibration reference standards identification

p	Minimum sample density along the scanning axis.

10.10.4 Procedure Re-qualification (Re-validation)

A change of a requirement outside of validated single value, or range of values, for each requirement identified as essential variable in Table 19 shall require requalification of the written procedure. All changes of requirements from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

10.10.5 Calibration and Verification Requirements

ET equipment shall be calibrated and verified for performance and accuracy at the intervals specified in Table 20 and Table 21 below.

Table 20 —Required Calibration Intervals for Eddy Current Examination

Equipment Calibration	Maximum Time Between Calibration [a]
ET equipment	Annually
[a] Shall be additionally calibrated, whenever malfunction is suspected; or whenever electrical maintenance that might affect equipment accuracy is performed.	

Table 21 —Required Verification Intervals for Eddy Current Examination

Item	Maximum Time Between Verification [a]
Calibration verification and recalibration	Prior to start of the examination [b]
	Whenever change in material properties that cause signal saturation.
	Any change of probe, extension cables, instrument, recording instruments or any other system hardware [b]
	Examination of new component
	when examination personnel (except for automated equipment) are changed
	At the completion of examination or series of examinations [b]
Encoder	Prior to use [b]
Probe condition	Prior to use
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 instrument stability (analog vs digital), the risk of having to conduct reexaminations, and the benefit of not performing interim calibration checks. [a] Intervals: The calibration check intervals not to exceed one shift or prior to first use thereafter. [b] To be recorded	

10.10.6 Techniques

Qualification/ validation shall be performed on all techniques detailed in the written procedure used for inspection of products being supplied.

10.10.7 Eddy Current Testing Equipment

The Eddy Current Testing equipment such as Eddy Current flaw detector, Probes, extension cables, calibration blocks shall meet the requirements specified in the ET procedure.

10.10.8 Calibration Blocks (Reference standards)

10.10.8.1 General

Calibration blocks shall conform to a recognized national, international, or industry standard relevant to the scope of work performed by the NDE service supplier. Non-standard calibration blocks shall be approved by customer and NDE Level III.

10.10.8.2 Material Requirements

The material from which the block is fabricated shall be of the same product form and material specification 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.

10.10.9 Calibration (Standardization for examination)

10.10.9.1 Equipment, probes, and cables to be used during the examination shall be used for calibration.

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

10.10.9.3 Calibrations shall be performed from the surface (OD or ID) corresponding to the surface of the material for which the examination will be performed.

10.10.9.4 The calibration for each technique/ method shall be completed for sensitivity calibration as applicable for the scope of work prior to start of the work.

10.10.10 Records of Qualification and Examination

10.10.10.1 Recording of Indications

Non-rejectable indications shall be recorded, when specified.

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

10.10.10.2 Qualification/ Re-qualification and Examination Records

10.10.10.2.1 Qualification / Re-qualification Records

Records of the qualification/ requalification results shall be maintained and retained per this section.

10.10.10.2.2 Examination Records

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

a) Material identification (description, grade, material traceability), thickness of material.
b) Identification of the procedure used, acceptance criteria used, including revision.
c) Part Surface condition (i.e., as forged, as cast, abrasive-blasted, machined)
d) Eddy current equipment including serial number and type of magnetizing current.
e) Length of probe and probe extension cables
f) Probes (serial number , type, size, manufacturers name, description)
g) Examination frequency or frequencies

h) Calibration standard, serial number, type of calibration reflectors and reflector dimensions
i) Mode of operation(absolute, differential etc.,) including instrument sample rate, drive voltage and gain settings
j) Scan direction and scanning speed during data acquisition.
k) Scanning limitations
l) Map or record of indications,
m) Results of examination.
n) ET technician's printed full name and certification level.
o) 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.

10.11 Qualification Requirements for Other NDE Methods

10.11.1 General

For those NDE methods/techniques not specifically addressed in this standard (e.g. Acoustic Emission), sections 1 through 9, section 11 and this section shall be followed.

10.11.2 Procedures

When the NDE methodology is not specifically covered in this document, The organization shall document, implement, and maintain a procedure, approved by the Level 3, addressing the qualification requirements for all methods to which conformance to this standard is claimed.

The NDE service supplier shall develop a written procedure that conforms to relevant scope of work based on internal or external standards, which shall as a minimum contain or reference the requirements listed below. The written procedure shall establish a single value, or range of values, for each requirement identified as essential variable.

a) Examination material types, shapes, sizes, product form, and the extent of examination.
b) Personnel qualification requirements
c) Identification of essential and non-essential variables
d) Testing steps, including Essential variables for those steps.
e) Controls / limits for essential variables
f) Validation and revalidation requirements.
g) Internal or external standards to which the procedure is being validated.
h) Surfaces from which the examination to be performed and stage of inspection.
i) Surface Condition of the part and calibration standard
j) NDE Methods/Techniques (e.g. Acoustic Emission)
k) method of establishing calibration sensitivity.
l) Calibration and verification requirements, System performance verification.
m) Examination part surface temperature and calibration block temperature requirements
n) Type of Equipment and equipment setting
o) Material handling requirements, if applicable.
p) Shelf life for expendables; if applicable
q) Preservation and storage requirements for equipment and expendables, if applicable.
r) Method for sizing indications, discriminating geometric indications from flaw indications.
s) Interpretation and evaluation of indications and Acceptance/rejection criteria.
t) Methods of identification of reference system and marking
u) Documentation requirements and type of records.

10.11.3 Procedure Qualification (Validation)

The procedure shall address the essential variables needed to be used for procedure qualification/validation.

10.11.4 Procedure Re-qualification (Re-validation)

A change of a requirement outside of validated single value, or range of values, for each requirement identified as essential variable shall require requalification/ revalidation of the written procedure. All changes from those specified within the written procedure shall require revision of, or an addendum to, the written procedure.

10.11.5 Records of Qualification and Examination

Records showing evidence of conformance to the qualification requalification requirements and examination records shall be maintained.

11 Records Requirements

11.1 General

Records are required to show conformance to the requirements of this standard.

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

If digital signature is used, they shall be verifiable and protected.

Records to be maintained include, as a minimum:

a) NDE procedure(s).
b) NDE procedure qualification/ validation record(s).
c) NDE personnel certification record(s);
d) NDE process documentation including verification log(s).
e) NDE calibration record(s).
f) NDE examination record(s).

11.2 Records Retention

11.2.1 Records required by this standard shall be maintained for 10 years or as required by customer or applicable standards, whichever is longer. Documents and data may be in any type of media (hard copy or electronic) and shall be:

a) Signed and dated.
b) Maintained to demonstrate conformance to specified requirements.
c) Legible.
d) Retained and readily retrievable.
e) Stored in an environment to prevent damage, deterioration, or loss, and
f) Available and auditable by the user/purchaser.

11.2.2 For radiography,

a) NDE records (at a minimum NDE records are RT inspection reports and technique sheets).

b) The radiograph storage duration and location after delivery shall be as agreed upon between purchaser and supplier.

11.2.3 For advanced NDE methods,

a) NDE records (at a minimum NDE records are inspection reports and scan plans).
b) The raw data storage duration and location after delivery shall be as agreed upon between purchaser and supplier.

Bibliography

[1] ANSI/ASNT CP-106, *Nondestructive Testing—Qualification and Certification of Personnel*

[2] ASTM A388, *Standard Practice for Ultrasonic Examination of Steel Forgings*

[3] ASTM E164, *Standard Practice for Contact Ultrasonic Testing of Weldments*

[4] ASTM E1001, *Standard Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves*

[5] ASTM E1444, *Standard Practice for Magnetic Particle Testing*

[6] ASTM E2375, *Standard Practice for Ultrasonic Testing of Wrought Products*

[7] ASTM E165, *Standard Practice for Liquid Penetrant Testing for General Industry*

[8] ASTM E94 E94M - Standard Guide for Radiographic Examination Using Industrial Radiographic Film.

[9*]* *ISO 5817 - Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections.*

[10] ISO 13588 Non-destructive testing of welds - Ultrasonic testing - Use of automated phased array technology