INSPECTION TECHNICAL PROCEDURE

I-120

NONDESTRUCTIVE TESTING INSPECTION PROCEDURE

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Table of Contents

1.0 PURPOSE 1
2.0 OBJECTIVES 1
3.0 DEFINITIONS..2
4.0 INSPECTION REQUIREMENTS 2
4.1 Adequacy and effectiveness of Construction Implementing procedures................ 2
4.1.1 Visual Examination.. 2
4.1.2 Radiographic Examination... 3
4.1.3 Ultrasonic Examination 3
4.1.4 Liquid Penetrant Examination 4
4.1.5 Magnetic Particle Examination... 4
4.2 Adequacy and effectiveness of construction Activities 5
4.2.1 Visual Examination.. 5
4.2.2 Radiographic Examination... 5
4.2.3 Ultrasonic Examination 5
4.2.4 Liquid Penetrant Examination 5
4.2.5 Magnetic Particle Examination... 5
4.3 Adequacy and Effectiveness of the Training and Qualification of Personnel 5
4.3.1 Visual Examination.. 5
4.3.2 Radiographic Examination... 6
4.3.3 Ultrasonic Examination 6
4.3.4 Liquid Penetrant... 6
4.3.5 Magnetic Particle 6
4.4 Adequacy and Effectiveness of the System of Records... 6
4.4.1 Visual Examination.. 6
4.4.2 Radiographic Examination... 6
4.4.3 Ultrasonic Examination 7
4.4.4 Liquid Penetrant Examination 7
4.4.5 Magnetic Particle Examination... 7
5.0 INSPECTION GUIDANCE 7
5.1 Adequacy and Effectiveness of Construction Implementing Procedures............... 8
5.1.1 Visual Examination.. 8
5.1.2 Radiographic Examination... 9
5.1.3 Ultrasonic Examination 11
5.1.4 Liquid Penetrant Examination 12
5.1.5 Magnetic Particle Examination... 13
5.2 Adequacy and Effectiveness of Construction Activities 15
5.2.1 Visual Examination.. 15
5.2.2 Radiographic Examination... 16
5.2.3 Ultrasonic Examination 16
5.2.4 Liquid Penetrant Examination 16
5.2.5 Magnetic Particle Examination... 16

5.3 Adequacy and Effectiveness of the Training and Qualification of Personnel 16
5.4 Adequacy and Effectiveness of the System of Records 17
6.0 REFERENCES 17
7.0 LIST OF TERMS 18

Attachments

Attachment 1. Visual 19
Attachment 2. Radiography 23
Attachment 3. Ultrasonic 33
Attachment 4. Liquid Penetrant 47
Attachment 5. Magnetic Particle 55

INSPECTION TECHNICAL PROCEDURE I-120, REV. 0
NONDESTRUCTIVE TESTING INSPECTION

1.0 PURPOSE

This procedure provides guidance for assessing the Contractor's activities for nondestructive testing (examinations). This procedure provides guidance for assessing five methods of nondestructive examinations: (1) Visual, (2) Radiographic, (3) Ultrasonic, (4) Liquid Penetrant, (5) Magnetic Particle. This guidance is based on the requirements set forth in the Safety Requirements Document (SRD), the Quality Assurance Manual (QAM), and the Integrated Safety Management Plan (ISMP).

For each of the five methods, this procedure assesses the adequacy and effectiveness of:

- Nondestructive examination implementing procedures
- Construction activities requiring nondestructive examination
- Training and qualification of personnel
- Records.

2.0 OBJECTIVES

This procedure verifies the Contractor has established effective programs for: (1) implementing commitments regarding nondestructive examinations and ensuring those commitments are adequately addressed by the Contractor's specifications, drawings, and procedures; (2) conducting nondestructive examinations in accordance with the approved construction procedures; (3) training and qualification of nondestructive examination personnel; and (4) recording nondestructive examination activities.

This inspection procedure is a component of a complete construction inspection program. This and other inspection procedures will be used on an on-going bases, as needed, to provide assurance that construction activities are being conducted as required by authorization basis commitments and Contractor procedures. Although during the construction phase, it is expected a significant portion of this inspection procedure will be accomplished at least once for each major Contractor/subcontractor involved with the activities covered by this procedure, it is not expected completion of the entire procedure will be accomplished during any one inspection and/or every time the inspection procedure is used.

3.0 DEFINITIONS

The definition of terms for each of the five areas of nondestructive examination are provided in appendixes to this procedure as follows:

Visual examination terms	Attachment 1, Section 1.0.
Radiography examination terms	Attachment 2, Section 1.0.
Ultrasonic examination terms	Attachment 3, Section 1.0.
Liquid Penetrant examination terms	Attachment 4, Section 1.0.
Magnetic particle examination terms	Attachment 5, Section 1.0

4.0 INSPECTION REQUIREMENTS

The inspection requirements for nondestructive testing are divided into five parts: (1) Visual Examination, (2) Radiographic Examination, (3) Ultrasonic Examination, (4) Liquid Penetrant Examination, and (5) Magnetic Particle Examination. The inspection requirements for each part are listed separately in the sections below.

4.1 Adequacy and effectiveness of Construction Implementing procedures

4.1.1 Visual Examination

4.1.1.1 The inspector should verify all Contractor/subcontractors with construction responsibilities that include visual examination of important-to-safety structures, systems or components (SSCs) have approved implementing procedures describing administrative controls, and work processes implementing the design. (QAM, Policy Q-05, Sections 3.1.1 and 3.3; ISMP, Table 1-3, item 5; and SRD, Safety Criterion (SC) 4.1-2 and 7.3-5)

4.1.1.2 The inspector should verify procedures provide for quality control (QC) inspection to ensure important-to-safety aspects of visual examination are verified and documented. As part of the assessment of the QC inspection procedures, ensure the procedures include or reference appropriate quantitative or qualitative acceptance criteria for determining that the prescribed activities have been accomplished satisfactorily. (QAM, Policy Q-05.1, Section 3.5.1; ISMP, Table 1-3, items 5 and 8; and SRD SC 4.1-2, and 7.3-7)

4.1.1.3 The inspector should verify procedures require that equipment used for visual examination, as appropriate, is calibrated and maintained. (QAM Q-12.1, Sections 3.1.2 and 3.2 ; ISMP, Table 1-3, items 5 and 8; and SRD, SC 7.3-7 and 7.3-5)

4.1.1.4 The inspector should verify the Contractor has established procedures for ensuring test and QC inspection personnel performing visual examination activities, are qualified to perform their assigned work. (QAM, Policy Q-02.2, Section 3.3.2; and ISMP, Table 1-3, item 2)

4.1.2 Radiographic Examination

4.1.2.1 The inspector should verify all Contractor/Subcontractors with construction responsibilities that include radiographic examination of important-to-safety SSCs have approved implementing procedures describing administrative controls, and work processes implementing the design. (Same requirements as 4.1.1.1 above)

4.1.2.2 The inspector should verify procedures provide for quality control (QC) inspection to ensure important-to-safety aspects of radiographic examination are verified and documented. As part of the assessment of the QC inspection procedures, ensure the procedures include or reference appropriate quantitative or qualitative acceptance criteria for determining the prescribed activities have been accomplished satisfactorily. (Same requirements as 4.1.1.2 above)

4.1.2.3 The inspector should verify procedures require equipment used for radiographic examination process monitoring or data collection is calibrated and maintained. (Same requirements as 4.1.1.3 above)

4.1.2.4 The inspector should verify the Contractor has established procedures for ensuring test and QC inspection personnel, performing radiography activities, are qualified to perform their assigned work. (Same requirements as 4.1.1.4 above)

4.1.3 Ultrasonic Examination

4.1.3.1 The inspector should verify all Contractor/Subcontractors with construction responsibilities that include ultrasonic examination of important-to-safety SSCs have approved implementing procedures describing administrative controls, and work processes implementing the design. (Same requirements as 4.1.1.1 above)

4.1.3.2 The inspector should verify procedures provide for quality control (QC) inspection to ensure important-to-safety aspects of ultrasonic examinations are verified and documented. As part of the assessment of the QC inspection procedures, ensure the procedures include or reference appropriate quantitative or qualitative acceptance criteria for determining the prescribed activities have been accomplished satisfactorily. (Same requirements as 4.1.1.2 above)

4.1.3.3 The inspector should verify procedures require equipment used for ultrasonic examination process monitoring or data collection is calibrated and maintained. (Same requirements as 4.1.1.3 above)

4.1.3.4 The inspector should verify the Contractor has established procedures for ensuring test and QC inspection personnel, performing ultrasonic examinations, are qualified to perform their assigned work. (Same requirements as 4.1.1.4 above)

4.1.4 Liquid Penetrant Examination

4.1.4.1 The inspector should verify all Contractor/subcontractors with construction responsibilities that include liquid penetrant examination of important-to-safety SSCs have approved implementing procedures describing administrative controls, and work processes implementing the design. (Same requirements as 4.1.1.1 above)

4.1.4.2 The inspector should verify procedures provide for quality control (QC) inspection to ensure important-to-safety aspects of liquid penetrant examinations are verified and documented. As part of the assessment of the QC inspection procedures, ensure the procedures include or reference appropriate quantitative or qualitative acceptance criteria for determining prescribed activities have been accomplished satisfactorily. (Same requirements as 4.1.1.2 above)

4.1.4.3 The inspector should verify procedures require equipment used for liquid penetrant examination process monitoring or data collection is calibrated and maintained. (Same requirements as 4.1.1.3 above)

4.1.4.4 The inspector should verify the Contractor has established procedures for ensuring that test and QC inspection personnel, performing liquid penetrant examinations, are qualified to perform their assigned work. (Same requirements as 4.1.1.4 above)

4.1.5 Magnetic Particle Examination

4.1.5.1 The inspector should verify all Contractor/subcontractors with construction responsibilities that include magnetic particle examination of important-to-safety SSCs have approved implementing procedures describing administrative controls, and work processes implementing the design. (Same requirements as 4.1.1.1 above)

4.1.5.2 The inspector should verify procedures provide for quality control (QC) inspection to ensure important-to-safety aspects of magnetic particle examinations are verified and documented. As part of the assessment of the QC inspection procedures, ensure the procedures include or reference appropriate quantitative or qualitative acceptance criteria for determining prescribed activities have been accomplished satisfactorily. (Same requirements as 4.1.1.2 above)

4.1.5.3 The inspector should verify procedures require equipment used for magnetic particle examination process monitoring or data collection is calibrated and maintained. (Same requirements as 4.1.1.3 above)

4.1.5.4 The inspector should verify the Contractor has established procedures for ensuring test and QC inspection personnel, performing magnetic particle examinations, are qualified to perform their assigned work. (Same requirements as 4.1.1.4 above)

4.2 Adequacy and effectiveness of construction Activities

4.2.1 Visual Examination

The inspector should verify visual examination activities are being controlled and accomplished under controlled conditions using approved instructions, procedures, and checklists prepared at a level of detail based on the importance and complexity of the work process being performed. (QAM, Policy Q-09.1, Section 3.1.2; SRD, SC 4.1-2 and 7.3-5; and ISMP, Table 1-3, item 5)

4.2.2 Radiographic Examination

The inspector should verify radiographic examination activities are being controlled and accomplished under controlled conditions using approved instructions, procedures, and checklists prepared at a level of detail based on the importance and complexity of the work process being performed. (Same requirements as Section 4.2.1 above)

4.2.3 Ultrasonic Examination

The inspector should verify ultrasonic examination activities are being controlled and accomplished under controlled conditions using approved instructions, procedures, and checklists prepared at a level of detail based on the importance and complexity of the work process being performed. (Same requirements as Section 4.2.1 above)

4.2.4 Liquid Penetrant Examination

The inspector should verify liquid penetrant examination activities are being controlled and accomplished under controlled conditions using approved instructions, procedures, and checklists prepared at a level of detail based on the importance and complexity of the work process being performed. (Same requirements as Section 4.2.1 above)

4.2.5 Magnetic Particle Examination

The inspector should verify magnetic particle activities are being controlled and accomplished under controlled conditions using approved instructions, procedures, and checklists prepared at a level of detail based on the importance and complexity of the work process being performed. (Same requirements as Section 4.2.1 above)

4.3 Adequacy and Effectiveness of the Training and Qualification of Personnel

4.3.1 Visual Examination

The inspector should verify testing and QA/QC personnel involved in the performance of visual examination and inspection activities are qualified to perform their job functions. (QAM, Policy Q-02.2, Section 3.3.3 and Policy Q-09.1, Section 3.1.7; ISMP, Table 1-3, item 2; and SRD, SC 7.2-2 and 7.3-3)

4.3.2 Radiographic Examination

The inspector should verify testing and QA/QC personnel involved in the performance of radiographic examination and inspection activities are qualified to perform their job functions. (Same requirements as Section 4.3.1 above)

4.3.3 Ultrasonic Examination

The inspector should verify testing and QA/QC personnel involved in the performance of ultrasonic examination and inspection activities are qualified to perform their job functions. (Same requirements as Section 4.3.1 above)

4.3.4 Liquid Penetrant

The inspector should verify testing and QA/QC personnel involved in the performance of liquid penetrant examination and inspection activities are qualified to perform their job functions. (Same requirements as Section 4.3.1 above)

4.3.5 Magnetic Particle

The inspector should verify testing and QA/QC personnel involved in the performance of magnetic particle examination and inspection activities are qualified to perform their job functions. (Same requirements as Section 4.3.1 above)

4.4 Adequacy and Effectiveness of the System of Records

4.4.1 Visual Examination

The inspector should verify records of visual examinations are as specified, reviewed by the Contractor for accuracy and assurance that the recorded information meets project requirements, approved, and stored and maintained sufficient to support technical and contract requirements. (QAM, Policy Q-17.1, Sections 3.1.2, 3.3.1 and 3.6.1; SRD, SC 4.0-3, 4.1-2, and 7.3-4; and ISMP, Section 8 and Table 1-3, item 4)

4.4.2 Radiographic Examination

The inspector should verify records of radiographic examination are as specified, reviewed by the Contractor for accuracy and assurance that the recorded information meets project requirements, approved, and stored and maintained sufficient to support technical and contract requirements. (Same requirements as Section 4.1.1)

4.4.3 Ultrasonic Examination

The inspector should verify records of ultrasonic examinations are as specified, reviewed by the Contractor for accuracy and assurance that the recorded information meets project requirements, approved, and stored and maintained sufficient to support technical and contract requirements. (Same requirements as Section 4.4.1)

4.4.4 Liquid Penetrant Examination

The inspector should verify records of liquid penetrant examinations are as specified, reviewed by the Contractor for accuracy and assurance that the recorded information meets project requirements, approved, and stored and maintained sufficient to support technical and contract requirements. (Same requirements as Section 4.4.1)

4.4.5 Magnetic Particle Examination

The inspector should verify records of magnetic particle examinations are as specified, reviewed by the Contractor for accuracy and assurance that the recorded information meets project requirements, approved, and stored and maintained sufficient to support technical and contract requirements. (Same requirements as Section 4.4.1)

5.0 INSPECTION GUIDANCE

There are several industry standards that provide requirements for nondestructive testing. The code or standard used for fabrication or welding will often invoke the code or standard used for a specific activity. For example, ANS/ASME B 31.3-96, “Process Piping, ASME Code for Pressure Piping,” Paragraph 344.5, specifies that radiography of welds shall be performed in accordance with the ASME Boiler and Pressure Vessel Code, Section V, Article 2.” Therefore to ensure the correct standard is used for this evaluation, the inspector shall obtain from the Contractor or subcontractor the applicable code or standard used for design and construction of the SSCs being assessed.

For each of the inspection elements, the inspector should: (1) obtain a copy of the Contractor’s procedures and the related industry codes and standards committed to by the Contractor; (2) become familiar with the contents of the procedures and standards; and (3) assess whether the procedures and implementation of the procedures adequately conform to the applicable commitments. SRD, SC 4.1-2, refers to ANS/AISC N690-94, “Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities.” ANS/AISC N690-94 references AWS D1.1 for all structural steel welding. AWS D1.1 includes inspection requirements for nondestructive testing. AWS D1.1 is one of the primary industry standards referenced for this inspection. SRD, SC 4.4-15, refers to ASME Section III of the Boiler and Pressure Vessel (B&PV) Codes. ASME Section III of the B&PV Code references Section V of the B&PV Code for nondestructive testing. SRD, SC 4.4-19 refers to Section VIII of the B&PV Code and ASME B31.3-96, “ASME Code For Pressure Piping, B31.” Both of these codes also reference ASME Section V of the B&PV Code for nondestructive testing. ASME Section V is also one of the primary industry standards for this inspection. The referenced codes in the SRD do not specify the revision of ASME Section V of the B&PV Code to use. The references to Section V below will refer to the 1998 revision. If a different standard is selected by the Contractor and approved by the RU, the appropriate requirements from the approved standard will be used for inspection.

Included in the Section 5.2 below are suggested sample selections. The inspector can follow the suggestions or choose samples more appropriate for the inspection due to construction progress, completion of Contractor's QA/QC reviews, or inspector experience. The inspector should use judgement in determining sample selection, focusing on examination of the most important aspects of the particular activity being inspected. The intent is to establish a high level of assurance that the end product meets requirements.

5.1 Adequacy and Effectiveness of Construction Implementing Procedures

The adequacy and effectiveness of the Contractor's procedures is assessed by how well the procedures conform to the applicable commitments and implement the applicable code or standard. Inspection guidance for each of the five areas of nondestructive testing is provided separately in the sections below.

5.1.1 Visual Examination

5.1.1.1 The inspector should review the implementing procedures for visual examination of important-to-safety SSCs provided by the Contractor. Verify the procedures (1) are approved and (2) specify the appropriate requirements from the selected standard (i.e. AWS D1.1, Section 6.9 or ASME B&PV Code, Section V, Article 9).

The inspector should determine whether the visual examination procedures contains information sufficient to ensure the following attributes are specified and controlled within the limits permitted by the applicable standard:

- Application of procedure (i.e. inspection of all welds, direct or remote viewing)
- Material and weld surface condition (cleaning prior to inspection)
- Sequence for performing the inspection
- Accept/reject criteria
- Permitted time interval during which the inspection is performed
- Minimum light intensity at the inspection site
- Special illumination, instruments, or equipment to be used, if any.

5.1.1.2 The inspector should review the QC inspection procedures for visual examination of important-to-safety SSCs. Verify the procedures (1) are approved and (2) provide for adequate QC inspections to ensure the visual examinations are completed in accordance with engineering drawings, procedures and authorization basis requirements. The QC procedures should ensure that the visual examinations are performed in accordance with the referenced standard (such as AWS D1.1, Section 6 or ASME B&PV Code, Section V, Division 1, Article 9).

The inspector should determine whether the QC inspection procedures are adequate to verify the attributes listed in Section 5.1.1.1 above.

5.1.1.3 The inspector should review the procedures establishing the requirements for the qualification of visual examination and inspection personnel, and determine whether the procedures conform to the requirements of QAM, Policy Q-02.2 Section 3.3.3.

5.1.2 Radiographic Examination

5.1.2.1 The inspector should review the implementing procedures for radiographic examination of important-to-safety SSCs provided by the Contractor. Verify the procedures (1) are approved and (2) specify the appropriate requirements from the selected standard (i.e. AWS D1.1, Section 6.12 or ASME B&PV Code, Section V, Article 2).

The inspector should determine whether the radiographic examination procedures contain information sufficient to ensure that the following attributes are specified and controlled within the limits permitted by the applicable standard:

- Material and weld surface condition (irregularities, weld ripples, surface finish, etc.)
- Type of material and allowable thickness range
- Type of radiation source, effective focal spot or effective source size, and X-ray equipment voltage rating, as applicable
- Minimum source-to-object distance
- Maximum distance from source side of object to the film
- Maximum source size
- Film brand and designation and number of films in each cassette
- Blocking or masking technique, if used
- Type, thickness and use of intensifying screens and filters
- Exposure conditions for procedure qualification, if applicable
- Radiographic film processing requirements
- Quality of radiographs (limits on mechanical, chemical or other blemishes, such as fogging, processing marks, scratches, finger marks, loss of detail or false indications)

- Film density limits for single and composite viewing
- Use of image quality indicators (IQIs) or densitometers for assuring film density
- System of radiographic identification
- Selection of image quality indicator (IQI)
- Number and placement of IQIs
- Use of location markers
- Method of reducing and testing for backscatter
- Description of, or reference to, the welding procedure
- Geometrical unsharpness limitations
- Selection and use of penetrameters including:
  - Penetrameter design
  - Selection of essential hole
  - Penetrameter thickness including special considerations for single and double wall viewing
  - Number of penetrameters
  - Shims under penetrameters
- Radiographic technique for double wall viewing
- Qualification of radiographic procedure (radiographs taken to demonstrate procedure capability)
- Evaluation and disposition of radiographic findings

5.1.2.2 The inspector should review QC inspection procedures for radiographic examination of important-to-safety SSCs. Verify the procedures (1) are approved and (2) provide for adequate QC inspections to ensure the radiographic examinations are completed in accordance with engineering drawings, procedures and authorization basis requirements. The QC procedures should ensure that the radiographic examinations are performed in accordance with the referenced standard (i.e. AWS D1.1, Section 6 or ASME B&PV Code, Section V, Article 2).

The inspector should determine whether QC inspection procedures are adequate to verify the attributes listed in Section 5.1.2.1 above.

5.1.2.3 The inspector should ensure procedures require that equipment such as film density (densitometers) and radiation (radiation monitors) measuring devices are calibrated and maintained. The calibration standards should be traceable to industry recognized criteria (for example, the National Bureau of Standards). (**Not Committed)**

5.1.2.4 The inspector should review procedures establishing the requirements for the qualification of radiographic testing and inspection personnel and determine whether the procedures conform to the requirements of QAM, Policy Q-02.2 Section 3.3.3 .

5.1.3 Ultrasonic Examination

5.1.3.1 The inspector should review implementing procedures for ultrasonic examination of important-to-safety SSCs provided by the Contractor. Verify the procedures (1) are approved and (2) specify the appropriate requirements from the selected standard (i.e. AWS D1.1, Section 6.13 or ASME B&PV Code, Section V, Article 5).

The inspector should determine whether the ultrasonic examination procedures contain information sufficient to ensure that the following attributes are specified and controlled within the limits permitted by the applicable standard:

- Weld and/or material types and configurations to be examined, including thickness dimensions
- Surface condition
- Couplant, brand name or type
- The type of apparatus to be used, frequency range, linearity, and signal attenuation accuracy
- The extent of coverage (beam angles, scanning rate and direction) and scanning technique
- Calibration requirements, methods, and frequency including type, size, geometry, and material of calibration block as well as location and size of reflectors within the calibration block
- Size and frequencies of the search unit
- Methods of compensation for distance traversed by the ultrasonic beam as it passes through the material including distance-amplitude correction curves, electronic distance-amplitude correction and transfer mechanisms
- Reference level for monitoring discontinuities and scanning gain setting
- Levels or limits for evaluating and recording indications
- Post-examination cleaning.

5.1.3.2 The inspector should review QC inspection procedures for ultrasonic examination of important-to-safety SSCs. Verify the procedures (1) are approved and (2) provide for adequate QC inspections to ensure the ultrasonic examinations are completed in accordance with engineering drawings, procedures and authorization basis requirements. The QC procedures should ensure that the ultrasonic examinations are performed in accordance with the referenced standard (i.e. AWS D1.1, Section 6 or ASME B&PV Code, Section V, Article 5).

The inspector should determine whether the QC inspection procedures are adequate to verify the attributes listed in Section 5.1.3.1 above.

5.1.3.3 The inspector should ensure the procedures require that equipment such as the ultrasonic search units calibration blocks are calibrated and maintained. The calibration standards should be traceable to industry recognized criteria (for example, the National Bureau of Standards). (**Not Committed)**

5.1.3.4 The inspector should review procedures establishing the requirements for the qualification of ultrasonic testing and inspection personnel and determine whether the procedures conform to the requirements of QAM, Policy Q-02.2 Section 3.3.3 .

5.1.4 Liquid Penetrant Examination

5.1.4.1 The inspector should review implementing procedures for liquid penetrant examination of important-to-safety SSCs provided by the Contractor. Verify the procedures (1) are approved and (2) specify the appropriate requirements from the selected standard (i.e. AWS D1.1, Section 6.14.6[1] or ASME B&PV Code, Section V, Article 6).

The inspector should determine whether the liquid penetrant examination procedures contains information sufficient to ensure that the following attributes are specified and controlled within the limits permitted by the applicable standard:

- Brand names and specific types (number or letter designation, if available) of penetrant, penetrant remover, emulsifier, and developer.
- Methods for acceptable pre-examination of the surface preparation and cleanliness of surface to be examined including minimum time allowed for drying.
- Processing details for applying the penetrant, the length of time the penetrant will remain on the surface (dwell time), and the temperature of the surface and the penetrant during the examination.

[1] AWS D1.1, "Structural Steel Weld Code," Section 6.14.6, "Dye Penetrant Testing," references ASTM E165, "Standard Test Method for Liquid Penetrant Examination," as the standard for inspection.

- Processing details for removing excess penetrant from the surface and for drying the surface before applying the developer.

- Method for applying the emulsifier (when applicable) and the maximum emulsification time.

- Processing details for applying the developer and length of developing time before interpretation.

- Examination technique and the permitted time interval during which the "final interpretation" is performed.

- Minimum light intensity at the inspection site.

- Processing details for post-examination cleaning.

5.1.4.2 The inspector should review QC inspection procedures for liquid penetrant examination of important-to-safety SSCs. Verify the procedures (1) are approved and (2) provide for adequate QC inspections to ensure the liquid penetrant examinations are completed in accordance with engineering drawings, procedures and authorization basis requirements. The QC procedures should ensure that the liquid penetrant examinations are performed in accordance with the referenced standard (i.e. AWS D1.1, Section 6 or ASME B&PV Code, Section V, Article 6).

The inspector should determine whether the QC inspection procedures are adequate to verify the attributes listed in Section 5.1.4.1 above.

5.1.4.3 The inspector should ensure procedures require that equipment such as the liquid penetrant comparator blocks, if used, are calibrated and maintained. The calibration standards should be traceable to industry recognized criteria (for example, the National Bureau of Standards). (**Not Committed)**

5.1.4.4 The inspector should review procedures establishing the requirements for the qualification of liquid penetrant examination and inspection personnel and determine whether the procedures conform to the requirements of QAM, Policy Q-02.2 Section 3.3.3 .

5.1.5 Magnetic Particle Examination

5.1.5.1 The inspector should review implementing procedures for magnetic particle examination of important-to-safety SSCs provided by the Contractor. Verify the procedures (1) are approved and (2) specify the appropriate requirements from the selected standard (i.e. AWS D1.1, Section 6.14.5[2] or ASME B&PV Code, Section V, Article 6).

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[2] AWS D1.1, "Structural Steel Weld Code," Section 6.14.5, "Magnetic Particle Testing," references ASTM E709, "Standard Guide for Magnetic Particle Examination," as the standard for inspection.

The inspector should determine whether magnetic particle examination procedures contain information sufficient to ensure the following attributes are specified and controlled within the limits permitted by the applicable standard:

- Areas to be examined
- Type of magnetic particle (dry or wet, visible or fluorescent)
- Magnetic particle equipment
- Part surface preparation requirements
- Magnetizing process (continuous, true-continuous, or residual)
- Magnetizing current (alternating, half-wave rectified AC, full-wave rectified AC, or direct)
- Means of establishing part magnetization (direct prods, head/tailstock contact or cable wrap, indirect-coil/cable wrap, yoke, central conductor, etc.
- Direction of magnetic field (circular or longitudinal)
- System performance/sensitivity checks
- Magnetic field strength (ampere turns, field density, magnetizing force, and number and duration of application of magnetizing current)
- Application of examination media
- Interpretation and evaluation of indications
- Type of records including accept/reject criteria
- Demagnetizing techniques, if required
- Post-examination cleaning, if required

5.1.5.2 The inspector should review QC inspection procedures for magnetic particle examination of important-to-safety SSCs. Verify the procedures (1) are approved and (2) provide for adequate QC inspections to ensure the magnetic particle examinations are completed in accordance with engineering drawings, procedures and authorization basis requirements. The QC procedures should ensure magnetic particle examinations are performed in accordance with the referenced standard (i.e. AWS D1.1, Section 6 or ASME B&PV Code, Section V, Article 7).

The inspector should determine whether the QC inspection procedures are adequate to verify the attributes listed in Section 5.1.5.1 above.

5.1.5.3 The inspector should ensure procedures require equipment with ammeters are calibrated and maintained. Also the lifting power of yokes, if used, is required to be calibrated. The calibration standards should be traceable to industry recognized criteria (for example, the National Bureau of Standards). (**Not Committed)**

5.1.5.4 The inspector should review procedures establishing the requirements for the qualification of magnetic particle testing and inspection personnel and determine whether the procedures conform to the requirements of QAM, Policy Q-02.2 Section 3.3.3 .

5.2 Adequacy and Effectiveness of Construction Activities

Prior to performing work observation inspections in the field, the inspector should review the procedures and industry standards which apply to the work that will be observed to ensure familiarity with the requirements and acceptance criteria pertinent to the planned observations. Based on the preliminary design submitted by the Contractor, the applicable standards are AWS D1.1 and ASME Section V of the B&PV Code. During the field observations, the inspector should carry a copy of the sections of the procedure and industry standards pertinent to the planned observations and verify that work is being accomplished using procedures of the proper revision.

The adequacy and effectiveness of the Contractor's construction activities is assessed by how well the Contractor's procedures are being implemented. For each of the five areas of nondestructive testing, selected code requirements are provided and can be used to verify implementation of the procedures. The five parts of nondestructive testing are addressed separately below.

During the field observations, the inspector should interview and obtain the names of a sample of the test and QC personnel performing the observed activities to assess whether their knowledge of the job and procedures is satisfactory. The sample size will be determined by the number of Contractor personal performing the activity, but not less than one or more than four of each discipline (test and QC personnel). Information on these same personnel will be used pursuant to Section 4.3, below, to determine the adequacy of their experience and training.

5.2.1 Visual Examination

The inspector should select six visual inspections used to verify the quality of welds for important-to-safety SSCs. Observe the ongoing inspections to the extent possible; otherwise review the appropriate documents. Select visual inspections for weld joints for steel structures and process piping. For each visual examination, verify the applicable code requirements were incorporated. Listed in Attachment 1, Section 2, are selected code requirements that the inspector can select for verification.

5.2.2 Radiographic Examination

The inspector should select six radiographs used to verify the quality of welds for important-to-safety SSCs. Observe the ongoing inspections to the extent possible; otherwise review the appropriate documents. Select visual inspections for weld joints for steel structures and process piping. For each radiograph, verify the applicable code requirements were incorporated. Listed in Attachment 2, Section 2, are selected code requirements that the inspector can select for verification.

5.2.3 Ultrasonic Examination

The inspector should select six ultrasonic examinations used to verify the quality of welds for important-to-safety SSCs. Observe the ongoing inspections to the extent possible; otherwise review the appropriate documents. If available, select ultrasonic examinations for weld joints for steel structures and process piping. For each ultrasonic examination, verify the applicable code requirements were incorporated. Listed in Attachment 3, Section 2, are selected code requirements that the inspector can select for verification.

5.2.4 Liquid Penetrant Examination

The inspector should select six liquid penetrant examinations used to verify the quality of welds for important-to-safety SSCs. Observe the ongoing inspections to the extent possible; otherwise review the appropriate documents. If available, select liquid penetrant examinations for weld joints for steel structures and process piping. For each liquid penetrant examination, verify the applicable code requirements were incorporated. Listed in Attachment 4, Section 2, are selected code requirements that the inspector can select for verification.

5.2.5 Magnetic Particle Examination

The inspector should select six magnetic particle examinations used to verify the quality of welds for important-to-safety SSCs. Observe the ongoing inspections to the extent possible; otherwise review the appropriate documents. If available, select magnetic particle examinations for weld joints for steel structures and process piping. For each magnetic particle examination, verify the applicable code requirements were incorporated. Note: Magnet particle examination is usually best suited to production operations. There may not be any magnetic particle examination performed at a construction site. Listed in Attachment 5, Section 2, are selected code requirements that the inspector can select for verification

5.3 Adequacy and Effectiveness of the Training and Qualification of Personnel

During the observation of work activities (Section 5.2, above), the inspector should carry a copy of the procedures specifying the Contractor's requirements for education and experience levels, training and certification. The inspector should interview four test and four QA/QC personnel involved in the performance of nondestructive examination activities being inspected, and record which job they were performing. The inspector should verify that the personnel are sufficiently knowledgeable of procedure requirements. The inspector should also review the training and qualification records for those individuals to determine if they meet the requirements. This activity should be repeated for each of the five nondestructive examination types (visual, radiographic, ultrasonic, liquid penetrant, and magnetic particle).

5.4 Adequacy and Effectiveness of the System of Records

The inspector should select a sample of ten (10) records that were reviewed during the conduct of each of the five types of nondestructive examinations, and the records of qualification for those craft and QA/QC personnel selected during the performance of Section 5.3, above. The inspector should verify that the records selected for examination were approved by proper authority and were stored and maintained in such a manner to demonstrate conformance with procedure requirements.

6.0 REFERENCES

The Contractor requirements that form the basis for this procedure are identified below:

10 CFR 830, Subpart A, "Quality Assurance Requirements"

Quality Assurance Manual, 24590-WTP-QAM-QA-01-001, Revision 0, BNI Inc., 2001

Safety Requirements Document, BNI-5193-SRD-01-02, Revision 4, 2001

Integrated Safety Management Plan, BNI-5193-ISP-01, Revision 5, 2000

ANS/AISC N690-1994, "Specification for the Design, Fabrication, and Erection of Steel Safety –Related Structures for Nuclear Facilities," American National Standard/American Institute for Steel Construction

American Welding Society (AWS), "Structural Welding Code", D1.1-1996

American Society of Mechanical Engineers (ASME), Boiler and Pressure Vessel (B&PV) Code, 1998, Sections III, V, and VIII.

ASME Code for Process Piping, B31.3-96

Annual Books of ASTM Standards-1996, Section 3, Volume 03.03, "Nondestructive Testing".

American Society for Nondestructive Testing (ASNT), Recommended Practice No. SNT-TC-1A, 1996

7.0 LIST OF TERMS

AC	alternating current
ANS	American National Standard
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	American Society for Testing and Materials
B&PV Code	ASME Boiler and Pressure Vessel Code
IQI	image quality indicators
ISMP	Integrated Safety Management Plan
QA	Quality Assurance
QAM	Quality Assurance Manual
RPP	River Protection Program
SC	Safety Criteria
SRD	Safety Requirements Document
WTP	Waste Treatment Plant

Attachments:
Attachment 1: Visual examination definitions and selected code requirements
Attachment 2: Radiography examination definitions and selected code requirements
Attachment 3: Ultrasonic examination definitions and selected code requirements
Attachment 4: Liquid Penetrant examination definitions and selected code requirements
Attachment 5: Magnetic Particle examination definitions and selected code requirements

Attachment 1. Visual

1.0 Definitions

Defect - One or more flaws whose aggregate size, shape, orientation, location, or properties do not meet specified acceptance criteria and are rejectable.

Discontinuity - A lack of continuity or cohesion; an intentional or unintentional interruption in the physical structure or configuration of a material or component.

Evaluation - A review, following interpretation of the indications noted, to determine whether they meet specified acceptance criteria.

Flaw - An imperfection or discontinuity that may be detectable by nondestructive testing and is not necessarily rejectable.

Imperfection - A departure of a quality characteristic from its intended condition.

Indication - Evidence of a discontinuity that requires interpretation to determine its significance.

2.0 Selected Requirements from Applicable Codes

The requirements listed below are numbered with the same numbers used in the code. Since all the requirements are not listed the numbers may not be sequential.

Requirements from AWS D1.1, Section 6.9, "Visual Inspection"

6.9 All welds will be visually inspected and shall be acceptable if the criteria of Table 1, below, are satisfied.

Table 6.1. Visual Inspection Acceptance Criteria

DISCONTINUITY CATEGORY AND INSPECTION CRITERIA	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections	Tubular Connections (All Loads)
(1) Crack Prohibition The weld shall have no cracks.	X	X	X
(2) Weld/Base-Metal Fusion Thorough fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.	X	X	X
(3) Crater Cross Section All craters shall be filled to the full cross section of the weld, except for the ends of intermittent fillet welds outside of their effective length.	X	X	X
(4) Weld Profiles Weld profiles shall be in conformance with Paragraph 5.24, Section 5 of AWS D1.1.	X	X	X
(5) Time of Inspection Visual inspection of welds in all steels may begin immediately after the completed welds have cooled to ambient temperature. Acceptance criteria for ASTM A514 and A517 steels shall be based on visual inspection performed not less than 48 hours after completion of the weld.	X	X	X
(6) Underrun A fillet weld in any single continuous weld shall be permitted to underrun the nominal fillet size specified by 1/16 in. (1.6 mm) without correction, provided that the undersize portion of the weld does not exceed 10% of the length of the weld. On web-to-flange welds on girders, no underrun is permitted at the ends for a length equal to twice the width of the flange.	X	X	X
(7) Undercut (A) For material less than 1 in. (25.4 mm) thick, undercut shall not exceed 1/32 in. (1 mm), except that a maximum 1/16 in. (1.6 mm) is permitted for an accumulated length of 2 in. (50 mm) in any 12 in. (305 mm). For material equal to or greater than 1 in. thick, undercut shall not exceed 1/16 in. for any length of weld.	X		
(B) In primary members, undercut shall be no more than 0.01 in. (0.25 mm) deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall be no more than 1/32 in. (1 mm) deep for all other cases.		X	X
(8) Porosity (A) Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity. For all other groove welds and for fillet welds, the sum of the visible piping	X		

porosity 1/32 in. (1 mm) or greater in diameter shall not exceed 3/8 in. (10 mm) in any linear inch of weld and shall not exceed 3/4 in. (19 mm) in any 12 in. (305 mm) length of weld.			
(B) The frequency of piping porosity in fillet welds shall not exceed one in each 4 in. (100 mm) of weld length and the maximum diameter shall not exceed 3/32 in. (2 mm). Exception: for fillet welds connecting stiffeners to web, the sum of the diameters of piping porosity shall not exceed 3/8 in. (10 mm) in any linear inch of weld and shall not exceed 3/4 in. (19 mm) in any 12 in. (305 mm) length of weld.		X	X
(C) Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds the frequency of piping porosity shall not exceed one in 4 in. (100 mm) of length and the maximum diameter shall not exceed 3/32 in. (2 mm).		X	X

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Attachment 2. Radiography

1.0 Definitions

Area of interest - The specific portion of the object image on the radiograph that is to be evaluated.

Artifact – Spurious indications on a radiograph arising from, but not limited to, faulty manufacture, storage, handling, exposure or processing.

Blocking or masking – Surrounding specimens or covering their sections with absorptive material.

Cassette – A light-tight container for holding radiographic recording media during exposure, for example, film, with or without intensifying or conversion screens.

Characteristic curve – The plot of density verse log of exposure or relative exposure. (Also called the D-log E curve or the H and D curve.)

Definition, image definition - The sharpness of delineation of image detail in a radiograph. Generally used qualitatively.

Densitometer - A device for measuring the optical density of radiographic film.

Density – The quantitative measure of film blackening when light is transmitted or reflected.

$$D = \log (I_0/I) \text{ or } D = \log (I_0/R)$$

Where:

D = density
I_0 = light intensity incident on the film
I = light intensity transmitted
R = light intensity reflected

Equivalent IQI – That thickness of IQI expressed as a percentage of the section thickness radiologically examined in which a 2T hole or 2% wire size equivalent would be visible under the same radiological conditions.

Equivalent penetrameter sensitivity – That thickness of penetrameter expressed as a percentage of the section thickness radiographed, in which a 2T hole would be visible under the same radiological conditions

Exposure, radiographic exposure – The subjection of a recording medium to radiation for the purpose of producing a latent image. Radiographic exposure is commonly expressed in terms of milliampere-seconds or millicurie-hours for a known source-to-film distance.

Exposure table – A summary of values of radiographic exposures suitable for the different thicknesses of a specified material.

Filter – A uniform layer of material, usually of a higher atomic number than the specimen, placed between the radiation source and the film for the purpose of preferentially absorbing the softer radiation.

Focal spot – For X-ray generators, that area of the anode (target) of a X-ray tube, which emits x-ray when, bombarded with electrons.

Fog – A general term used to denote any increase in optical density of a processed photographic emulsion caused by anything other than direct action of the image forming radiation and due to one or more of the following:

(*a*) *aging* – deterioration, before or after exposure, or both, resulting from a recording medium that has been stored for too long a period of time, or improper conditions.

(*b*) *base* – the minimum uniform density inherent in a processed emulsion without prior exposure.

(c) chemical – resulting from unwanted reactions during chemical processing.

(d) dichroic – characterized by the production of colloidal silver within the developed sensitive layer.

(e) oxidation – caused by exposure to the air during developing.

(f) exposure – arising from the unwanted exposure of an emulsion to ionizing radiation or light at any time between manufacture and final fixing.

(g) photographic – arising solely from the properties of an emulsion and the processing conditions, for example, the total effect of inherent fog and chemical fog.

(h) threshold – the minimum uniform density inherent in a processed emulsion without prior exposure.

Geometric unsharpness – the penumbral shadow in a radiological image which is dependent upon 1) the radiation source dimensions, 2) the source to object distance, and 3) object to detector distance.

Half-value layer (HVL) – The thickness of an absorbing material required to reduce the intensity of a beam of incident radiation to one half of its original intensity.

Half-value thickness – The thickness of a specified substance which, when introduced into the path of a given beam of radiation, reduces its intensity to one half.

Image quality indicator (IQI) – In industrial radiology, a device or combination of devices whose demonstrated image or images provide visual or quantitative data, or both, to determine radiographic quality and sensitivity.

Indication – The response or evidence from a nondestructive examination that requires interpretation to determine relevance.

Intensifying screen – A material that converts a part of the radiographic energy into light or electrons and that, when in contact with a recording medium during exposure, improves the quality of the radiograph, or reduces the exposure time required to produce a radiograph, or both. Three kinds of screens in common use are:

(a) *metal screen* – a screen consisting of a dense metal (usually lead) or a dense metal compound (for example, lead oxide) that emits primary electrons when exposed to X- or gamma-rays.
(*b*) *fluorescent screen* – a screen consisting of phosphors which fluoresces when exposed to X or gamma radiation.
(c) fluorescent-metallic – a screen consisting of a metallic foil (usually lead) coated with a material that fluoresces when exposed to X or gamma radiation. The coated surface is placed next to the film to provide fluorescence; the metal functions as a normal metal screen.

Location marker – A number or letter made of lead or other highly radiation attenuative material that is placed on an object to provide traceability between a specific area on the image and the part.

Object-film distance – The distance between the surface of the source side object and the plane of the recording medium.

Shim – A material, typically placed under the IQI, which is radiographically similar to the object being imaged.

Source – A machine or radioactive material that emits penetrating radiation.

Step wedge – A device with discrete step thickness increments used to obtain an image with discrete density step values.

Step-wedge calibration film – A step-wedge comparison film the densities of which are traceable to a nationally recognized standards body.

Step wedge comparison film – A radiograph with discrete density steps that have been verified by comparison with a calibrated step wedge film.

2.0 Selected Requirements from Applicable Codes

The requirements listed below are numbered with the same numbers used in the code. Since all the requirements are not listed, the numbers may not be sequential.

2.1 Requirements from AWS D1.1, Section 6.12, Acceptance Criteria

6.12.1. Acceptance criteria for statically loaded nontubular connections.

6.12.1.1 Discontinuities. Welds that are subject to radiographic examination in addition to visual inspection shall have no cracks and shall be unacceptable if the radiographic examination shows any discontinuities exceeding the following limitations (E = weld size).

(1) Elongated discontinuities exceeding the maximum size of Figure 6.1.

(2) Discontinuities closer than the minimum clearance allowance of Figure 6.1.

(3) Rounded discontinuities greater than a maximum of size of E/3, not to exceed ¼ in. Exceptions to this requirement are noted in AWS D1.1, Section 6.12.

(4) Isolated discontinuities such as a cluster of rounded indications, having a sum of their greatest dimensions exceeding the maximum size single discontinuity permitted in Figure 6.1.

(5) The sum of individual discontinuities each having a greater dimension of less than 3/32 in. (2 mm) shall not exceed 2E/3 or 3/8 in. (10 mm), which ever is less in any 1 in. (25 mm) of weld. This requirement is independent of (1), (2), and (3) above.

(6) In-line discontinuities, where the sum of the greatest dimension exceeds E in any length of 6E. When the length of the weld being examined is less than E, the permissible sum of the greatest dimensions shall be proportionally less.

2.2 Requirements from AWS D1.1, Section 6.17, "Radiographic Procedures"

6.17.1 Procedure. Radiographs shall be made with a single source of either X- or gamma radiation. The radiographic sensitivity shall be judged base on hole type IQI image or wire image quality indicators (IQI).

6.17.5 Technique. Radiographs shall be made with a single source of radiation centered as near as practicable with respect to the length and width of that portion of the weld being examined.

6.17.5.1 Geometric Unsharpness. Gamma ray sources, regardless of size, shall be capable of meeting the geometric unsharpness limitation of ASME Boiler and Pressure Vessel Code, Section V, Article 2.

6.17.5.2 The source-to-subject distance shall be not less than the total length of the film being exposed in a single plane. This provision does not apply to panoramic exposures made under the provisions of Section 6.17.8.2.

6.17.5.3 The source-to-subject distance shall not be less than seven times the thickness of weld plus reinforcement and backing, if any, nor such that the inspecting radiation shall penetrate any portion of the weld represented in the radiograph at an angle greater than 26-1/2° from a line normal to the weld surface.

6.17.6 Sources. X-ray units, 600 kvp maximum, and iridium 192 may be used as a source for all radiographic inspection provided they have adequate penetrating ability. Cobalt 60 shall only be used as a radiographic source when the steel being radiographed exceeds 2.5 in. (63.6 mm) in thickness. Other radiographic sources shall be subject to the approval of the Engineer.

6.17.7 IQIs shall be selected and placed on the weldment in the area of interest being radiographed as shown in table below.

IQI Selection and Placement

IQI Types	Equal T ≥ 10 in. L		Equal T < 10 in. L		Unequal T ≥ 10 in. L		Unequal T < 10 in. L	
Number of IQIs	Hole	Wire	Hole	Wire	Hole	Wire	Hole	Wire
Nontubular	2	2	1	1	3	2	2	1
Pipe Girth[3]	3	3	3	3	3	3	3	3
ASTM Standard Selection-	E1025	E747	E1025	E747	E1025	E747	E1025	E747
Table	6.4	6.5	6.4	6.5	6.4	6.5	6.4	6.5
Figures	6.11		6.12		6.13		6.14	

T = Nominal base metal thickness (T1 and T2 of Figures) (See Notes 1 and 2 below).
L = Weld Length in area of interest of each radiograph.

Notes:

1. Steel backing shall not be considered part of the weld or weld reinforcement in IQI selection.
2. T may be increased to provide for the thickness of allowable weld reinforcement provided shims are used under hole IQIs per Section 6.17.3 of AWS D1.1-96.
3. When a complete circumferential pipe weld is radiographed with a single exposure and the radiation source is placed at the center of the curvature at least three equally spaced hole type IQIs shall be used.

6.17.8 Technique. Weld joints shall be radiographed and the film indexed by methods that will provide complete and continuous inspection of the joint within the limits specified to be examined. Joint limits shall show clearly in the radiographs. Short film, short screens, excessive undercut by scattered radiation, or any other process that obscures portions of the total weld length shall render the radiograph unacceptable.

6.17.8.1 Film Length. Film shall have sufficient length and shall be placed to provide at least 1/2 in. (13 mm) of film beyond the projected edge of the weld.

6.17.8.2 Overlapping Film. Welds longer than 14 in. (355 mm) may be radiographed by overlapping film cassettes and making a single exposure, or by using single film cassettes and making separate exposures. The provisions of Section 6.17.5 shall apply.

6.17.8.3 Backscatter. To check for backscatter radiation, a lead symbol "B," 1/2 in. (13 mm) high. 1/16 in. (1.6 mm) thick shall be attached to the back of each film cassette. If the "B" image appears on the radiograph, the radiograph shall be considered unacceptable.

6.17.9 Film Width. Film widths shall be sufficient to depict all portions of the weld joint, including the heat-affected zones, and shall provide sufficient additional space for the required hole type IQIs or wire IQI and film identification without infringing upon the area of interest in the radiograph.

6.17.10 Quality of Radiographs. All radiographs shall be free from mechanical, chemical, or other blemishes to the extent that they cannot mask or be confused with the image of any discontinuity in the area of interest in the radiograph. Such blemishes include, but are not limited to the following:

(1) fogging
(2) processing defects such as streaks, water marks, or chemical stains.
(3) scratches, finger marks, crimps, dirtiness, static marks, smudges, or tears
(4) loss of detail due to poor screen-to-film contact
(5) false indications due to defective screens or internal faults

6.17.11 Density Limitations. The transmitted film density through the radiographic image of the body of the required hole type IQI(s) and the area of interest shall be 1.8 minimum for single film viewing for radiographs made with an X-ray source and 2.0 minimum for radiographs made with a gamma-ray source. For composite viewing of double film exposures, the minimum density shall be 2.6. Each radiograph of a composite set shall have a minimum density of 1.3. The maximum density shall be 4.0 for either single or composite viewing.

6.17.11.1 H & D Density. The density measured shall be H & D density (radiographic density), which is a measure of film blackening, expressed as:

$D = \log I_0/I$

where:

D= H & D (radiographic) density
I_0 = light intensity on the film, and
I = light transmitted through the film.

6.17.11.2 When weld transitions in thickness are radiographed and the ratio of the thickness of the thicker section to the thickness of the thinner section is 3 or greater, radiographs should be exposed to produce single film densities of 3.0 to 4.0 in the thinner section. When this is done, the minimum density requirements of AWS D1.1, Section 6.17.11 shall be waived unless otherwise provided in the contract documents.

6.17.12 Identification Marks. A radiograph identification mark and two location identification marks shall be placed on the steel at each radiograph location. A corresponding radiograph identification mark and two location identification marks, all of which shall show in the radiograph, shall be produced by placing lead numbers or letters, or both, over each of the identical identification and location marks made on the steel to provide a means for matching the developed radiograph to the weld. Additional information may be preprinted no less than ¾ in. (19 mm) from the edge of the weld or be produced on the radiograph by placing lead figures on the steel. Information required to be shown on the radiograph shall include the owner's contract identification, initials of the radiographic inspection company, initials of the fabricator, the fabricator shop order number, the radiographic identification mark, the date, and the weld repair number, if applicable.

2.3 Requirements from ASME B&PV Code, Section V, Article 2

T-222.2 The weld ripples or weld surface irregularities on both the inside (where accessible) and outside shall be removed by any suitable process to such a degree that the resulting radiographic image due to surface irregularities cannot mask or be confused with the image of any discontinuity.

T-223 A lead symbol "B" with minimum dimension ½ in. (13 mm) in height and 1/16 in. (1.6 mm) in thickness, shall be attached to the back of each film holder during each exposure to determine if backscatter radiation is exposing the film.

T-284 If a light image of the "B" appears on a darker background of the radiograph, protection from backscatter is insufficient and the radiograph shall be considered unacceptable. A dark image of the "B" on a lighter background is not cause for rejection.

T-224 A system shall be used to produce permanent identification on the radiograph traceable to the contract, component, weld or weld seam, or part numbers, as appropriate. In addition, Manufacture's symbol or name and the date of the radiograph shall be plainly and permanently included on the radiograph. This identification system does not necessarily require that the information appear as radiographic images. In any case, this information shall not obscure the area of interest.

T-225 Either a densitometer or step wedge comparison film shall be used for judging film density.

T- 231 Film selection shall be in accordance with SE-1815, Standard Test Method for Film Systems for Industrial Radiography. The film manufacture shall determine the film system class for the family of films manufactured and provide a classification table. A typical Film Classification Table is shown in SE-1815, Table 1. Film system classes Special, I, II, III, W-A, and W-B are permitted.

T-262 The densitometer shall be calibrated in accordance with paragraph 5 of SE-1079, Calibration of Transmission Densitometers, using a calibrated step wedge film traceable to a national standard. The density of the step wedge comparison films and densitometer calibration shall be verified by comparison with a calibrated step wedge film.

T-271 A single-wall exposure technique shall be used for radiography whenever practical. When it is not practical to use a single-wall technique, a double-wall technique shall be used. An adequate number of exposures shall be made to demonstrate that the required coverage has been obtained. See Article 2, Section T-271.2, for additional requirements on double-wall technique.

T-272.1For X-Radiation, the radiographic technique shall demonstrate that the required radiographic sensitivity has been obtained.

T-272.2For gamma radiation, The recommended minimum thickness for which radioactive isotopes may be used is as follows:

Minimum Thickness[1]		
Material	**Iridium 192**	**Colbalt 60**
Steel	0.75 in.	1.50 in.
Copper or High Nickel	0.65 in.	1.30 in.
Aluminum	2.50 in.	

NOTE:
(1) Overall radiographic sensitivity is primarily influenced by factors such as:
(a) film selection
(b) intensifying screen selection
(c) geometric unsharpness
(d) film density

The maximum thickness for the use of radioactive isotopes is primarily dictated by exposure time; therefore, upper limits are not shown. The minimum recommended thickness limitation may be reduced when the radiographic techniques used demonstrate that the required radiographic sensitivity has been obtained.

T-273 The direction of the central beam of radiation should be centered on the area of interest whenever practical.

T-274 Geometric unsharpness of the radiograph shall be determined in accordance with:

$$Ug = Fd/D$$

where
Ug = geometric unsharpness
F = source size: the maximum projected dimension of the radiating source (or effective focal spot) in the plane perpendicular to the distance D from the weld or object being radiographed, in.
D = distance from source of radiation to weld or object being radiographed, in.
d = distance from source side of weld or object being radiographed to the film, in.

NOTE: Refer to Standard Guide for Radiographic Testing, SE-94, for a method of determining geometric unsharpness. Alternatively, a nomograph as shown in Standard Guide for Radiographic Testing, SE-94, may be used.

T-275 Location markers, which are to appear as radiographic images on the film, shall be placed on the part, not on the exposure holder/cassette. Their locations shall be permanently marked on the surface of the part being radiographed when permitted, or on a map, in a manner permitting the area of interest on a radiograph to be accurately traceable to its location on the part, for the required retention period of the radiograph. Evidence shall also be provided on the radiograph that the required coverage of the region being examined has been obtained. See Article 2, Section T-275 for additional requirements for location markers.

T-276.1 Material for IQIs shall be selected from either the same alloy material group or grade as identified in SE-1025 or from an alloy material group or grade with less radiation absorption than the material being radiographed.

T-276.2 In regard to the IQIs size, the designated hole penetrameter with essential hole or designated wire diameter shall be as specified in Section T-276 of Article 2.

T-277.2 When one or more film holders are used for an exposure, at least one penetrameter image shall appear on each radiograph. See Article 2, Section T-277.2 for exceptions.

T-277.3 For welds, a shim of material radio graphically similar to the weld metal shall be placed between the part and the penetrameter, if needed, so that the radiographic density throughout the area of interest is no more than minus 15% from (lighter than) the radiographic density through the penetrameter. The shim dimensions shall exceed the penetrameter dimensions such that the outline of at least three sides of the penetrameter image shall be visible in the radiograph.

T-281 In regards to the quality of the radiographs, all radiographs shall be free from mechanical, chemical, or other blemishes to the extent that they do not mask and are not confused with the image of any discontinuity in the area of interest of the object being radiographed. Such blemishes include, but are not limited to:

(a) fogging;
(b) processing defects such as streaks, watermarks, or chemical stains;
(c) scratches, finger marks, crimps, dirtiness, static marks, smudges, or tears;
(d) false indications due to defective screens.

T-282.1 In regard to the radiographic density limitations, the transmitted film density through the radiographic image of the body of the appropriate hole penetrameter or adjacent to the designated wire of a wire penetrameter and the area of interest shall be 1.8 minimum for single film viewing for radiographs made with an X-ray source and 2.0 minimum for radiographs made with a gamma ray source. For composite viewing of multiple film exposures, each film of the composite set shall have a minimum density of 1.3. The maximum density shall be 4.0 for either single or composite viewing. A tolerance of 0.05 in density is allowed for variations between densitometer readings.

T-283 Radiography shall be performed with a technique of sufficient sensitivity to display the hole penetrameter image and the specified hole, or the designated wire of a wire penetrameter, which are essential indications of the image quality of the radiograph. The radiographs shall also display the identifying numbers and letters. If the required hole penetrameter image and specified hole, or designated wire, do not show on any film in a multiple film technique, but do show in composite film viewing, interpretation shall be permitted only by composite film viewing.

T-285 When geometric unsharpness limitations are required by the referencing Code Section, geometric unsharpness of the radiograph shall not exceed the following:

Material Thickness, in.	*Ug* Maximum, in.
Under 2	0.020
2 through 3	0.030
Over 3 through 4	0.040
Greater than 4	0.070

Note: Material thickness is the thickness on which the penetrameter is based.

Attachment 3. Ultrasonic

1.0 Definitions

A-scan - A method of data presentation utilizing a horizontal base line that indicates distance, or time, and a vertical deflection from the base line which indicates amplitude.

Amplitude - The vertical pulse height of a signal, usually base to peak, when indicated by an A-scan presentation.

Angle beam – A term used to describe an angle of incidence or refraction other than normal to the surface of the test object, as in angle beam examination, angle beam search unit, angle beam longitudinal waves, and angle beam shear waves.

Apparent attenuation - The observed ultrasound energy loss. In addition to the true loss, the apparent attenuation may also include losses attributable to instrumentation, specimen configuration, beam divergence, interface reflections, and measurement procedure.

Area amplitude response curve - A curve showing the changes in amplitude at normal incidence from planar reflectors of different areas located at equal distances from the search unit in an ultrasonic-conducting medium.

Attenuation - A factor that describes the decrease in ultrasound intensity with distance. Normally expressed in decibel per unit length.

NOTE - The attenuation parameter is sometimes expressed in nepers (Np) per unit length. The value in decibels (dB) is 8.68 times the value in nepers. If the loss over a path is 1 Np, then the amplitude has fallen to l/e of its initial value (e = 2.7183...).

Attenuator - A device for altering the amplitude of an ultrasonic indication in known increments, usually decibels.

B-scan presentation – A means of ultrasonic data presentation which displays a cross section of the specimen indicating the approximate length (as detected per scan) of reflectors and their relative positions.

Back reflection - Indication of the echo from the far boundary of the material under test.

Back surface - The end of a reference block that is opposite the entry surface.

Base line - The time of flight or distance trace (horizontal) across the A-scan CRT display (for no signal condition).

Beam spread - A divergence of the ultrasonic beam as the sound travels through a medium.

Bottom echo - *See* back reflection.

C-scan - An ultrasonic data presentation which provides a plain view of the test object, and discontinuities therein.

Collimator – A device for controlling the size and direction of the ultrasonic beam.

Control echo - Reference signal from a constant reflecting surface, such as a back reflection.

Corner effect - The reflection of an ultrasonic beam directed at normal incidence to the line of intersection of two perpendicular planes.

Couplant - A substance used between the search unit and test surface to permit or improve transmission of ultrasonic energy.

Critical angle - The incident angle of the ultrasonic beam beyond which a specific refracted wave no longer exists.

Cross talk - The signal leakage (acoustic or electric) across an intended acoustic or electric barrier.

Crystal (see transducer) - The piezoelectric element in an ultrasonic search unit. The term is used to describe single crystal piezoelectrics as well as polycrystalline piezo-electrics, such as ferroceramics.

DAC (distance amplitude correction) - Electronic change of amplification to provide equal amplitude from equal reflectors at different depths.

dB control - A control that adjusts the amplitude of the display signal in dB units.

Dead zone - The distance in the material from the surface of the test object to the depth at which a reflector can first be resolved under specified conditions. It is determined by the characteristics of the search unit, the ultrasonic test instrumentation, and the test object.

Decibel (dB) - Twenty times the base ten logarithm of the ratio of two ultrasonic signal amplitudes, dB = 20 $\log_{10}$ (amplitude ratio).

Distance amplitude compensation (electronic) - The compensation or change in receiver amplification necessary to provide equal amplitude on the display of the ultrasonic flaw detector for reflectors of equal area which are located at different depths in the material.

Distance amplitude response curve - A curve showing the relationship between the different distances and the amplitudes of ultrasonic response from targets of equal size in an ultrasonic response from targets of equal size in an ultrasonic transmitting medium.

Distance linearity range - The range of horizontal deflection in which a constant relationship exists between the incremental horizontal displacement of vertical indications on the A-scan presentation and the incremental time required for reflected waves to pass through a known length in a uniform transmission medium.

Dual search unit - A search unit containing two elements, one a transmitter, the other a receiver.

Dynamic range - A measure of the capability of a test system to accept input signals of varying magnitudes, given by the ratio of the maximum to minimum input signals which at constant gain will produce distortion-free outputs having discernable changes with incremental variations in input.

Echo - Indication of reflected energy.

Focused beam - Converging energy of the sound beam at a specified distance.

Frequency (fundamental) - In resonance testing, the frequency at which the wave length is twice the thickness of the examined material.

Frequency (inspection) - Effective ultrasonic wave frequency of the system used to inspect the material.

Frequency (pulse repetition) – The number of times per second an electro-acoustic search unit is excited by the pulse generator to produce a pulse of ultrasonic energy. This is also called pulse repetition rate.

Gate - An electronic means of selecting a segment of the time range for monitoring or further processing.

Harmonics - Those vibrations which are integral multiples of the fundamental frequency.

Immersion testing - An ultrasonic examination method in which the search unit and the test part are submerged (at least locally) in a fluid, usually water.

Impedance (acoustic) - A mathematical quantity used in computation of reflection characteristics at boundaries; product of wave velocity and material density.

Indication - That which marks or denotes the presence of a reflector.

Initial pulse - The response of the ultrasonic system display to the transmitter pulse (sometimes called main bang).

Interface - The boundary between two materials.

Linearity (amplitude) - A measure of the proportionality of the amplitude of the signal input to the receiver, and the amplitude of the signal appearing on the display of the ultrasonic instrument or on an auxiliary display.

Linearity (time or distance) - A measure of the proportionality of the signals appearing on the time or distance axis of the display and the input signals to the receiver from a calibrated time generator or from multiple echos from a plate of material of known thickness.

Longitudinal wave - Those waves in which the particle motion of the material is essentially in the same direction as the wave propagation.

Loss of back reflection - An absence or significant reduction in the amplitude of the indication from the back surface of the part under examination.

Markers - The electronically generated time pulses or other indicators that are used on the instrument display to measure distance or time.

Mode - The type of ultrasonic wave propagating in the materials as characterized by the particle motion (for example, longitudinal, transverse, etc.).

Near field - The region of the ultrasonic beam adjacent to the transducer and having complex beam profiles. Also known as the Fresnel zone.

Noise - Many undesired signal (electrical or acoustic) that tends to interfere with the reception, interpretation, or processing of the desired signal.

Normal incidence (also see straight beam) - A condition in which the axis of the ultrasonic beam is perpendicular to the entry surface of the part under examination.

Penetration depth - The maximum depth in a material from which usable ultrasonic information can be obtained and measured.

Pulse echo method - An inspection method in which the echo amplitude and time indicate the presence and position of a reflector.

Pulse length - A measure of the duration of a signal as expressed in time or number of cycles.

Range - The maximum sound path length that is displayed.

Reference block - A block that is used both as a measurement scale and as a means of providing an ultrasonic reflection of known characteristics.

Reflection - *See* echo.

Reflector - An interface at which an ultrasonic beam encounters a change in acoustic impedance and at which at least part of the energy is reflected.

Reject (suppression) – A control for minimizing or eliminating low amplitude signals (electrical or material noise) so that larger signals are emphasized.

Resolution - The ability of ultrasonic equipment to give simultaneous, separate indications from discontinuities having nearly the same range and lateral position with respect to the beam axis.

Resonance method – A technique in which continuous ultrasonic waves are varied in frequency to identify resonant characteristics in order to discriminate some property of a part such as thickness, stiffness, or bond integrity.

Saturation – A condition in which an increase in input signal produces no increase in amplitude on the display.

Saturation level - *See* vertical limit.

Scanning - The movement of a search unit relative to the test piece in order to examine a volume of the material.

Scanning index - The distance the search unit is moved between scan paths after each traverse of the part.

Scattered energy - Energy that is reflected in a random fashion by small reflectors in the path of a beam of ultrasonic waves.

Scattering - The dispersion, deflection, or redirection of the energy in an ultrasonic beam caused by small reflectors in the material being examined.

Search unit - An electro-acoustic device used to transmit or receive ultrasonic energy, or both. The device generally consists of a nameplate, connector, case, backing, piezo-electric element, wearface, or lens, or wedge.

Sensitivity – A measure of the smallest ultrasonic signal which will produce a discernible indication on the display of an ultrasonic system.

Shadow - A region in a body that cannot be reached by ultrasonic energy traveling in a given direction because of the geometry of the body or a discontinuity in it.

Shear wave - Wave motion in which the particle motion is perpendicular to the direction of propagation.

Shear wave search unit (Y cut quartz search unit) - A straight beam search unit used for generating and detecting shear waves.

Signal-to-noise ratio - The ratio of the amplitude of an ultrasonic indication to the amplitude of the maximum background noise.

Straight beam - A vibrating pulse wave train traveling normal to the test surface.

Sweep - The uniform and repeated movement of an electron beam across the CRT.

Testing, ultrasonic - A nondestructive method of examining materials by introducing ultrasonic waves into, through or onto the surface of the article being examined and determining various attributes of the material from effects on the ultrasonic waves.

Transducer - An electro-acoustical device for converting electrical energy into acoustical energy and vice versa. See also crystal.

Ultrasonic - Pertaining to mechanical vibrations having a frequency greater than approximately 20 000 Hz.

Ultrasonic noise level - The large number of unresolved indications resulting from structure or possibly from numerous small discontinuities, or both.

Vertical limit - The maximum readable level of vertical indications determined either by an electrical or a physical limit of an A-scan presentation.

Wave front - A continuous surface drawn through the most forward points in a wave disturbance which have the same phase.

Wedge - In ultrasonic angle-beam examination by the contact method, a device used to direct ultrasonic energy into the material at an angle.

Wrap around - The display of misleading reflections from a previously transmitted pulse, caused by an excessively high pulse-repetition frequency.

2.0 Selected Requirements from Applicable Codes

The requirements listed below are numbered with the same numbers used in the code. Since all the requirements are not listed, the numbers may not be sequential.

2.1 General Guidance from ASTM Designation: E 164-94, "Standard Practice for Ultrasonic Contact Examination of Weldments."

7.1.2 The scanning surfaces on the base material should be free of weld splatter, scale, dirt, rust, and any extreme roughness on each side of the weld for a distance equal to several times the thickness of the material. This distance to be determined by the size of the search unit and the angle of the sound beam. Where scanning is performed along the top or across the weld, the weld reinforcement may be ground to provide a flat scanning surface. Generally, the surfaces do not require polishing; light sanding with a disk or belt sander will usually provide a satisfactory surface for examination.

7.1.3 The area of the base metal through which the sound will travel in the angle-beam examination should be completely scanned with a straight-beam search unit to detect reflectors that might affect the interpretation of the angle-beam results by obstructing the sound beam. Consideration must be given to these reflectors during interpretation of the weld examination results.

7.2.1 A couplant, usually a liquid or simi-liquid, is required between the face of the search unit and the test surface to permit transmission of the acoustic energy from the search unit to the material under test. The couplant should wet the surfaces of the search unit and the test piece, and eliminate any air space between the two. Typical couplants include water, oil, grease, glycerin, and cellulose gum.

7.2.3 In performing the examination, it is important that the same couplant, at the same temperature, be used for comparing the responses between the calibration blocks and the examination material. Attenuation in couplants and wedge materials varies with temperature so that a calibration performed in a comfortable room is not valid for examination of either hotter or colder materials.

2.2 Requirements from AWS D1.1, Section 6.13, "Ultrasonic Inspection"

6.13.1 Statically loaded nontubular weld connections are acceptable, if they meet the requirements of Table 6.2 of AWS D1.1-96.

6.13.2 Cyclically loaded nontubular weld connections are acceptable, if they meet requirements of Table 6.3 of AWS D1.1-96.

2.3 Requirements from AWS D1.1, Part F, "Ultrasonic Inspection of Groove Welds"

6.22.1 The ultrasonic instrument shall be the pulse echo type suitable for use with transducers oscillating at frequencies between 1 and 6 megahertz. The display shall be an "A" scan rectified video trace.

6.22.2 The horizontal linearity of the test instrument shall be qualified over the full sound-path distance to be used in testing in accordance with Section 6.30.1 of AWS D1.1-96.

6.22.3 Test instruments shall include internal stabilization so that after warm-up, no variation in response greater than ± 1 dB occurs with a supply voltage change of 15% nominal or, in the case of a battery, throughout the charge operating life. There shall be an alarm or meter to signal a drop in battery voltage prior to instrument shutoff due to battery exhaustion.

6.22.4 The test instrument shall have a calibrated gain control (attenuator) adjustable in discrete 1 or 2 dB steps over a range of at least 60 dB. The accuracy of the attenuator settings shall be within plus or minus 1 dB. The procedure for qualification shall be as described in Sections 6.24.2 and 6.30.2 of AWS D1.1-96.

6.22.5 The dynamic range of the instrument's display shall be such that a difference of 1 dB of amplitude can be easily detected on the display.

6.22.6 Straight-beam (longitudinal wave) search unit transducers shall have an active area of not less than 1/2 square inches (323 square millimeters) nor more than 1 square inch (645 square millimeters). The transducer shall be round or square. Transducers shall be capable of resolving the three reflections as described in Section 6.29.1.3 of AWS D1.1-96.

6.22.7 Angle-beam search units shall consist of a transducer and an angle wedge. The unit may be comprised of the two separate elements or may be an integral unit.

6.22.7.1 For angle beam search units, the transducer frequency shall be between 2 and 2.5 MHz, inclusive.

6.22.7.2 For angle beam search units, the transducer crystal shall be square or rectangular in shape and may vary from 5/8 in. to 1 in. (16 to 25 mm) in width and from 5/8 to 13/16 in. (16 to 21 mm) in height. The maximum width to height ratio shall be 1.2 to 1.0, and the minimum width-to-height ratio shall be 1.0 to 1.0.

6.22.7.3 For angle beam search units, the search unit shall produce a sound beam in the material being tested within plus or minus 2° of one of the following proper angles: 70°, 60°, or 45, as described in Section 6.29.2.2.

6.22.7.4 For angle beam search units, each search unit shall be marked to clearly indicate the frequency of the transducer, nominal angle of refraction, and index point. The index point location procedure is described in Section 6.29.2.1 of AWS D1.1-96.

6.22.7.5 Maximum allowable internal reflections from the search unit shall be verified at a maximum time interval of 40 hours of instrument use in accordance with Section 6.30.3 of AWS D1.1-96.

6.22.7.6 The dimensions of the search unit shall be such that the distance from the leading edge of the search unit to the index point shall not exceed 1 in. (25 mm).

6.22.7.7 The qualification procedure using the International Institute of Welding (IIW) reference block shall be in accordance with Section 6.29.2.6 of AWS D1.1-96.

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2.4 Requirements form AWS D1.1, Section 6.26, "Testing Procedures"

6.26.1 An "X" line for flaw location shall be marked on the test face of the weldment in a direction parallel to the weld axis. The location distance perpendicular to the weld axis is based on the dimensional figures on the detail drawing and usually falls on the centerline of the butt joint welds, and always falls on the near face of the connecting member of T and corner joint welds (the face opposite Face C).

6.26.2 A "Y" accompanied with a weld identification number shall be clearly marked on the basemetal adjacent to the weld that is ultrasonically tested. This marking is used for the following purposes:

(1) Weld identification
(2) Identification of Face A
(3) Distance measurements and direction (+ or -) from the "X" line
(4) Location measurement from weld ends or edges.

2.26.3 All surfaces to which a search unit is applied shall be free of weld spatter, dirt, grease, oil (other than that used as a couplant), paint, and loose scale and shall have a contour permitting intimate coupling.

2.26.4 A couplant material shall be used between the search unit and the test material. The couplant shall be either glycerin or cellulose gum and water mixture of a suitable consistency. A wetting agent may be added if needed. Light machine oil may be used for couplant on calibration blocks.

2.26.5 The entire base metal through which ultrasound must travel to test the weld shall be tested for laminar reflectors using a straight-beam search unit conforming to the requirements of Section 6.22.6 and calibrated in accordance with Section 6.25.4 of AWS D1.1-96. If any area of base metal exhibits total loss of back reflection or an indication equal to or greater than the original back reflection height is located in a position that will interfere with the normal weld scanning procedure, its size, location, and depth from the A face shall be determined and reported on the ultrasonic test report, and an alternate weld scanning procedure shall be used.

6.26.5.1 The reflector size evaluation procedure shall be in accordance with Section 6.31.1 of AWS D1.1-96.

6.26.5.2 If part of a weld is inaccessible to testing in accordance with the requirements of Table 6.6, due to laminar content recorded in accordance with Section 6.26.5 of AWS D1.1-96, the testing shall be conducted using one or more of the following alternative procedures as necessary to attain full weld coverage:

(1) Weld surface(s) shall be ground flush in accordance with Section 5.24.4.1.
(2) Testing from Faces A and B shall be performed.
(3) Other search unit angles shall be used.

6.26.6 Welds shall be tested using an angle beam search unit conforming to the requirements of Section 6.22.7 of AWS D1.1-96 with the instrument calibrated in accordance with Section 6.25.5 using the angle as shown in Table 6.6. Following calibration and during testing, the only instrument adjustment permitted is the sensitivity level adjustment with the calibrated gain control (attenuator). The reject (clipping or suppression) control shall be turned off. Sensitivity shall be increased from the reference level for weld scanning in accordance with Table 6.2 or 6.3, as applicable.

6.26.6.1 The testing angle and scanning procedure shall be in accordance with those shown in Table 6.6.

6.26.6.2 All butt joint welds shall be tested from each side of the weld axis. Corner and T-joint welds shall be primarily tested from one side of the weld axis only. All welds shall be tested using the applicable scanning pattern or patterns shown in Figure 6.24 as necessary to detect both longitudinal and transverse flaws. It is intended that, as a minimum, all welds be tested by passing sound through the entire volume of the weld and the heat-affected zone in two crossing directions, wherever practical.

6.26.6.3 When a discontinuity indication appears on the screen, the maximum attainable indication from the discontinuity shall be adjusted to produce a horizontal reference level trace deflection on the display. This adjustment shall be made with the calibrated gain control (attenuator), and the instrument reading in decibels shall be used as the "Indication Level, a," for calculating the "Indication Rating, d," as shown on the test report (Annex D, Form D 11 of AWS D1.1-96).

6.26.7 The length of flaws shall be determined in accordance with procedure Section 6.31.2 of AWS D1.1-96.

6.26.8 Each weld discontinuity shall be accepted or rejected on the basis of its indication rating and its length, in accordance with Table 6.2 for statically loaded structures or Table 6.3 for cyclically loaded structures, whichever is applicable. Only those discontinuities which are rejectable need be recorded on the test report, except that for welds designated in the contract documents as being "Fracture Critical," acceptable ratings that are within 6 dB, inclusive, of the minimum rejectable rating shall be recorded on the test report.

6.26.9 Each rejectable discontinuity shall be indicated on the weld by a mark directly over the discontinuity for its entire length. The depth from the surface and indication rating shall be noted on nearby base metal.

2.5 Requirements from ASME B&PV Code, Section V, Article 5, Ultrasonic Examination Methods for Material and Fabrication

T-523.1 With regard to examination coverage, the volume shall be examined by moving the search unit over the examination surface so as to scan the entire examination volume. Each pass of the search unit shall overlap a minimum of 10% of the transducer (piezo-electric element) dimension perpendicular to the direction of the scan.

T-523.2 With regard to the rate of search unit movements, **t**he rate of search unit movement for examination shall not exceed 6 in./sec. unless calibration is verified at the selected scanning speed.

T-523.3 With regard to recording sensitivity level, both manual and mechanized recording of indications shall be made with respect to the reference level.

T-531 This examination shall be conducted with a pulse-echo ultrasonic instrument capable of generating frequencies over the range of at least 1 MHz to 5 MHz. Instruments operating at other frequencies may be used if equal or better sensitivity can be demonstrated and documented.

T-532 The ultrasonic instrument shall provide linear vertical presentation within ± 5% of the full screen height for 20% to 80% of the calibrated screen height [base line to maximum calibrated screen point(s)]. The procedure for evaluating screen height linearity is provided in B&PV Code, Section V, Article 5, Attachment I and shall be performed at the beginning of each period of extended use (or every 3 months, whichever is less).

T-533 The ultrasonic instrument shall utilize an amplitude control accurate over its useful range to ± 20% of the nominal amplitude ratio, to allow measurement of indications beyond the linear range of the vertical display on the screen. The procedure for evaluating amplitude control linearity is given in B&PV Code, Section V, Article 5, Attachment II and shall be performed at the beginning of each period of extended use (or every 3 months, whichever is less).

T-534 The proper functioning of the examination equipment shall be checked and the equipment shall be calibrated by the use of the calibration standard at the beginning and end of each examination, when examination personnel are changed, and at any time that malfunctioning is suspected, as a minimum. If during any check it is determined that the testing equipment is not functioning properly, all of the product that has been tested since the last valid equipment calibration shall be reexamined.

T-242 The requirements for ultrasonic examination of full penetration welds in wrought (rolled, drawn, forged, or extruded) and cast materials are provided in B&PV Code, Section V, Article 5, Paragraph T-542. These paragraphs describe the requirements for welds in ferritic products other than pipe and for welds in ferritic pipe.

T-242.6.1.1 Basic Calibration Block. The basic calibration block shall be as specified in B&PV Code, Section V, Article 5, Paragraph 542.2.1, and shall use side-drilled holes as calibration reflectors. See Fig. T-542.2.1.

T-242.6.1.2 Angle Beam Calibration. Angle beam calibration shall be performed as described in Article 4, Attachment B, supplemented by the additional requirements of T-242.6.1.3 through T-242.6.1.7.

T-242.7 The examination of weld (excluding pipe welds) shall be in accordance with Paragraph T-242.7.1.2 through T-242.7.2.5.

T-242.7.1.1 Surface preparation of base metal. The base metal on each side of the weld shall be free of weld spatter, surface irregularities, or foreign matter that might interfere with the examination. Where the weld surface interferes with the examination, the weld shall be prepared as needed to permit examination.

T-242.7.1.2 Surface preparation of weld metal. Where the weld surface interferes with the examination, the weld shall be prepared as needed to permit examination.

T-242.7.2.1 Straight Beam Scanning**.** The scanning of the adjacent base metal shall be performed to detect reflectors that might affect interpretation of angle beam results, and is not to be used as an acceptance-rejection examination. Locations and areas of such reflectors shall be recorded.

T-242.7.2.2 The weld and base metal shall be scanned, where required by the referencing Code Section to the extent possible with the straight beam search unit. The scanning shall be performed at a gain setting of at least two times the primary reference level. Evaluation shall be performed with respect to the primary reference level.

T-242.7.2.3 Angle Beam Scanning for Reflectors Oriented Parallel to the Weld. The angle beam shall be directed at approximate right angles to the weld axis from two directions where possible. The search unit shall be manipulated so that the ultrasonic energy passes through the required volumes of weld and adjacent base metal. The scanning shall be performed at a gain setting at least two times the primary reference level. Evaluation shall be performed with respect to the primary reference level.

T-242.7.2.4 Angle Beam Scanning for reflectors Oriented Transverse to the Weld. The angle beam shall be directed essentially parallel to the weld axis. The search unit shall be manipulated so that the angle beam passes through the required volumes of weld and adjacent base metal specified by the referencing Code Section. The scanning shall be performed at a gain setting at least two times the primary reference level. Evaluation shall be performed with respect to the primary reference level. The search unit shall be rotated 180 degrees and the examination repeated.

T-242.7.2.5 Evaluation. Any imperfection that causes an indication in excess of 20% DAC shall be investigated to the extent that it can be evaluated in terms of the acceptance standards of the referencing Code Section.

T-242.8.1.1 Basic Calibration Block (See Article 5, Fig**.** T-542.8.1.1). Basic calibration block for weldments shall be a section of pipe of the same nominal size, schedule, heat treatment, and material specification or equivalent P-Number grouping as one of the materials being examined. For the purposes of this paragraph, P-Nos, 1, 3, 4, and 5 materials are considered equivalent. The block size and reflector locations shall be adequate to perform calibration for the beam angles used. The surface finish of the calibration block shall be representative of the surface finish of the piping.

T-242.8.1.2 Basic Calibration Reflectors**.** The basic calibration reflectors shall be longitudinal and with circumferential notches on both the inner and outer surfaces. The sizes and locations of the calibration reflectors are shown in Fig. T-542.8.1.1.

T-242.8.2 Angle Beam Calibration. The nominal frequency shall be 2.25 MHz, unless attenuation or a need for greater resolution makes some other frequency more suitable. The nominal beam angle of 45 degrees shall generally be used, but other angles may be used where appropriate for the configuration being examined.

T-242.8.2.3 Distance-Amplitude Correction (DAC). A DAC curve is required for all pipe welds. For examination of a full wall thickness, the notches shall be used as calibration reflectors. The angle beam shall be directed toward the calibration reflector that yields the maximum response, setting the instrument adjustment to yield 80% of screen height. The search unit shall then be manipulated, without changing instrument settings, to obtain the maximum responses from the calibration reflectors at the distance increments necessary to generate a 3-point DAC curve.

T-242.8.2.4 Selection of Calibration Reflectors**.** A side-drilled hole may be used for initial acceptance of a pipe weld, provided that it can be demonstrated that the hole calibration produces a sensitivity equal to or greater than the notch calibration.

T-242.8.2.5 Straight Beam Calibration**.** Straight beam examination, when required by the referencing Code Section, or, if needed to evaluate an angle beam indication, shall be calibrated on the side drilled holes in the basic calibration block. When required, the straight beam calibration shall be performed to the requirements of B&PV Code, Section V, Article 4, Attachment C.

T-242.8.3.1 Surface preparations for examination of pipe weldments shall be shall be performed to the requirements of Article 5, Paragraph T-542.7.1.

T-242.8.4.1 Straight Beam Scanning of Pipe Welds. When straight beam scanning is required, it shall be performed according to the requirements of Article 5, Paragraph T-542.7.2.1.

T-242.84.2 Angle Beam Scanning of Pipe Welds**.** Angle beam scanning of pipe welds shall be performed according to the requirements of Article 5, T-542.7.2.3 and T-542.7.2.4.

T-242.8.4.3 Evaluation of Pipe Welds. Any imperfection that causes an indication in excess of 20% DAC shall be investigated to the extent that it can be evaluated in terms of the acceptance standards of the referencing Code Section.

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Attachment 4. Liquid Penetrant

1.0 Definitions

Background - The surface of the test part against which the indication is viewed. It may be the natural surface of the test part or the developer coating on the surface.

Black light - Electromagnetic radiation in the near-ultra-violet range of wavelength. (330-390 nm) (3300-3900/A).

Black light filter – A filter that transmits near-ultraviolet radiation while absorbing other wavelengths.

Bleedout - The action of an entrapped liquid penetrant in surfacing from discontinuities to form indications.

Blotting - The action of the developer in soaking up the penetrant from the discontinuity to accelerate bleedout.

Carrier - A liquid, either aqueous or nonaqueous, in which liquid penetrant examination materials are dissolved or suspended.

Clean - Free of contaminants.

Color contrast penetrant –A highly penetrating liquid incorporating a nonfluorescent dye which produces indications of such intensity that they are readily visible during examination under white light.

Contaminant - Any foreign substance present on the test surface or in the inspection materials which will adversely affect the performance of liquid penetrant materials.

Contrast - The difference in visibility (brightness or coloration) between an indication and the background.

Detergent remover - A penetrant remover that is a solution of a detergent in water.

Developer - A material that is applied to the test surface to accelerate bleedout and to enhance the contrast of indications.

Developer, aqueous – A suspension of developer particles in water.

Developer, dry powder - A fine free-flowing powder used as supplied.

Developer, liquid film - A suspension of developer particles in a vehicle that leaves a resin/polymer film on the test surface after drying.

Developer, non-aqueous - Developer particles suspended in a nonaqueous vehicle prior to application.

Developer, soluble - Developer completely soluble in its carrier, not a suspension of powder in a liquid, which dries to an absorptive coating.

Developing time - The elapsed time between the application of the developer and the examination of the part.

Dragout - The carryout or loss of penetrant materials as a result of their adherence to the test pieces.

Drain time - That portion of the dwell time during which the excess penetrant or emulsifier drains from the part.

Drying time – The time required for a cleaned, rinsed or wet developed part to dry.

Dwell time - The total time that the penetrant or emulsifier is in contact with the test surface, including he time required for application and the drain time.

Eluant – A liquid used to extract one material from another, as in chromatography.

Emulsification time - The time that an emulsifier is permitted to remain on the part to combine with the surface penetrant prior to removal. Also called emulsification dwell time.

Emulsifier - A liquid that interacts with an oily substance to make it water-washable.

Emulsifier, hydrophilict - A water-based liquid used in penetrant examination which interacts with the penetrant oil rendering it water-washable.

Emulsifier, lipophilic - An oil based liquid used in penetrant examination which interacts with the penetrant oil rendering it water-washable.

Etching - The removal of surface material by chemical or electrochemical methods.

Fluorescence - The emission of visible radiation by a substance as a result of, and only during, the absorption of black light radiation.

Inspection - Visual examination of the test part after completion of the liquid penetrant processing steps.

Liquid penetrant examination - A nondestructive test that uses suitable liquids that penetrate discontinuities open to the surface of solid materials and, after appropriate treatment, indicate the presence of discontinuitites.

Overemulsification - Excessive emulsifier dwell time which results in the removal of penetrants from some discontinuities.

Penetrant – A solution or suspension of dye.

Penetrant comparator - An intentionally flawed specimen having separate but adjacent areas for the application of different liquid penetrant materials so that a direct comparison of their relative effectiveness can be obtained.

Penetrant, post emulsifiable - A liquid penetrant that requires the application of a separate emulsifier to render the excess surface penetrant water-washable.

Penetrant, solvent-removable - A liquid penetrant so formulated that most of the excess surface penetrant can be removed by wiping with a lint-free material, with the remaining surface penetrant traces removable by further wiping with a lint-free material lightly moistened with solvent remover.

Penetrant, water-washable - A liquid penetrant with a built-in emulsifier.

Visible light - Electromagnetic radiation in the 400-700 (4000-7000A) wavelength range.

Water tolerance - The amount of water that a penetrant or emulsifier can absorb before its effectiveness is impaired.

Wetting action - The ability of a liquid to spread over and adhere to solid surfaces.

2.0 Selected Requirement from Applicable Codes

The requirements listed below are numbered with the same numbers used in the code. Since all the requirements are not listed, the numbers may not be sequential.

2.1 General Guidance from ASTM E165-95, "Standard Test Method for Liquid Penetrant Examination"

The following is a general description of the liquid penetrant examination method. Refer to ASTM E165-95 for a description of the examination procedure.

5. Liquid penetrant examination methods indicate the presence, location and, to a limited extent, the nature and magnitude of the detected discontinuities. Each of the various methods has been designed for specific uses such as critical service items, volume of parts, portability or localized areas of examination. The method selected will depend accordingly on the service requirements.

6.1 Liquid penetrant examination methods and types are classified as shown in **Table 1** below. The two methods are fluorescent penetrant examination and visible penetrant examination.

6.2 Fluorescent penetrant examination utilizes penetrants that fluoresce brilliantly when excited by black light. The sensitivity of fluorescent penetrants depends on their ability to be retained in the various size discontinuities during processing, then to bleed out into the developer coating and produce indications that will fluoresce. Fluorescent indications are many times brighter than their surroundings when viewed under black light illumination.

6.3 Visible penetrant examination uses a penetrant that can be seen in visible light. The penetrant is usually red, so that the indications produce a definite contrast with the white background of the developer. The visible penetrant process does not require the use of black light. However, visible penetrant indications must be viewed under adequate white light.

Table 1 - Classification of Penetrant Examination Types and Methods

Type I--Fluorescent Penetrant Examination
Method A--Water-washable Method B--Post-emulsifiable, lipophilic Method C--Solvent removable Method D--Post-emulsifiable, hydrophilic
Type II--Visible Penetrant Examination
Method A--Water-washable Method C--Solvent removable

7.2.1 Post-Emulsifiable Penetrants are designed to be insoluble in water and cannot be removed with water rinsing alone. They are designed to be selectively removed from the surface using a separate emulsifier. The emulsifier, properly applied and given a proper emulsification time, combines with the excess surface penetrant to form a water-washable mixture, which can be rinsed from the surface, leaving the surface free of fluorescent background. Proper emulsification time must be experimentally established and maintained to ensure that over-emulsification does not occur, resulting in loss of indications.

7.2.2 Water-Washable Penetrants are designed to be directly water-washable from the surface of the test part, after a suitable penetrant dwell time. Because the emulsifier is "built-in" to the water-washable penetrant, it is extremely important to exercise proper process control in removal of excess surface penetrant to ensure against over washing. Water-washable penetrants can be washed out of discontinuities, if the rinsing step is too long or too vigorous. Some penetrants are less resistant to over washing than others.

7.2.3 Solvent-Removable Penetrants are designed so that excess surface penetrant can be removed by wiping until most of the penetrant has been removed. The remaining traces should be removed with the solvent remover. To minimize removal of penetrant from discontinuities, care should be taken to avoid the use of excess solvent. Flushing the surface with solvent to remove the excess penetrant is prohibited.

7.3.1 Lipophilic Emulsifiers are oil-miscible liquids used to emulsify the excess oily penetrant on the surface of the part, rendering it water-washable. The rate of diffusion establishes the emulsification time. They are either slow- or fast-acting, depending on their viscosity and chemical composition, and also the surface roughness of the area being examined.

7.3.2 Hydrophilic Emulsifiers are water-miscible liquids used to emulsify the excess oily fluorescent penetrant on the surface of the part, rendering it water-washable. These water-base emulsifiers (detergent-type removers) are supplied as concentrates to be diluted with water and used as a dip or spray. The concentration, use and maintenance shall be in accordance with manufacturer's recommendations.

7.3.2.1 Hydrophilic emulsifiers function by displacing the excess penetrant film from the surface of the part through detergent action. The force of the water spray or air/mechanical agitation in an open dip tank provides the scrubbing action while the detergent displaces the film of penetrant from the part surface. The emulsification time will vary, depending on its concentration.

7.4 Solvent Removers function by dissolving the penetrant, making it possible to wipe the surface clean and free of excess penetrant.

7.5 Developers--Development of penetrant indications is the process of bringing the penetrant out of open discontinuities through blotting action of the applied developer, thus increasing the visibility of the indications.

7.5.1 Dry Powder Developers are used as supplied (that is, free-flowing, non-caking powder) in accordance with ASTM E165-95, Section 8.8.2. Care should be taken not to contaminate the developer with fluorescent penetrant, as the penetrant specks can appear as indications.

7.5.2 Aqueous Developers are normally supplied as dry powder particles to be either suspended or dissolved (soluble) in water. The concentration, use and maintenance shall be in accordance with manufacturer's recommendations.

Caution--Aqueous developers may cause stripping of indications if not properly applied and controlled. The procedure should be qualified in accordance with Section 10.2 of ASTM E165-95.

7.5.3 Nonaqueous Wet Developers are supplied as suspensions of developer particles in a nonaqueous solvent carrier ready for use as supplied. Nonaqueous, wet developers form a coating on the surface of the part when dried, which serves as the developing medium.

Caution--This type and developer is intended for application by spray only.

8.2 Temperature Limits--The temperature of the penetrant materials and the surface of the part to be processed should be between 50 and 100F (10 and 38'C). Where it is not practical to comply with these temperature limitations, qualify the procedure as described in Section10.2 of ASTM E165-95 at the temperature of intended use and as agreed to by the contracting parties.

2.2 Requirements from AWS D1.1, Section 6.10, "Liquid Penetrant and Magnetic Particle Testing"

6.10 Welds that are subject to magnetic particle and liquid penetrant testing, in addition to visual inspection, shall be evaluated on the basis of the requirements for visual inspection. (See Table 6.1, Visual Inspection Acceptance Criteria). The testing shall be performed in accordance with Section 6.14.6 and 6.14.7, whichever is applicable.

2.3 Requirements from ASME B& PV Code, Section V, Article 6, "Liquid Penetrant Examination"

T-642 (b) Prior to each liquid penetrant examination, the surface to be examined and all adjacent areas within at least 1 in. shall be dry and free of all dirt, grease, lint, scale, welding flux, weld spatter, paint, oil, and other extraneous matter that could obscure surface openings or otherwise interfere with the examination. Typical cleaning agents which may be used are detergents, organic solvents, descaling solutions, and paint removers. Degreasing and ultrasonic cleaning methods may also be used.

T-643 After cleaning, drying of the surfaces to be examined shall be accomplished by normal evaporation or with forced hot or cold air. A minimum period of time shall be established to ensure that the cleaning solution has evaporated prior to application of the penetrant.

T-651 Either a color contrast (visible) penetrant or fluorescent penetrant shall be used with one of the following three penetrant processes:
(a) water washable
(b) post-emulsifying
(c) solvent removable.

The visible and fluorescent penetrants used in combination with these three penetrant processes result in six liquid penetrant techniques.

T-652 As a standard technique, the temperature of the penetrant and the surface of the part to be processed shall not be below 50°F (10°C) nor above 125°F (52°C) throughout the examination period. Local heating or cooling is permitted provided the part temperature remains in the range of 50°F to 125°F (10°C to 52°C) during the examination. Where it is not practical to comply with these temperature limitations, other temperatures and times may be used, provided the procedures are qualified.

T-671 The penetrant may be applied by any suitable means, such as dipping, brushing, or spraying. If the penetrant is applied by spraying using compressed air type apparatus, filters shall be placed on the upstream side near the air inlet to preclude contamination of the penetrant by oil, water, dirt, or sediment that may be collected.

T-672 Penetration time is critical. The minimum penetration time shall be as required in Table 4 or as qualified by demonstration for specific applications. After the specified penetration time has elapsed, any penetrant remaining on the surface shall be removed taking care to minimize removal of penetrants from discontinuities.

T-673.1 Excess water washable penetrant shall be removed with water spray. The water pressure shall not exceed 50 psi (345 kPa), and the water temperature shall not exceed 110 degrees F (43 degrees C)

T-673.2 With post-emulsifying penetrants, the emulsifier shall be applied by spraying or dipping. Emulsifier time is critical, and governed by surface roughness and type of emulsifier employed. It shall be qualified by actual tests. After emulsification, the mixture shall be removed by a water spray using the same processes as for water washable penetrants.

T-673.3 Excess solvent removable penetrants shall be removed by wiping with a cloth or absorbent paper, repeating the operation until most traces of penetrant have been removed. The remaining traces shall be removed by lightly wiping the surface with cloth or absorbent paper moistened with solvent. To minimize removal of penetrant from discontinuities, care shall be taken to avoid the use of excess solvent. Flushing the surface with solvent, following the application of the penetrant and prior to developing, is prohibited.

T-674 The examination surface shall be dried after excess penetrant has been removed.

(a) For the water washable or post-emulsifying technique, the surfaces may be dried by blotting with clean materials or by using circulating air, provided the temperature of the surface is not raised above 125°F (52°C).

(b) For the solvent removable technique, the surfaces may be dried by normal evaporation, blotting, wiping, or forced air.

T-675 The developer shall be applied as soon as possible after penetrant removal; the time interval shall not exceed that established in the procedure. Insufficient coating thickness may not draw the penetrant out of discontinuities; conversely, excessive coating thickness may mask indications. With color contrast penetrants, only a wet developer shall be used. With fluorescent penetrants, a wet or dry developer may be used.

T-675.1 Dry developer shall be applied only to a dry surface by a soft brush, hand powder bulb, powder gun, or other means, provided the powder is dusted evenly over the entire surface being examined.

T-675.2 Prior to applying suspension type wet developer (aqueous and nonaqueous) to the surface, the developer must be thoroughly agitated to ensure adequate dispersion of suspended panicles.

(a) Aqueous developer may be applied to either a wet or dry surface. Shall be applied by dipping, brushing, spraying, or other means, provided a thin coating is obtained over the entire surface being examined. Drying time may be decreased by using warm air, provided the surface temperature of the part is not raised above 125°F. **Blotting is not permitted**.

(b) Nonaqueous developer shall be applied only to a dry surface. It shall be applied by spraying, except where safety or restricted access preclude it. Under such conditions, developer may be applied by brushing. Drying shall be by normal evaporation.

T-675.3 Developing time for final interpretation begins immediately after the application of a dry developer or as soon as a wet developer coating is dry. The minimum developing time (also known as "dwell time") shall be as required by Table 672.

TABLE 672 - MINIMUM DWELL TIMES

Material	Form	Type of Discontinuity	Dwell Times[1] Penetrant	 Developer
Aluminum, magnesium, steel, brass and bronze, titanium and high temperature alloys	Casting and welds	Cold shuts, porosity, lack of fusion	5	7
	Wroght materials	Laps, craks, (all forms)	10	7

Note: (1) For temperature range from 50^{o}F to 125^{o}F (10 – 52^{o}C).

Attachment 5. Magnetic Particle

1.0 Definitions

Background - In magnetic particle examination, the appearance of the surface of the test part against which indications are viewed.

Black light - Electromagnetic radiation in the near ultraviolet range of wavelength (330 to 390 nm) (3300 to 3900 A).

Black light intensity - A quantitative expression of ultraviolet irradiance.

Central conductor - A conductor passed through a hollow part and used to produce circular magnetization within the part.

Circular magnetization - The magnetization in a part resulting from current passed directly through the part or through a central conductor.

Demagnetization –The reduction of residual magnetism to an acceptable level.

Dry power –Finely divided ferromagnetic particles suitably selected and prepared for magnetic particle inspection.

Full wave direct current (FWDC) – A rectified three-phase alternating current.

Full-wave rectified current – When the reverse half of the cycle is turned around to flow in the same direction as the forward half. The result is full-wave rectified current. Three-phase alternating current when full-wave rectified is unidirectional with very little pulsation; only a ripple of varying voltage distinguishes it from straight DC single-phase. Full rectified current is usually not employed for magnetic particle examination.

Half-wave rectified current AC - When a single-phase alternating current is rectified in the simplest manner, the reverse of the cycle is blocked out entirely. The result is a pulsating unidirectional current with intervals when no current at all is flowing. This is often referred to as "half-wave" or pulsating direct current.

Longitudinal magnetization - A magnetic field wherein the lines of force traverse the part in a direction essentially parallel with its longitudinal axis.

Magnetic field – The volume within and surrounding either a magnetic part or a current-carrying conductor wherein a magnetic force is exerted.

Magnetic field strength – The measured intensity of a magnetic field at a point, expressed in oersteds or amperes per meter.

Magnetic flux - The concept that the magnetic field is flowing along the lines of force suggests that these lines are therefore "flux" lines, and they are called magnetic flux. The strength of the field is defined by the number of flux lines crossing a unit area taken at right angles to the direction of the lines.

Magnetic particle examination – A nondestructive test method utilizing magnetic leakage fields and suitable indicating materials to disclose surface and near-surface discontinuity indications.

Magnetic particle field indicator – An instrument, typically a bi-metal (for example, carbon steel and copper) octagonal disk, containing artificial flaws used to verify the adequacy or direction, or both, of the magnetizing field.

Magnetic particles – Finely divided ferromagnetic material capable of being individually magnetized and attracted to another piece of ferromagnetic material.

Multidirectional magnetization – The alternative application of magnetic fields in different directions during the same time frame.

Permanent magnet – A magnet that retains a high degree of magnetization virtually unchanged for a long period of time (characteristic of materials with high retentivity).

Prods - Hand-held electrodes.

Rectified magnetic current - By means of a device called a rectifier, which permits current to flow in one direction only, alternating current can be convened to unidirectional current. This differs from direct current in that the current value varies from a steady level. This variation may be extreme, as in the case of the half-wave rectified single phase AC, or slight, as in the case of three-phase rectified AC.

Sensitivity - The degree of capability of a magnetic particle examination technique for indicating surface or near surface discontinuities in ferromagnetic materials.

Suspension – A two-phase system consisting of a finely divided solid dispersed in a liquid.

True continuous technique – Magnetic particle examination in which the magnetizing current is applied prior to the application of the magnetic particles and is maintained without interruption throughout the examination.

Yoke – A magnet that induces a magnetic field in the area of a part that lies between its poles. Yokes may be permanent magnets or either alternating-current or direct-current electromagnets.

2.0 Selected Requirements from Applicable Codes

The requirements listed below are numbered with the same numbers used in the code. Since all the requirements are not listed, the numbers may not be sequential.

2.1 General Guidance from ASTM E709-95, “Standard Guide for Magnetic Particle Examination”

The following is a general description of the magnetic particle examination method. Refer to ASTM E709-95 for a description of the equipment, materials and examination procedure.

4.1 The magnetic particle method is based the principle that magnetic field lines when present in ferromagnetic material, will be distorted by a change in material continuity, such as a sharp dimensional change or discontinuity. If the discontinuity is open to or close to the surface of a magnetized material, flux lines will be distort at the surface, a condition termed as "flux leakage." When fine magnetic particles are distributed over the area of the discontinuity while the flux leakage exists, they will be held in place and the accumulation of particles will be visible under the proper lighting conditions. While there are variations in the magnetic particle method, they all are depend on this principle, that magnetic particles will be retained at the location of flux leakage.

4.2 Method - While this practice permits and describes many variables in equipment, materials, and procedures, there are three steps essential to the method:

4.2. The part must be magnetized.

4.2.2 Magnetic particles of the type designated in the contract/purchase order/specification must be applied while the part is magnetized.

4.2.3 Any accumulation of magnetic particles must be observed, interpreted, and evaluated.

4.3 Magnetization:

4.3.1 Ways to Magnetize - A ferromagnetic material can be magnetized either by passing an electric current through the material or by placing the material within a magnetic field originated by an external source. The entire mass or a portion of the mass can be magnetized as dictated by size and equipment capacity or need. As previously noted, the discontinuity must interrupt the normal path of the magnetic field lines. If a discontinuity is open to the surface, the flux leakage will be at the maximum for that particular discontinuity. When that same discontinuity is below the surface, flux leakage evident on the surface will be less. Practically, discontinuities must be open to the surface, to create sufficient flux leakage to accumulate magnetic particles.

4.3.2 Field Direction - If a discontinuity is oriented parallel to the magnetic field lines, it may be essentially undetectable. Therefore, since discontinuities may occur in any orientation, it may be necessary to magnetize the part or area of interest twice or more sequentially in different directions by the same method or a combination of methods to induce magnetic field lines in a suitable direction in order to perform an adequate examination.

4.3.3 Field Strength - The magnetic field must be of sufficient strength to indicate those discontinuities which are unacceptable, yet must not be so strong that an excess of particles is accumulated locally thereby masking relevant indications.

4.4 Types of Magnetic Particles and Their Use - There are various types of magnetic particles available for use in magnetic particle examination. They are available as dry powders (fluorescent and nonfluorescent) ready for use as supplied, powder concentrates (fluorescent and nonfluorescent) for dispersion in water or suspending light petroleum distillates, magnetic slurries/paints, and magnetic polymer dispersions.

4.5 Evaluation of Indications - When the material to be examined has been properly magnetized, the magnetic particles have been properly applied, and the excess particles properly removed, there will be accumulations of magnetic particles at the points of flux leakage. These accumulations show the distortion of the magnetic field and are called indications. Without disturbing the particles, the indications must be examined, classified, interpreted as to cause, compared with the acceptance standards, and a decision made concerning the disposition of the material that contains the indication.

4.6 Typical Magnetic Particle Indications:

4.6.1 Surface Discontinuities - Surface discontinuities, with few exceptions, produce sharp, distinct patterns.

4.6.2 Near-surface discontinuities produce less distinct indications than those open to the surface. The patterns are broad, rather than sharp, and the particles are less tightly held.

2.2 Requirements from AWS D1.1, Section 6.10, "Liquid Penetrant and Magnetic Particle Testing"

6.10 Welds that are subject to magnetic particle and liquid penetrant testing, in addition to visual inspection, shall be evaluated on the basis of the requirements for visual inspection. (See Table 6.1, Visual Inspection Acceptance Criteria). The testing shall be performed in accordance with Section 6.14.6 and 6.14.7, whichever is applicable.

2.3 Requirements from ASTM E 709-95, "Standard Guide for Magnetic Particle Examination"

6.5 The black light must be capable of developing the required wavelengths of 330 to 390 nm with an intensity at the examination surface of not less than 1000 $\mu W/cm^2$ when measured with a suitable black light meter. Wavelengths at or near 365 nm shall predominate. Suitable filters should remove the extraneous visible light emitted by black lights (violet or blue 405 and 435-nm Hg lines and greenish-yellow 577-nm Hg line). Some high-intensity black light bulbs may emit unacceptable amounts of greenish-yellow light which may cause fluorescent indications to become invisible. A change in line voltage of greater than ±10% can cause a change in black light output with consequent inconsistent performance. A constant voltage transformer should be used where there is evidence of voltage change of greater than 10%.

7.1.1 The intensity of the visible light at the surface of the part/work piece undergoing examination should be a minimum of 100 foot candles (1000 lux). The intensity of ambient visible light in the darkened area where fluorescent magnetic particle examination is performed should not exceed 2 foot candles (20 lux).

7.1.2.2 Black Light Warm-up - Allow the black light to warm up for a minimum of 5 min prior to its use or measurement of the intensity of the ultraviolet light emitted.

7.1.3 Dark Area Eye Adaptation - It is recommended that the inspector be in the darkened area for at least 3 min. prior to examining parts using black light so that his eyes will adapt to dark viewing. Caution--Photochromic or permanently tinted lenses shall not be worn during the examination.

2.4 Requirements from ASME B&PV Code, Section V, Article 7, "Magnetic Particle Examination"

T-731 The finely divided ferromagnetic particles used for the examination shall meet the following requirements.

T-731(a) Dry Particles. If dry particles are used, the color of the particles (dry powder) shall provide adequate contrast with the surface being examined. Additional specific requirements on the use of dry particles are given in ASTM E-709, Standard Guide for Magnetic Particle Examination. Magnetic particles examination shall not be performed if the surface temperature of the part exceeds 600°F (316°C).

T-731(b) Wet Particles. If wet particles are used, the color of the particles shall provide adequate contrast with the surface being examined. The particles shall be suspended in a suitable liquid medium in the concentration recommended in ASTM E-709, Standard Guide for Magnetic Particle Examination, which contains additional specific requirements on the use of wet particles. The temperature of the wet particle suspension and the surface of the part shall not exceed 135°F (57°C).

T-731(c) Fluorescent Particles. With fluorescent particles the examination is performed using an ultraviolet light, called *black light.* The examination shall be performed as follows.

(1) It shall be performed in a darkened area.
(2) The examiner shall be in the darkened area for at least 5 min prior to performing the examination to enable his eyes to adapt to dark viewing. If the examiner wears glasses or lenses, they shall not be photosensitive.
(3) The black light shall be allowed to warm up for a minimum of 5 min prior to use or measurement of the intensity of the ultraviolet light emitted.
(4) The black light intensity shall be measured with a black light meter. A minimum of 1000/$\mu W/cm^2$ on the surface of the part being examined shall be required. The black light intensity shall be measured at least once every 8 hr, and whenever the workstation is changed.

T-741 Surface Preparation

T-741.1(a) Satisfactory results are usually obtained when the surfaces are in the as-welded, as-rolled, as-cast, or as-forged conditions. However, surface preparation by grinding or machining may be necessary where surface irregularities could mask indications due to discontinuities.

T-741.1(b) Prior to magnetic particle examination, the surface to be examined and all adjacent areas within at least 1 in. shall be dry and free of all dirt, grease, lint, scale, welding flux and spatter, oil, or other extraneous matter that could interfere with the examination.

T-741.1(c) Cleaning may be accomplished using detergents, organic solvents, descaling solutions, paint removers, vapor degreasing, sand or grit blasting, or ultrasonic cleaning methods.

T-741.1(d) If coatings are left on the part in the area being examined, it must be demonstrated in accordance with Mandatory Attachment I that indications can be detected through the existing maximum coating thickness applied.

T-750 Examination procedures shall be based on the following information:

(a) the materials, shapes, or sizes to be examined, and the extent of the examination;
(b) magnetization techniques to be used;
(c) equipment to be used for magnetization;
(d) surface preparation (finishing and cleaning);
(e) type of ferromagnetic particles to be used: manufacturer;
(f) magnetization currents (type and amperage):
(g) demagnetization.

T-751 Examination shall be done by the continuous method: that is, the magnetizing current remains on while the examination medium is being applied and while excess of the examination medium is being removed.

T-752 The ferromagnetic particles used as an examination medium shall be either wet or dry, and may be either fluorescent or nonfluorescent. One or more of the following five magnetization techniques shall be used:

(a) prod technique;
(b) longitudinal magnetization technique;
(c) circular magnetization technique;
(d) yoke technique;
(e) multidirectional magnetization technique.

T-754(a) Whenever direct current is required rectified current may be used. The rectified current for magnetization shall be either three-phase (full-wave rectified) current, or single phase (half-wave rectified) current.

T-754(b) The amperage required with three-phase, full-wave rectified current shall be verified by measuring the average current.

T-754(c) The amperage required with single-phase (half-wave rectified) current shall be verified by measuring the average current output during the conducting half cycle only.

T-755 When residual magnetism in the part could interfere with subsequent processing or usage, the part shall be demagnetized any time after completion of the examination.

T-761(a) Each piece of magnetizing equipment with an ammeter shall be calibrated at least once a year, or whenever the equipment has been subjected to major electric repair, periodic overhaul, or damage. If equipment has not been in use for a year or more, calibration shall be done prior to first use.

T-761(b) The accuracy of the unit's meter shall be verified annually by equipment traceable to a national standard. Comparative readings shall be taken for at least three different current output levels encompassing the usable range.

T-761(c) The unit's meter reading shall not deviate by more than ±10% of full scale, relative to the actual current value as shown by the test meter.

NOTE: When measuring halt-wave rectified current with a direct current test meter, readings shall be multiplied by 2.

T-762(a) The magnetizing force of the yokes shall be checked at least once a year, or when ever a yoke has been damaged. If a yoke has not been in use for a year or more, a check shall be done prior to first use.

T-762(b) Each alternating current electromagnetic yoke shall have a lifting power of at least 10 lb. (4.5 kg) at the maximum pole spacing that will be used.

T-762(c) Each direct current or permanent magnetic yoke shall have a lifting power of at least 40 lb. (18.1 kg) at the maximum pole spacing that will be used.

T-762(d) Each weight shall be weighed with a scale from a reputable manufacturer and stenciled with the applicable nominal weight prior to first use. A weight need only be verified again if damaged in a manner that could have caused potential loss of material.

T-771 At least two separate examinations shall be performed on each area. During the second examination, the lines of magnetic flux shall be approximately perpendicular to those used during the first examination. A different technique for magnetization may be used for the second examination.

T-772 All examinations shall be conducted with sufficient overlap to assure 100% coverage at the required sensitivity.

T-773.1 For the prod technique, magnetization is accomplished by portable prod type electrical contacts pressed against the surface in the area to be examined. To avoid arcing, a remote control switch, which may be built into the prod handles, shall be provided to permit the current to be turned on after the prods have been properly positioned.

T-773.2 For the prod technique, direct or rectified magnetizing current shall be used. The current shall be 100 (minimum) amp/in, to 125 (maximum) amp/in. of prod spacing for sections 3/4 in. (19 mm) thick or greater. For sections less than 3/4 in. (19 mm) thick, the current shall be 90 amp/in, to 110 amp/in, of prod spacing.

T-773.3 For the prod technique, prod spacing shall not exceed 8 in. (203 mm). Shorter spacing may be used to accommodate the geometric limitations of the area being examined or to increase the sensitivity, but prod spacing of less than 3 in. (76 mm) are usually not practical due to banding of the particles around the prods. The prod tips shall be kept clean and dressed. If the open circuit voltage of the magnetizing current source is greater than 25 V, lead, steel, or aluminum (rather than copper) tipped prods are recommended to avoid copper deposits on the part being examined.