2001 ASME BOILER & PRESSURE VESSEL CODE

AN INTERNATIONAL CODE



The American Society of Mechanical Engineers

V

NONDESTRUCTIVE EXAMINATION

ASME BOILER AND PRESSURE VESSEL CODE
AN INTERNATIONAL CODE



NONDESTRUCTIVE EXAMINATION

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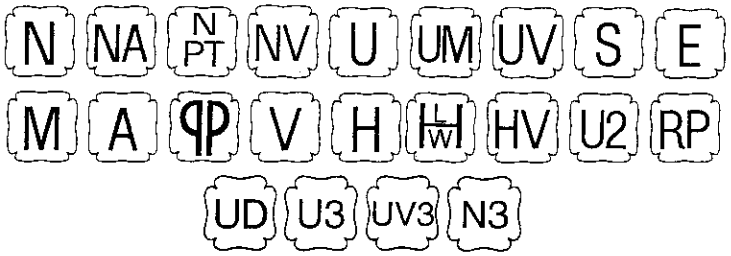
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2001 ASME
BOILER AND PRESSURE VESSEL CODE

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ADDENDA

Colored-sheet Addenda, which include additions and revisions to individual Sections of the Code, are published annually and will be sent automatically to purchasers of the applicable Sections up to the publication of the 2004 Code. The 2001 Code is available only in the loose-leaf format; accordingly, the Addenda will be issued in the loose-leaf, replacement-page format.

INTERPRETATIONS

ASME issues written replies to inquiries concerning interpretation of technical aspects of the Code. The Interpretations for each individual Section will be published separately and will be included as part of the update service to that Section. They will be issued semiannually (July and December) up to the publication of the 2004 Code. Interpretations of Section III, Divisions 1 and 2, will be included with the update service to Subsection NCA.

CODE CASES

The Boiler and Pressure Vessel Committee meets regularly to consider proposed additions and revisions to the Code and to formulate Cases to clarify the intent of existing requirements or provide, when the need is urgent, rules for materials or constructions not covered by existing Code rules. Those Cases which have been adopted will appear in the appropriate 2001 Code Cases book: (1) Boilers and Pressure Vessels and (2) Nuclear Components. Supplements will be sent automatically to the purchasers of the Code Cases books up to the publication of the 2004 Code.

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FOREWORD

The American Society of Mechanical Engineers set up a committee in 1911 for the purpose of formulating standard rules for the construction of steam boilers and other pressure vessels. This committee is now called the Boiler and Pressure Vessel Committee.

The Committee's function is to establish rules of safety governing the design, fabrication, and inspection during construction of boilers and pressure vessels, and to interpret these rules when questions arise regarding their intent. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of pressure vessels. The objective of the rules is to afford reasonably certain protection of life and property and to provide a margin for deterioration in service so as to give a reasonably long, safe period of usefulness. Advancements in design and material and the evidence of experience have been recognized.

This Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction[1] activities. The Code does not address all aspects of these activities and those aspects which are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable designers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code neither requires nor prohibits the use of computers for the design or analysis of components constructed to the requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and they are responsible for the application of these programs to their design.

The Code does not fully address tolerances. When dimensions, sizes, or other parameters are not specified with tolerances, the values of these parameters are considered nominal and allowable tolerances or local variances may be considered acceptable when based on engineering judgment and standard practices as determined by the designer.

The Boiler and Pressure Vessel Committee deals with the care and inspection of boilers and pressure vessels in service only to the extent of providing suggested rules of good practice as an aid to owners and their inspectors.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Boiler and Pressure Vessel Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code Cases, and requests for interpretations. Only the Boiler and Pressure Vessel Committee has the authority to provide official interpretations of this Code. Requests for revisions, new rules, Code Cases, or interpretations shall be addressed to the Secretary in writing and shall give full particulars in order to receive consideration and action (see Mandatory Appendix covering preparation of technical inquiries). Proposed revisions to the Code resulting from inquiries will be presented to the Main Committee for appropriate action. The action of the Main Committee becomes effective only after confirmation by letter ballot of the Committee and approval by ASME.

Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute and published in *Mechanical Engineering* to invite comments from all interested persons. After the allotted time for public review and final

[1] *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and pressure relief.

approval by ASME, revisions are published annually in Addenda to the Code.

Code Cases may be used in the construction of components to be stamped with the ASME Code symbol beginning with the date of their approval by ASME.

After Code revisions are approved by ASME, they may be used beginning with the date of issuance shown on the Addenda. Revisions, except for revisions to material specifications in Section II, Parts A and B, become mandatory 6 months after such date of issuance, except for boilers or pressure vessels contracted for prior to the end of the 6 month period. Revisions to material specifications are originated by the American Society for Testing and Materials (ASTM), and other recognized national or international organizations and are usually adopted by ASME. However, those revisions may or may not have any effect on the suitability of material, produced to earlier editions of specifications, for use in ASME construction. ASME material specifications approved for use in each construction Code are listed in the Appendices of Section II, Parts A and B. These Appendices list, for each specification, the latest edition adopted by ASME, and earlier and later editions considered by ASME to be identical for ASME construction.

Manufacturers and users of components are cautioned against making use of revisions and Cases that are less restrictive than former requirements without having assurance that they have been accepted by the proper authorities in the jurisdiction where the component is to be installed.

Each state and municipality in the United States and each province in Canada that adopts or accepts one or more Sections of the Boiler and Pressure Vessel Code is invited to appoint a representative to act on the Conference Committee to the Boiler and Pressure Vessel Committee. Since the members of the Conference Committee are in active contact with the administration and enforcement of the rules, the requirements for inspection in this Code correspond with those in effect in their respective jurisdictions. The required qualifications for an Authorized Inspector under these rules may be obtained from the administrative authority of any state, municipality, or province which has adopted these rules.

The Boiler and Pressure Vessel Committee in the formulation of its rules and in the establishment of maximum design and operating pressures considers materials, construction, methods of fabrication, inspection, and safety devices. Permission may be granted to regulatory bodies and organizations publishing safety standards to use a complete Section of the Code by reference. If usage of a Section, such as Section IX, involves exceptions, omissions, or changes in provisions, the intent of the Code might not be attained.

Where a state or other regulatory body, in the printing of any Section of the Boiler and Pressure Vessel Code, makes additions or omissions, it is recommended that such changes be clearly indicated.

The National Board of Boiler and Pressure Vessel Inspectors is composed of chief inspectors of states and municipalities in the United States and of provinces in Canada that have adopted the Boiler and Pressure Vessel Code. This Board, since its organization in 1919, has functioned to uniformly administer and enforce the rules of the Boiler and Pressure Vessel Code. The cooperation of that organization with the Boiler and Pressure Vessel Committee has been extremely helpful.

The Code Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The Scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules. Laws or regulations issued by municipality, state, provincial, federal, or other enforcement or regulatory bodies having jurisdiction at the location of an installation establish the mandatory applicability of the Code rules, in whole or in part, within their jurisdiction. Those laws or regulations may require the use of this Code for vessels or components not considered to be within its Scope or may establish additions or deletions in that Scope. Accordingly, inquiries regarding such laws or regulations are to be directed to the issuing enforcement or regulatory body.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the ASME Boiler and Pressure Vessel Committee. ASME is to be notified should questions arise concerning improper use of an ASME Code symbol.

The specifications for materials given in Section II are identical with or similar to those of the Specifications published by ASTM, AWS, and other recognized national or international organizations. When reference is made in an ASME material specification to a non-ASME specification for which a companion ASME specification exists, the reference shall be interpreted as applying to the ASME material specification. Not all materials included in the material specifications in Section II have been adopted for Code use. Usage is limited to those materials and grades adopted by at least one of the other Sections of the Code for application under rules of that Section. All materials allowed by these various Sections and used for construction

within the scope of their rules shall be furnished in accordance with material specifications contained in Section II or referenced in Appendices A of Section II, Parts A and B except where otherwise provided in Code Cases or in the applicable Section of the Code. Materials covered by these specifications are acceptable for use in items covered by the Code Sections only to the degree indicated in the applicable Section. Materials for Code use should preferably be ordered, produced, and documented on this basis; Appendix A to Section II, Part A and Appendix A to Section II, Part B list editions of ASME and year dates of specifications that meet ASME requirements and which may be used in Code construction. Material produced to an acceptable specification with requirements different from the requirements of the corresponding specifications listed in Appendix A of Part A or Part B may also be used in accordance with the above, provided the material manufacturer or vessel manufacturer certifies with evidence acceptable to the Authorized Inspector that the corresponding requirements of specifications listed in Appendix A of Part A or Part B have been met. Material produced to an acceptable material specification is not limited as to country of origin.

When required by context in this Section, the singular shall be interpreted as the plural, and vice-versa; and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

Publication of the SI (Metric) Edition of the ASME Boiler and Pressure Vessel Code was discontinued with the 1986 Edition. Effective October 1, 1986, the SI Edition was withdrawn as an ASME Boiler and Pressure Vessel Code document.

STATEMENT OF POLICY ON THE USE OF CODE SYMBOLS AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use Code Symbols for marking items or constructions which have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the Code Symbols for the benefit of the users, the enforcement jurisdictions, and the holders of the symbols who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the symbols, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications which might so indicate. An organization holding a Code Symbol and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code."

The ASME Symbol shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of a Code Symbol who may also use the facsimile in advertising to show that clearly specified items will carry the symbol. General usage is permitted only when all of a manufacturer's items are constructed under the rules.

The ASME logo, which is the cloverleaf with the letters ASME within, shall not be used by any organization other than ASME.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the official Code Symbol Stamp described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the various Code Symbols shall not be used on any item which is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME which tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

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The 2001 Edition of the Code contains both U.S. Customary and SI units. In all cases, the U.S. Customary units are the standard and SI units are provided for the convenience of the user.

SUMMARY OF CHANGES

The 2001 Edition of this Code contains revisions in addition to the 1998 Edition with 1999 and 2000 Addenda. The revisions are identified with the designation **01** in the margin and, as described in the Foreword, become mandatory six months after the publication date of the 2001 Edition. To invoke these revisions before their mandatory date, use the designation "2001 Edition" in documentation required by this Code. If you choose not to invoke these revisions before their mandatory date, use the designation "1998 Edition through the 2000 Addenda" in documentation required by this Code.

Changes given below are identified on the pages by a margin note, **01**, placed next to the affected area.

Page	*Location*	*Change*
12	Footnote 3	Corrected by Errata
16	Article 2 Contents	Updated to reflect 01
21	T-221.1	Title deleted and paragraph revised
24	T-272	Revised in its entirety
29	T-285	Note revised by Errata
	T-286	Last sentence corrected by Errata
44–45	VI-A-220	Title revised
	VI-A-230	Title revised
	VI-A-232.1	Title added
	VI-A-232.2	Title added
	VI-A-233	(1) Old VI-A-232.3 redesignated as VI-A-233 (2) Title added
	VI-A-234	(1) Old VI-A-232.4 redesignated as VI-A-234 (2) Title added
	VI-A-235	(1) Old VI-A-232.5 redesignated as VI-A-235 (2) Title added
	VI-A-240	Title revised
	VI-A-244	Paragraph references updated
63	T-423	New paragraph added
101	T-522	Title and paragraph revised
102	T-541.1	Subparagraphs (a)–(d) revised
	T-541.2	Subparagraphs (a) and (b) revised
103	T-541.3	Subparagraphs (a) and (b) revised
115	T-544(a), (b)	Cross-references revised
116	III-520	Subparagraph (c) corrected by Errata
122	T-610.1	Revised in its entirety
	T-621	Title revised
	T-621.1	Title deleted and paragraph revised
129	Article 7 Contents	Updated to reflect 01

Page	*Location*	*Change*
132	T-750	Revised in its entirety
137	T-778.1	Revised in its entirety
141	Appendix III	Added
147–148	T-810	Revised in its entirety
	T-821	Revised in its entirety
	T-822	Revised in its entirety
	T-823	Revised in its entirety
	Table T-823	Added
	T-830	Paragraph added
	T-831	Revised in its entirety
	T-832	Added
	T-833	Added
	T-850	Added
	T-861	Revised in its entirety
	T-862	Added
	T-870	Added
149	T-880	Paragraph added
	T-890	Paragraph T-881 revised and redisgnated as T-890
	T-891	Added
	T-892	Added
157	II-860.1.1	Subparagraph (f) revised
160	III-810	Revised in its entirety
	III-822	Added
	III-823	Added
	III-850	Title revised
	III-851	Revised in its entirety
	III-852	(1) Old III-852 deleted (2) Old III-853 redesignated as III-852
161	III-890	Revised in its entirety
	III-891	Added
	III-892	Added
164–165	T-910	Revised in its entirety
	T-921	Revised in its entirety
	T-922	Added
	T-923	Added
	Table T-923	Added
	T-930	Added
	T-940	Title revised
	T-941	Title revised
	T-941.1	Revised in its entirety
	T-950	Title revised
	T-952	Revised in its entirety
166	T-954	Last sentence deleted
	T-980.2	Revised
	T-990	Title revised
	T-991	Revised in its entirety
	T-992	(1) New T-992 added

Page	*Location*	*Change*
		(2) Old T-992 redesignated as T-993
167	I-920	(1) Definition for *lux* added (2) Revised
173	T-1010	(1) Titles for Appendices IX and X added (2) Appendix references updated
	T-1021	Revised
	T-1031	Revised
174	T-1040	Title revised
	T-1050	Title revised
	T-1052	Revised in its entirety
	T-1063.1	Revised
177–180	I-1080	Revised in its entirety
	II-1080	Revised in its entirety
	III-1061	Revised in its entirety
	III-1062	Revised
	III-1063	Revised
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181–184	III-1077	Revised
	III-1078.2	Revised
	III-1080	Revised in its entirety
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	IV-1061.3	Deleted
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	IV-1062.3	Revised in its entirety
	IV-1062.4	(1) Old IV-1062.4 deleted (2) Old IV-1062.5 redesignated as IV-1062.4
	IV-1073	Revised
	IV-1077	Revised
	IV-1078.2	Revised
	IV-1080	Revised in its entirety
	Appendix V	Appendix title revised
	V-1010	Revised in its entirety
	V-1031	Revised
	V-1032	(1) Subparagraph (e) deleted (2) Subparagraph (f) redesignated as (e)
	V-1033	Revised in its entirety
	V-1061.2	Revised in its entirety
	V-1062.1	Revised
	V-1062.2	(1) New title added (2) Subparagraph revised
	V-1062.3	(1) New title added (2) Subparagraph revised
	V-1062.4	Added
	V-1062.5	Old V-1062.2 redesignated as V-1062.5
	V-1071	(1) Old V-1071 deleted (2) Old V-1071.1 revised and redesignated as V-1071

Page	*Location*	*Change*
	V-1072	(1) Old V-1072 Deleted (2) Old V-1071.2 revised and redesignated as V-1072
	V-1073	Old V-1071.3 revised and redesignated as V-1073
	V-1074	Old V-1071.4 revised and redesignated as V-1074
	V-1075	Added
	V-1080	Revised in its entirety
186	VII-1020	Revised in its entirety
	VII-1030	Paragraph designator deleted
188	VIII-1061	Revised
	VIII-1062	Revised
	VIII-1063	Revised
	VIII-1064	(1) New VIII-1064 added (2) Old VIII-1064 revised and redesignated as VIII-1065
189	VIII-1077	Revised
	VIII-1078.2	Revised
	VIII-1080	Revised in its entirety
190	Appendix IX	Added
193	Appendix X	Added
195	A-10	Revised in its entirety
199	T-1128	Title and paragraph revised
223	T-1225	Title and paragraph revised
247	T-1350	Title and paragraph revised
264	Article 22 Contents	Updated to reflect 01
280	SE-142	Deleted
281	SE-186	Deleted
282	SE-242	Deleted
283	SE-280	Deleted
284	SE-446	Deleted
365	SE-1647	Updated to reflect ASTM E 1647-98a
444	Article 24 Contents	Updated to reflect 01
489	SE-1209	Deleted
490	SE-1219	Deleted
491	SE-1220	Deleted
536	Article 26 Contents	Updated to reflect 01
537	SE-215	Deleted
545	SE-309	Deleted
546	SE-426	Deleted
547	SE-571	Deleted
601	Article 30 Contents	Updated to reflect 01
602	SE-1316	Updated to reflect ASTM E 1316-99

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Nondestructive Methods of Examination

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ARTICLE 1
GENERAL REQUIREMENTS

T-110 SCOPE

(a) Unless otherwise specified by the referencing Code Section or other referencing documents, this Section of the Code contains requirements and methods for nondestructive examination which are Code requirements to the extent they are specifically referenced and required by other Code Sections. These nondestructive examination methods are intended to detect surface and internal discontinuities in materials, welds, and fabricated parts and components. They include radiographic examination, ultrasonic examination, liquid penetrant examination, magnetic particle examination, eddy current examination, visual examination, leak testing, and acoustic emission examination.

(b) For general terms such as *Inspection, Flaw, Discontinuity, Evaluation*, etc., refer to Mandatory Appendix I.

T-120 GENERAL

(a) Subsection A describes the methods of nondestructive examination to be used if referenced by other Code Sections.

(b) Subsection B lists Standards covering nondestructive examination methods which have been accepted as standards. These standards are intended to be informative only and are nonmandatory unless specifically referenced in whole or in part in Subsection A or as indicated in other Code Sections.

(c) Reference to a paragraph of any Article in Subsection A of this Section or in the referencing Code Section includes all of the applicable rules in the paragraph.[1] In every case, reference to a paragraph includes all the subparagraphs and subdivisions under that paragraph.

(d) Reference to a Standard contained in Subsection B is mandatory only to the extent specified in an Article of Subsection A or as specified in other Code Sections.[2]

T-130 EQUIPMENT

It is the responsibility of the Manufacturer, fabricator, or installer to ensure that the examination equipment being used conforms to the requirements of this Code Section.

T-140 REQUIREMENTS 01

(a) Nondestructive Examination Personnel shall be qualified in accordance with the requirements of the referencing Code Section.

(b) For those Code Sections that directly reference this Article for the qualification of NDE personnel, the qualification shall be in accordance with one of the following documents:

(1) SNT-TC-1A,[3] Personnel Qualification and Certification in Nondestructive Testing; or

(2) ANSI/ASNT CP-189,[3] ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel; or

(3) ACCP,[3] ASNT Central Certification Program.

(c) When the referencing Code Section does not specify qualifications or does not reference directly Article 1 of this Section, qualification may simply involve demonstration in routine manufacturing operations to show that the personnel performing the nonde-

[1] For example, reference to T-270 includes all the rules contained in T-271 through T-277.3.

[2] For example, T-233 requires that Image Quality Indicators be manufactured and identified in accordance with the requirements or alternatives allowed in SE-747 or SE-1025, and Appendices, as appropriate for the style of IQI to be used. These are the only parts of either SE-747 or SE-1025 that are mandatory in Article 2.

[3] SNT-TC-1A (1996 Edition, with 1998 Addendum), "Personnel Qualification and Certification in Nondestructive Testing;" ANSI/ASNT CP-189 (1995 Edition), "ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel;" and ACCP [Revision 3 (November 1997)], "ASNT Central Certification Program;" published by the American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228-0518.

:aminations are competent to do so in accord-
the Manufacturer's established procedures.
certificate holder shall ensure that NDE
ire qualified and certified in accordance with
:. The certificate holder's Quality Program
ate how this is to be accomplished.
ifications in accordance with a prior edition
C-1A, CP-189, or ACCP are valid until
on. Recertification or new certification shall
dance with the edition of SNT-TC-1A, CP-
CP specified in footnote 3.
ted certification of nondestructive examina-
nel who do not perform all of the operations
structive method that consists of more than
on, or who perform nondestructive examina-
nited scope, may be based on fewer hours
and experience than recommended in SNT-
-189, or ACCP. Any limitations or restric-
:d upon a person's certification shall be
n the written practice and on the certification.
SNT-TC-1A document is a guide to establish
)r training, qualification, and certification of
)nnel as required by the referencing Code

PROCEDURE

nondestructive examination methods included
ion are applicable to most geometric configu-
l materials encountered in fabrication under
ıditions. However, special configurations and
ıay require modified methods and techniques,
:ase the Manufacturer shall develop special
which are equivalent or superior to the
ıd techniques described in this Code Section,
are capable of producing interpretable exami-
lts under the special conditions. Such special
may be modifications or combinations of
escribed or referenced in this Code Section,
be proved by demonstration to be capable
g discontinuities under the special conditions,
lemonstrated capabilities shall be equivalent
ıabilities of the methods described in this
on when used under more general conditions.
on the quality assurance or quality control
uirements of the referencing Code Section,
ial procedures shall be submitted to the
'or acceptance where required, and shall be
part of the Manufacturer's quality control

n an examination to the requirements of this
the Code is required by other Sections of the Code, it shall be the responsibility of the Manufacturer, fabricator, or installer to establish nondestructive examination procedures and personnel certification procedures conforming to the referencing Code requirements.

(c) When required by the referencing Code Section, all nondestructive examinations performed under this Code Section shall be done to a written procedure. This procedure shall be demonstrated to the satisfaction of the Inspector. The procedure or method shall comply with the applicable requirements of this Section for the particular examination method. Where so required, written procedures shall be made available to the Inspector on request. At least one copy of each procedure shall be readily available to the Manufacturer's Nondestructive Examination Personnel for their reference and use.

T-160 CALIBRATION

(a) The Manufacturer, fabricator, or installer shall assure that all equipment calibrations required by Subsection A and/or Subsection B are performed.

(b) When special procedures are developed [see T-150(a)], the Manufacturer, fabricator, or installer shall specify what calibration is necessary, when calibration is required.

T-170 EXAMINATIONS AND INSPECTIONS

(a) The Inspector concerned with the fabrication of the vessel or pressure part shall have the duty of verifying to his satisfaction that all examinations required by the referencing Code Section have been made to the requirements of this Section and the referencing Code Section. He shall have the right to witness any of these examinations to the extent stated in the referencing Code Section. Throughout this Section of the Code, the word *Inspector* means the *Authorized Inspector* who has been qualified as required in the various referencing Code Sections.

(b) The special distinction established in the various Code Sections between *inspection* and *examination* and the personnel performing them is also adopted in this Code Section. In other words, the term *inspection* applies to the functions performed by the *Authorized Inspector*, but the term *examination* applies to those quality control functions performed by personnel employed by the Manufacturer. One area of occasional deviation from these distinctions exists. In the ASTM Standard Methods and Recommended Practices incorpo-

rated in this Section of the Code by reference or by reproduction in Subsection B, the words *inspection* or *Inspector*, which frequently occur in the text or titles of the referenced ASTM documents, may actually describe what the Code calls *examination* or *examiner*. This situation exists because ASTM has no occasion to be concerned with the distinctions which the Code makes between *inspection* and *examination*, since ASTM activities and documents do not involve the *Authorized Inspector* described in the Code Sections. However, no attempt has been made to edit the ASTM documents to conform with Code usage; this should cause no difficulty if the users of this Section recognize that the terms *inspection, testing,* and *examination* in the ASTM documents referenced in Subsection B do not describe duties of the *Authorized Code Inspector* but rather describe the things to be done by the Manufacturer's *examination* personnel.

T-180 EVALUATION

The acceptance standards for these methods shall be as stated in the referencing Code Section.

T-190 RECORDS/DOCUMENTATION

Records/Documentation shall be in accordance with the referencing Code Section and the applicable requirements of Subsection A and/or B of this Code Section. The Manufacturer, fabricator, or installer shall be responsible for all required Records/Documentation.

ARTICLE 1
MANDATORY APPENDIX

APPENDIX I — GLOSSARY OF TERMS FOR NONDESTRUCTIVE EXAMINATION

I-110 SCOPE

This Mandatory Appendix is used for the purpose of establishing standard terms and definition of terms common to all methods used in Nondestructive Examination.

I-120 GENERAL REQUIREMENTS

(a) The Standard Terminology for Nondestructive Examinations (ASTM E 1316) has been adopted by the Committee as SE-1316.

(b) SE-1316 Section A provides the definition of terms listed in I-130(a).

(c) Paragraph I-130(b) provides a list of terms and definitions, which are in addition to SE-1316 and are Code specific.

I-130 REQUIREMENTS

(a) The following SE-1316 terms are used in conjunction with this Article: *defect, discontinuity, evaluation, false indication, flaw, flaw characterization, imperfection, interpretation, nonrelevant indication, relevant indication.*

(b) The following Code terms are used in conjunction with this Article:

area of interest — the specific portion of the object that is to be evaluated as defined by the referencing Code Section

indication — the response or evidence from a nondestructive examination that requires interpretation to determine relevance

inspection — the observation of any operation performed on materials and/or components to determine its acceptability in accordance with given criteria

limited certification — an accreditation of an individual's qualification to perform some but not all of the operations within a given nondestructive examination method or technique that consists of one or more than one operation, or to perform nondestructive examinations within a limited scope of responsibility

method — the following is a list of nondestructive examination methods and respective abbreviations used within the scope of Section V:

RT — Radiography
UT — Ultrasonics
MT — Magnetic Particle
PT — Liquid Penetrants
VT — Visual
LT — Leak Testing
ET — Electromagnetic (Eddy Current)
AE — Acoustic Emission

nondestructive examination (NDE) — the development and application of technical methods to examine materials and/or components in ways that do not impair future usefulness and serviceability in order to detect, locate, measure, interpret, and evaluate flaws

operation — a specific phase of a method or technique

procedure — an orderly sequence of actions describing how a specific technique shall be applied

sensitivity — a measure of the level of response from a discontinuity by a nondestructive examination

technique — a technique is a specific way of utilizing a particular nondestructive examination (NDE) method

01

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A2.6.1 *Apparatus:*

A2.6.1.1 *Silver Billet Electrode.*

A2.6.1.2 *Glass Electrode,* pH measurement type.

A2.6.1.3 *Buret,* 25-mL capacity, 0.05-mL graduations.

A2.6.1.4 *Millivolt Meter,* or expanded scale pH meter capable of measuring 0 to 220 mV.

Note A2.7 — An automatic titrator is highly recommended in place of items A2.6.1.3 through A2.6.1.4. Repeatability and sensitivity of the method are much enhanced by the automatic equipment while much tedious effort is avoided.

A2.6.2 *Reagents and Materials:*

A2.6.2.1 *Acetone,* chlorine-free.

A2.6.2.2 *Methanol,* chlorine-free.

A2.6.2.3 *Silver Nitrate Solution (0.0282 N)* — Dissolve 4.7910 ± 0.0005 g of silver nitrate ($AgNO_3$) in water and dilute to 1 L.

A2.6.2.4 *Sodium Chloride Solution (0.0282 N)* — Dry a few grams of sodium chloride (NaCl) for 2 h at 130 to 150°C, weigh out 1.6480 ± 0.0005 g of the dried NaCl, dissolve in water, and dilute to 1 L.

A2.6.2.5 *Sulfuric Acid (1 + 2)* — Mix 1 volume of concentrated sulfuric acid (H_2SO_4, sp. gr 1.84) with 2 volumes of water.

A2.6.3 *Collection of Chlorine Solution* — Remove the sample cup with clean forceps and place in a 400-mL beaker. Wash down the walls of the bomb shell with a fine stream of methanol from a wash bottle, and pour the washings into the beaker. Rinse any residue into the beaker. Next, rinse the bomb cover and terminals into the beaker. Finally, rinse both inside and outside of the sample crucible into the beaker. Washings should equal but not exceed 100 mL. Add methanol to make 100 mL.

A2.6.4 *Determination of Chlorine* — Add 5 mL of H_2SO_4 (1:2) to acidify the solution (solution should be acid to litmus and clear of white Na_2CO_3 precipitate). Add 100 mL of acetone. Place the electrodes in the solution, start the stirrer (if mechanical stirrer is to be used), and begin titration. If titration is manual, set the pH meter on the expanded millivolt scale and note the reading. Add exactly 0.1 mL of $AgNO_3$ solution from the buret. Allow a few seconds stirring; then record the new millivolt reading. Subtract the second reading from the first. Continue the titration, noting each amount of $AgNO_3$ solution and the amount of difference between the present reading and the last reading. Continue adding 0.1-mL increments, making readings and determining differences between readings until a maximum difference between readings is obtained. The total amount of $AgNO_3$ solution required to produce this maximum differential is the end point. Automatic titrators continuously stir the sample, add titrant, measure the potential difference, calculate the differential, and plot the differential on a chart. The maximum differential is taken at the end point.

NOTE A2.8 — For maximum sensitivity, 0.00282 *N* $AgNO_3$ solution may be used with the automatic titrator. This dilute reagent should not be used with large samples or where chlorine content may be over 0.1% since these tests will cause end points of 10 mL or higher. The large amount of water used in such titrations reduces the differential between readings, making the end point very difficult to detect. For chlorine contents over 1% in samples of 0.8 g or larger, 0.282 *N* $AgNO_3$ solution will be required to avoid exceeding the 10-mL water dilution limit.

A2.6.5 *Blank* — Make blank determinations with the amount of white oil used but omitting the sample. (Liquid samples normally require only 0.15 to 0.25 g of white oil while solids require 0.7 to 0.8 g.) Follow normal procedure, making two or three test runs to be sure the results are within the limits of repeatability for the test. Repeat this blank procedure whenever new batches of reagents or white oil are used. The purpose of the blank run is to measure the chlorine in the white oil, the reagents, and that introduced by contamination.

A2.6.6 *Standardization* — Silver nitrate solutions are not permanently stable, so the true activity should be checked when the solution is first made up and then periodically during the life of the solution. This is done by titration of a known NaCl solution as follows: Prepare a mixture of the amounts of the chemicals (Na_2CO_3 solution, H_2SO_4 solution, acetone, and methanol) specified for the test. Pipet in 5.0 mL of 0.0282-*N* NaCl solution and titrate to the end point. Prepare and titrate a similar mixture of all the chemicals except the NaCl solution, thus obtaining a reagent blank reading. Calculate the normality of the $AgNO_3$ solution as follows:

$$N_{AgNO_3} = \frac{5.0 \times N_{NaCl}}{V_A - V_B}$$

where:

N_{AgNO_3} = normality of the $AgNO_3$ solution,
N_{NaCl} = normality of the NaCl solution,
V_A = millilitres of $AgNO_3$ solution used for the titration including the NaCl solution, and

T-226 Extent of Examination

The extent of radiographic examination shall be as specified by the referencing Code Section.

T-230 EQUIPMENT AND MATERIALS

T-231 Film

T-231.1 Selection. Film selection shall be in accordance with SE-1815, Standard Test Method for Film Systems for Industrial Radiography. The film manufacturer shall determine the film system class for the family of films manufactured and provide a classification table. A typical Film Classification Table is as shown in SE-1815, Table 1. Film system classes Special, I, II, III, W-A, and W-B are permitted.

Caution — If any of the film processing parameters are changed from those provided by the film manufacturer, the class may not be valid, in which case the film manufacturer should be contacted for further guidance.

T-231.2 Processing. Standard Guide for Controlling the Quality of Industrial Radiographic Film Processing, SE-999, or Part III of Standard Guide for Radiographic Testing SE-94 shall be used as a guide for processing film.

T-232 Intensifying Screens

Intensifying screens may be used when performing radiographic examination in accordance with this Article.

T-233 Image Quality Indicator (IQI) Design

IQIs shall be either the hole type or the wire type. Hole-type IQIs shall be manufactured and identified in accordance with the requirements or alternates allowed in SE-1025. Wire-type IQIs shall be manufactured and identified in accordance with the requirements or alternates allowed in SE-747, except that the largest wire number or the identity number may be omitted. ASME standard IQIs shall consist of those in Table T-233.1 for hole type and those in Table T-233.2 for wire type.

TABLE T-233.1
HOLE-TYPE IQI DESIGNATION, THICKNESS, AND HOLE DIAMETERS

IQI Designation, in. (mm)	IQI Thickness, in. (mm)	1*T* Hole Diameter, in. (mm)	2*T* Hole Diameter, in. (mm)	4*T* Hole Diameter, in. (mm)
5	0.005 (0.13)	0.010 (0.25)	0.020 (0.51)	0.040 (1.02)
7	0.0075 (0.19)	0.010 (0.25)	0.020 (0.51)	0.040 (1.02)
10	0.010 (0.25)	0.010 (0.25)	0.020 (0.51)	0.040 (1.02)
12	0.0125 (0.32)	0.0125 (0.32)	0.025 (0.64)	0.050 (1.27)
15	0.015 (0.38)	0.015 (0.38)	0.030 (0.76)	0.060 (1.52)
17	0.0175 (0.44)	0.0175 (0.44)	0.035 (0.89)	0.070 (1.78)
20	0.020 (0.51)	0.020 (0.51)	0.040 (1.02)	0.080 (2.03)
25	0.025 (0.64)	0.025 (0.64)	0.050 (1.27)	0.100 (2.54)
30	0.030 (0.76)	0.030 (0.76)	0.060 (1.52)	0.120 (3.05)
35	0.035 (0.89)	0.035 (0.89)	0.070 (1.78)	0.140 (3.56)
40	0.040 (1.02)	0.040 (1.02)	0.080 ((2.03)	0.160 (4.06)
45	0.045 (1.14)	0.045 (1.14)	0.090 (2.29)	0.180 (4.57)
50	0.050 (1.27)	0.050 (1.27)	0.100 (2.54)	0.200 (5.08)
60	0.060 (1.52)	0.060 (1.52)	0.120 (3.05)	0.240 (6.10)
70	0.070 (1.78)	0.070 (1.78)	0.140 (3.56)	0.280 (7.11)
80	0.080 (2.03)	0.080 (2.03)	0.160 (4.06)	0.320 (8.13)
100	0.100 (2.54)	0.100 (2.54)	0.200 (5.08)	0.400 (10.16)
120	0.120 (3.05)	0.120 (3.05)	0.240 (6.10)	0.480 (12.19)
140	0.140 (3.56)	0.140 (3.56)	0.280 (7.11)	0.560 (14.22)
160	0.160 (4.06)	0.160 (4.06)	0.320 (8.13)	0.640 (16.26)
200	0.200 (5.08)	0.200 (5.08)	0.400 (10.16)	...
240	0.240 (6.10)	0.240 (6.10)	0.480 (12.19)	...
280	0.280 (7.11)	0.280 (7.11)	0.560 (14.22)	...

TABLE T-233.2
WIRE IQI DESIGNATION, WIRE DIAMETER, AND WIRE IDENTITY

Set A			Set B		
Wire Diameter, in.	(mm)	Wire Identity	Wire Diameter, in.	(mm)	Wire Identity
0.0032	(0.08)	1	0.010	(0.25)	6
0.004	(0.01)	2	0.013	(0.33)	7
0.005	(0.13)	3	0.016	(0.41)	8
0.0063	(0.16)	4	0.020	(0.51)	9
0.008	(0.20)	5	0.025	(0.64)	10
0.010	(0.25)	6	0.032	(0.81)	11
Set C			Set D		
Wire Diameter, in.	(mm)	Wire Identity	Wire Diameter, in.	(mm)	Wire Identity
0.032	(0.81)	11	0.100	(2.54)	16
0.040	(1.02)	12	0.126	(3.20)	17
0.050	(1.27)	13	0.160	(4.06)	18
0.063	(1.60)	14	0.200	(5.08)	19
0.080	(2.03)	15	0.250	(6.35)	20
0.100	(2.54)	16	0.320	(8.13)	21

T-234 Facilities for Viewing of Radiographs

Viewing facilities shall provide subdued background lighting of an intensity that will not cause troublesome reflections, shadows, or glare on the radiograph. Equipment used to view radiographs for interpretation shall provide a variable light source sufficient for the essential IQI hole or designated wire to be visible for the specified density range. The viewing conditions shall be such that light from around the outer edge of the radiograph or coming through low-density portions of the radiograph does not interfere with interpretation.

T-260 CALIBRATION

T-261 Source Size

T-261.1 Verification of Source Size. The equipment manufacturer's or supplier's publications, such as technical manuals, decay curves, or written statements documenting the actual or maximum source size or focal spot, shall be acceptable as source size verification.

T-261.2 Determination of Source Size. When manufacturer's or supplier's publications are not available, source size may be determined as follows:

(a) X-Ray Machines. For X-ray machines operating at 500 kV and less, the focal spot size may be determined by the pinhole method,[1] or in accordance with SE-1165, Standard Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging.

(b) Iridium-192 Sources. For Iridium-192, the source size may be determined in accordance with SE-1114, Standard Test Method for Determining the Focal Size of Iridium-192 Industrial Radiographic Sources.

T-262 Densitometer and Step Wedge Comparison Film

T-262.1 Densitometers. Densitometers shall be calibrated at least every 90 days during use as follows:

(a) A national standard step tablet or a step wedge calibration film, traceable to a national standard step tablet and having at least 5 steps with neutral densities from at least 1.0 through 4.0, shall be used. The step wedge calibration film shall have been verified within the last year by comparison with a national standard step tablet.

(b) The densitometer manufacturer's step-by-step instructions for the operation of the densitometer shall be followed.

(c) The density steps closest to 1.0, 2.0, 3.0, and 4.0 on the national standard step tablet or step wedge calibration film shall be read.

(d) The densitometer is acceptable if the density readings do not vary by more than ± 0.05 density units from the actual density stated on the national standard step tablet or step wedge calibration film.

T-262.2 Step Wedge Comparison Films. Step wedge comparison films shall be verified prior to first use, unless performed by the manufacturer, as follows:

(a) The density of the steps on a step wedge comparison film shall be verified by a calibrated densitometer.

(b) The step wedge comparison film is acceptable if the density readings do not vary by more than ± 0.1 density units from the density stated on the step wedge comparison film.

T-262.3 Periodic Verification

(a) Densitometers. Periodic cablibration verification checks shall be performed as described in T-262.1 at the beginning of each shift, after 8 hr of continuous use, or after change of apertures, whichever comes first. The densitometer is acceptable if the density

[1] Nondestructive Testing Handbook, Volume I, First Edition, pp. 14.32–14.33, "Measuring Focal-Spot Size." Also, pp. 20–21 of *Radiography in Modern Industry,* Fourth Edition.

readings are within ± 0.05 of the calibration readings determined in T-262.1(c).

(b) Step Wedge Comparison Films. Verification checks shall be performed annually per T-262.2.

T-262.4 Documentation

(a) Densitometer calibration readings required by T-262.1(c) shall be recorded in an appropriate calibration log.

(b) Periodic verification readings required by T-262.3 do not have to be recorded.

T-270 EXAMINATION

T-271 Radiographic Technique[2]

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.

T-271.1 Single-Wall Technique. In the single-wall technique, the radiation passes through only one wall of the weld (material), which is viewed for acceptance on the radiograph.

T-271.2 Double-Wall Technique. When it is not practical to use a single-wall technique, one of the following double-wall techniques shall be used.

(a) Single-Wall Viewing. For materials and for welds in components, a technique may be used in which the radiation passes through two walls and only the weld (material) on the film-side wall is viewed for acceptance on the radiograph. When complete coverage is required for circumferential welds (materials), a minimum of three exposures taken 120 deg. to each other shall be made.

(b) Double-Wall Viewing. For materials and for welds in components $3\frac{1}{2}$ in. (89 mm) or less in nominal outside diameter, a technique may be used in which the radiation passes through two walls and the weld (material) in both walls is viewed for acceptance on the same radiograph. For double-wall viewing, only a source-side IQI shall be used. Care should be exercised to ensure that the required geometric unsharpness is not exceeded. If the geometric unsharpness requirement cannot be met, then single-wall viewing shall be used.

(1) For welds, the radiation beam may be offset from the plane of the weld at an angle sufficient to separate the images of the source-side and film-side portions of the weld so that there is no overlap of the areas to be interpreted. When complete coverage is required, a minimum of two exposures taken 90 deg. to each other shall be made for each joint.

(2) As an alternative, the weld may be radiographed with the radiation beam positioned so that the images of both walls are superimposed. When complete coverage is required, a minimum of three exposures taken at either 60 deg. or 120 deg. to each other shall be made for each joint.

(3) Additional exposures shall be made if the required radiographic coverage cannot be obtained using the minimum number of exposures indicated in (b)(1) or (b)(2) above.

T-272 Radiation Energy 01

The radiation energy employed for any radiographic technique shall achieve the density and IQI image requirements of this Article.

T-273 Direction of Radiation

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

T-274 Geometric Unsharpness

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

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

Location markers (see Fig. T-275), which are to appear as radiographic images on the film, shall be

[2] Sketches showing suggested source, film, and IQI placements for pipe or tube welds are illustrated in Article 2, Nonmandatory Appendix A.

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. Location markers shall be placed as follows.

T-275.1 Single-Wall Viewing

(a) Source-Side Markers. Location markers shall be placed on the source side when radiographing the following:

(1) flat components or longitudinal joints in cylindrical or conical components;

(2) curved or spherical components whose concave side is toward the source and when the "source-to-material" distance is less than the inside radius of the component;

(3) curved or spherical components whose convex side is toward the source.

(b) Film-Side Markers

(1) Location markers shall be placed on the film side when radiographing either curved or spherical components whose concave side is toward the source and when the "source-to-material" distance is greater than the inside radius.

(2) As an alternative to source-side placement in T-275.1(a)(1), location markers may be placed on the film side when the radiograph shows coverage beyond the location markers to the extent demonstrated by Fig. T-275, sketch (e), and when this alternate is documented in accordance with T-291.

(c) Either Side Markers. Location markers may be placed on either the source side or film side when radiographing either curved or spherical components whose concave side is toward the source and the "source-to-material" distance equals the inside radius of the component.

T-275.2 Double-Wall Viewing. For double-wall viewing, at least one location marker shall be placed adjacent to the weld (or on the material in the area of interest) for each radiograph.

T-275.3 Mapping the Placement of Location Markers. When inaccessibility or other limitations prevent the placement of markers as stipulated in T-275.1 and T-275.2, a dimensioned map of the actual marker placement shall accompany the radiographs to show that full coverage has been obtained.

T-276 IQI Selection

T-276.1 Material. 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 Size. The designated hole IQI or essential wire shall be as specified in Table T-276. A thinner or thicker hole-type IQI may be substituted for any section thickness listed in Table T-276, provided an equivalent IQI sensitivity is maintained. See T-283.2.

(a) Welds With Reinforcements. The thickness on which the IQI is based is the nominal single-wall thickness plus the estimated weld reinforcement not to exceed the maximum permitted by the referencing Code Section. Backing rings or strips shall not be considered as part of the thickness in IQI selection. The actual measurement of the weld reinforcement is not required.

(b) Welds Without Reinforcements. The thickness on which the IQI is based is the nominal single-wall thickness. Backing rings or strips shall not be considered as part of the weld thickness in IQI selection.

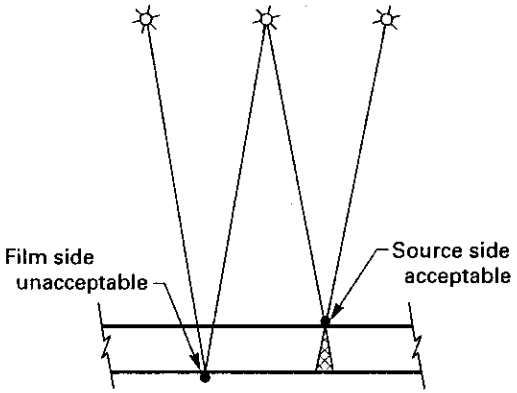
T-276.3 Welds Joining Dissimilar Materials or Welds With Dissimilar Filler Metal. When the weld metal is of an alloy group or grade that has a radiation attenuation that differs from the base material, the IQI material selection shall be based on the weld metal and be in accordance with T-276.1. When the density limits of T-282.2 cannot be met with one IQI, and the exceptional density area(s) is at the interface of the weld metal and the base metal, the material selection for the additional IQIs shall be based on the base material and be in accordance with T-276.1.

T-277 Use of IQIs to Monitor Radiographic Examination

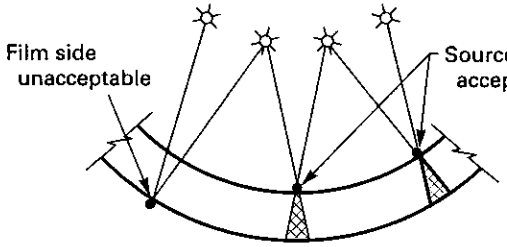
T-277.1 Placement of IQIs

(a) Source-Side IQI(s). The IQI(s) shall be placed on the source side of the part being examined, except for the condition described in T-277.1(b).

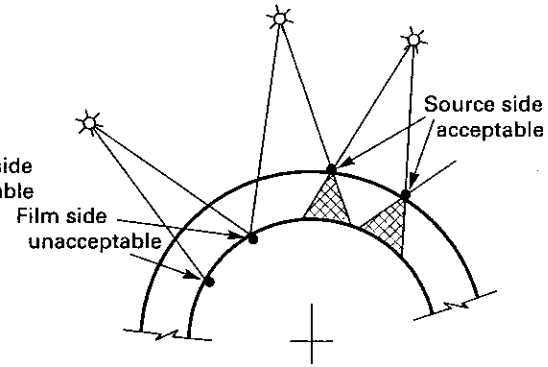
When, due to part or weld configuration or size, it is not practical to place the IQI(s) on the part or weld, the IQI(s) may be placed on a separate block. Separate blocks shall be made of the same or radiographically similar materials (as defined in SE-1025) and may be used to facilitate IQI positioning. There is no restriction on the separate block thickness, provided the IQI/area-of-interest density tolerance requirements of T-282.2 are met.



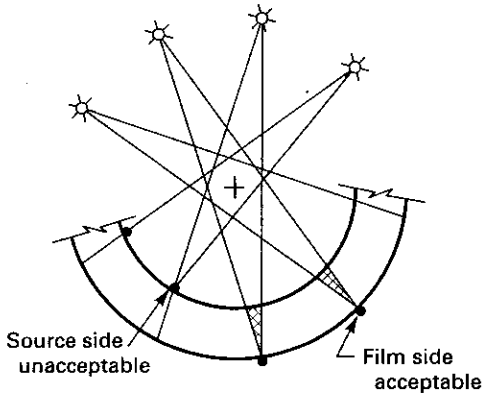
Flat component or longitudinal seam
[See T-275.1(a)(1)]
[See sketch (e) for alternate]
(a)



Curved components with radiation source to film distance less than radius of component
[See T-275.1(a)(2)]
(b)

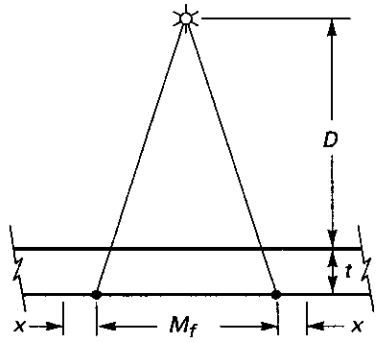


Curved components with convex surface towards radiation source
[See T-275.1(a)(3)]
(c)

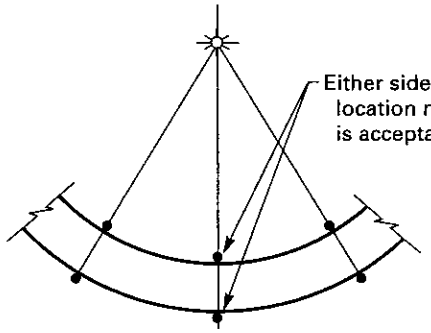


Curved components with radiation source to film distance greater than radius of curvature
[See T-275.1(b)(1)]
(d)

LEGEND: Radiation source — ☼
Location marker — •
Component center — +



Source side marker alternate
Flat component or logitudinal seam
$x = (t / D)(M_f / 2)$
x = **additional required coverage beyond film side location marker**
t = **component thickness**
M_f = **film side location marker interval**
D = **source to component distance**
[See T-275.1(b)(2)]
(e)



Curved components with radiation source at center curvature
[See T-275.1(c)]
(f)

FIG. T-275 LOCATION MARKER SKETCHES

TABLE T-276
IQI SELECTION

Nominal Single-Wall Material Thickness Range		IQI			
		Source Side		Film Side	
in.	mm	Hole-Type Designation	Wire-Type Essential Wire	Hole-Type Designation	Wire-Type Essential Wire
p to 0.25, incl.	Up to 6.4, incl.	12	5	10	4
ver 0.25 through 0.375	Over 6.4 through 9.5	15	6	12	5
ver 0.375 through 0.50	Over 9.5 through 12.7	17	7	15	6
ver 0.50 through 0.75	Over 12.7 through 19.0	20	8	17	7
ver 0.75 through 1.00	Over 19.0 through 25.4	25	9	20	8
ver 1.00 through 1.50	Over 25.4 through 38.1	30	10	25	9
ver 1.50 through 2.00	Over 38.1 through 50.8	35	11	30	10
ver 2.00 through 2.50	Over 50.8 through 63.5	40	12	35	11
ver 2.50 through 4.00	Over 63.5 through 101.6	50	13	40	12
ver 4.00 through 6.00	Over 101.6 through 152.4	60	14	50	13
ver 6.00 through 8.00	Over 152.4 through 203.2	80	16	60	14
ver 8.00 through 10.00	Over 203.2 through 254.0	100	17	80	16
ver 10.00 through 12.00	Over 254.0 through 304.8	120	18	100	17
ver 12.00 through 16.00	Over 304.8 through 406.4	160	20	120	18
ver 16.00 through 20.00	Over 406.4 through 508.0	200	21	160	20

(1) The IQI on the source side of the separate lock shall be placed no closer to the film than the ource side of the part being radiographed.

(2) The separate block shall be placed as close s possible to the part being radiographed.

(3) The block dimensions shall exceed the IQI imensions such that the outline of at least three sides f the IQI image shall be visible on the radiograph.

(b) Film-Side IQI(s). Where inaccessibility prevents and placing the IQI(s) on the source side, the IQI(s) hall be placed on the film side in contact with the art being examined. A lead letter "F" shall be placed djacent to or on the IQI(s), but shall not mask the ssential hole where hole IQIs are used.

(c) IQI Placement for Welds — Hole IQIs. The QI(s) may be placed adjacent to or on the weld. The lentification number(s) and, when used, the lead letter F," shall not be in the area of interest, except when eometric configuration makes it impractical.

(d) IQI Placement for Welds — Wire IQIs. The QI(s) shall be placed on the weld so that the length f the wires is perpendicular to the length of the weld. 'he identification numbers and, when used, the lead :tter "F," shall not be in the area of interest, except /hen geometric configuration makes it impractical.

(e) IQI Placement for Materials Other Than Welds. 'he IQI(s) with the IQI identification number(s), and, when used, the lead letter "F," may be placed in the area of interest.

T-277.2 Number of IQIs. When one or more film holders are used for an exposure, at least one IQI image shall appear on each radiograph except as outlined in (b) below.

(a) Multiple IQIs. If the requirements of T-282 are met by using more than one IQI, one shall be representative of the lightest area of interest and the other the darkest area of interest; the intervening densities on the radiograph shall be considered as having acceptable density.

(b) Special Cases[3]

(1) For cylindrical components where the source is placed on the axis of the component for a single exposure, at least three IQIs, spaced approximately 120 deg. apart, are required under the following conditions:

(a) When the complete circumference is radiographed using one or more film holders, or;

(b) When a section or sections of the circumference, where the length between the ends of the outermost sections span 240 or more deg., is radiographed using one or more film holders. Additional film locations may be required to obtain necessary IQI spacing.

[3] Refer to Nonmandatory Appendix D for additional guidance.

(2) For cylindrical components where the source is placed on the axis of the component for a single exposure, at least three IQIs, with one placed at each end of the span of the circumference radiographed and one in the approximate center of the span, are required under the following conditions:

(a) When a section of the circumference, the length of which is greater than 120 deg. and less than 240 deg., is radiographed using just one film holder, or;

(b) When a section or sections of the circumference, where the length between the ends of the outermost sections span less than 240 deg., is radiographed using more than one film holder.

(3) In *(1)* and *(2)* above, where sections of longitudinal welds adjoining the circumferential weld are radiographed simultaneously with the circumferential weld, an additional IQI shall be placed on each longitudinal weld at the end of the section most remote from the junction with the circumferential weld being radiographed.

(4) For spherical components where the source is placed at the center of the component for a single exposure, at least three IQIs, spaced approximately 120 deg. apart, are required under the following conditions:

(a) When a complete circumference is radiographed using one or more film holders, or;

(b) When a section or sections of a circumference, where the length between the ends of the outermost sections span 240 or more deg., is radiographed using one or more film holders. Additional film locations may be required to obtain necessary IQI spacing.

(5) For spherical components where the source is placed at the center of the component for a single exposure, at least three IQIs, with one placed at each end of the radiographed span of the circumference radiographed and one in the approximate center of the span, are required under the following conditions:

(a) When a section of a circumference, the length of which is greater than 120 deg. and less than 240 deg., is radiographed using just one film holder, or;

(b) When a section or sections of a circumference, where the length between the ends of the outermost sections span less than 240 deg. is radiographed using more than one film holder.

(6) In *(4)* and *(5)* above, where other welds are radiographed simultaneously with the circumferential weld, one additional IQI shall be placed on each other weld.

(7) When an array of components in a circle is radiographed, at least one IQI shall show on each component image.

(8) In order to maintain the continuity of records involving subsequent exposures, all radiographs exhibiting IQIs that qualify the techniques permitted in accordance with *(1)* through *(6)* above shall be retained.

T-277.3 Shims Under Hole IQIs. For welds, a shim of material radiographically similar to the weld metal shall be placed between the part and the IQI, 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 IQI.

The shim dimensions shall exceed the IQI dimensions such that the outline of at least three sides of the IQI image shall be visible in the radiograph.

T-280 EVALUATION

T-281 Quality of Radiographs

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

T-282.1 Density Limitations. The transmitted film density through the radiographic image of the body of the appropriate hole IQI or adjacent to the designated wire of a wire IQI 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-282.2 Density Variation

(a) General. If the density of the radiograph anywhere through the area of interest varies by more than minus 15% or plus 30% from the density through the body of the hole IQI or adjacent to the designated wire of a wire IQI, within the minimum/maximum allowable

TABLE T-283
EQUIVALENT HOLE-TYPE IQI SENSITIVITY

Hole-Type Designation 2*T* Hole	Equivalent Hole-Type Designations	
	1*T* Hole	4*T* Hole
10	15	5
12	17	7
15	20	10
17	25	12
20	30	15
25	35	17
30	40	20
35	50	25
40	60	30
50	70	35
60	80	40
80	120	60
100	140	70
120	160	80
160	240	120
200	280	140

density ranges specified in T-282.1, then an additional IQI shall be used for each exceptional area or areas and the radiograph retaken. When calculating the allowable variation in density, the calculation may be rounded to the nearest 0.1 within the range specified in T-282.1.

(b) With Shims. When shims are used the plus 30% density restriction of (a) above may be exceeded, provided the required IQI sensitivity is displayed and the density limitations of T-282.1 are not exceeded.

T-283 IQI Sensitivity

T-283.1 Required Sensitivity. Radiography shall be performed with a technique of sufficient sensitivity to display the designated hole IQI image and the 2*T* hole, or the essential wire of a wire IQI. The radiographs shall also display the IQI identifying numbers and letters. If the designated hole IQI image and 2*T* hole, or essential 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-283.2 Equivalent Hole-Type Sensitivity. If a thinner or thicker hole-type IQI than listed in Table T-276 was substituted, an equivalent IQI sensitivity, as specified in Table T-283, shall have been maintained as well as all other requirements for radiography having been met.

T-284 Excessive Backscatter

If a light image of the "B," as described in T-223, 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-285 Geometric Unsharpness Limitations 01

Geometric unsharpness of the radiograph shall not exceed the following:

Material Thickness, in. (mm)	*Ug* Maximum, in. (mm)
Under 2 (50.8)	0.020 (0.51)
2 through 3 (50.8–76.2)	0.030 (0.76)
Over 3 through 4 (76.2–101.6)	0.040 (1.02)
Greater than 4 (101.6)	0.070 (1.78)

NOTE: Material thickness is the thickness on which the IQI is based.

T-286 Evaluation by Manufacturer 01

The Manufacturer shall be responsible for the review, interpretation, evaluation, and acceptance of the completed radiographs to assure compliance with the requirements of Article 2 and the referencing Code Section. As an aid to the review and evaluation, the radiographic technique documentation required by T-291 shall be completed prior to the evaluation. The radiograph review form required by T-292 shall be completed during the evaluation. The radiographic technique details and the radiograph review form documentation shall accompany the radiographs. Acceptance shall be completed prior to presentation of the radiographs and accompanying documentation to the Inspector.

T-290 DOCUMENTATION

T-291 Radiographic Technique Documentation Details

The Manufacturer shall prepare and document the radiographic technique details. As a minumum, the following information shall be provided.

(a) identification, e.g., job/contract number and heat number (if applicable)

(b) the dimensional map (if used) of marker placement in accordance with T-275.3

(c) number of radiographs (exposures)

(d) X-ray voltage or isotope type used

(e) X-ray machine focal spot size or isotope physical sources size

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

(g) minimum source-to-object distance

(h) maximum distance from source side of object to the film

(i) film manufacturer and Manufacturer's type/designation

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

(k) single- or double-wall exposure

(l) single- or double-wall viewing

T-292 Radiograph Review Form

The Manufacturer shall prepare a radiograph review form. As a minimum, the following information shall be provided.

(a) a listing of each radiograph location

(b) the information required in T-291, by inclusion or by reference

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

(d) identification (name) of the Manufacturer's representative who performed the final acceptance of the radiographs

(e) date of Manufacturer's evaluation

ARTICLE 2
MANDATORY APPENDIX

APPENDIX I — IN-MOTION RADIOGRAPHY

I-210 SCOPE

In-motion radiography is a technique of radiography where the object being radiographed and/or the source of radiation is in motion during the exposure.

In-motion radiography may be performed on weldments when the following modified provisions to those in Article 2 are satisfied.

I-220 GENERAL REQUIREMENTS

I-223 Backscatter Detection Symbol Location

(a) For longitudinal welds the lead symbol "B" shall be attached to the back of each film cassette or at approximately equal intervals not exceeding 36 in. (914 mm) apart, whichever is smaller.

(b) For circumferential welds, the lead symbol "B" shall be attached to the back of the film cassette in each quadrant or spaced no greater than 36 in. (914 mm), whichever is smaller.

I-260 CALIBRATION

I-263 Beam Width

The beam width shall be controlled by a metal diaphragm such as lead. The diaphragm for the energy selected shall be at least 10 half value layers thick.

The beam width as shown in Fig. I-263 shall be determined in accordance with:

$$w = \frac{c\,(F + a)}{b} + a$$

where

w = beam width at the source side of the weld measured in the direction of motion
a = slit width in diaphragm in direction of motion
b = distance from source to the weld side of the diaphragm
c = distance from weld side of the diaphragm to the source side of the weld surface
F = source size: the maximum projected dimension of the radiating source (or focal spot) in the plane perpendicular to the distance $b + c$ from the weld being radiographed

NOTE: Use consistent units.

I-270 EXAMINATION

I-274 Geometric and In-Motion Unsharpness

I-274.1 Geometric Unsharpness. Geometric unsharpness for an in-motion radiograph shall be determined as specified in T-274.

I-274.2 In-Motion Unsharpness. In-motion unsharpness of the radiograph shall be determined in accordance with:

$$U_M = \frac{wd}{D}$$

where

U_M = in-motion unsharpness
w = beam width at the source side of the weld measured in the direction of motion determined as specified in I-263
d = distance from source side of the weld being radiographed to the film
D = distance from source of radiation to weld being radiographed

NOTE: Use consistent units

I-275 Location Markers

Location markers shall be placed adjacent to the weld at the extremity of each film cassette and

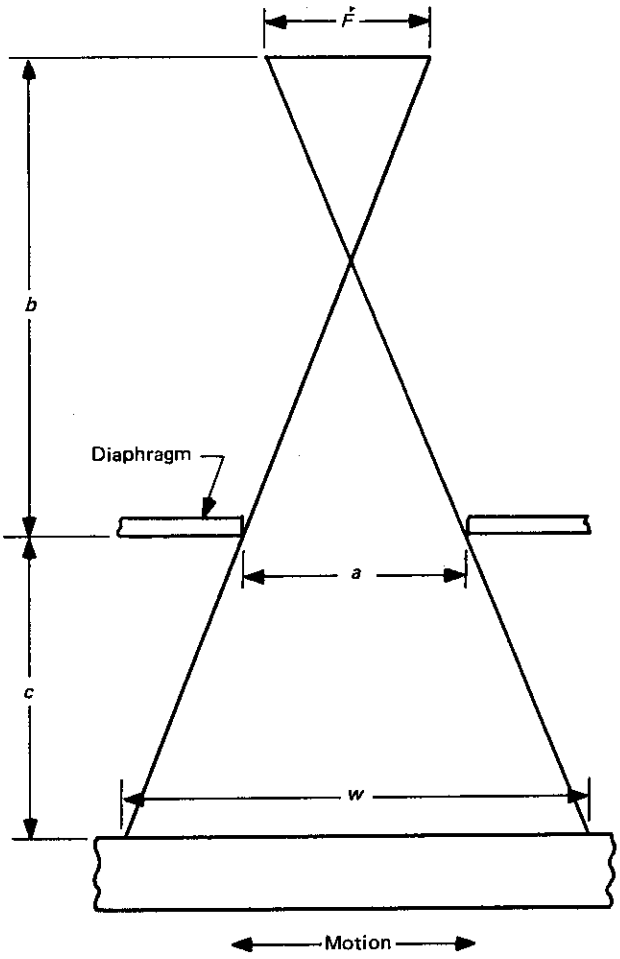


FIG. I-263

also at approximately equal intervals not exceeding 15 in. (381 mm).

I-277 Placement and Number of IQIs

(a) For longitudinal welds, hole IQIs shall be placed adjacent to and on each side of the weld seam, or on the weld seam at the beginning and end of the weld seam, and thereafter at approximately equal intervals not exceeding 36 in. (914 mm) or for each film cassette. Wire IQIs, when used, shall be placed on the weld seam so that the length of the wires is perpendicular to the length of the weld and spaced as indicated above for hole IQIs.

(b) For circumferential welds, hole IQIs shall be placed adjacent to and on each side of the weld seam or on the weld seam in each quadrant or spaced no greater than 36 in. (914 mm) apart, whichever is smaller. Wire IQIs, when used, shall be placed on the weld seam so that the length of the wires is perpendicular to the length of the weld and spaced as indicated above for hole IQIs.

I-279 Repaired Area

When radiography of a repaired area is required, the length of the film used shall be at least equal to the length of the original location marker interval.

I-280 EVALUATION

I-285 Geometric and In-Motion Unsharpness Limitations

Neither the geometric nor in-motion unsharpness of the radiograph shall exceed the values specified in T-285.

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APPENDIX II — REAL-TIME RADIOSCOPIC EXAMINATION

II-210 SCOPE

Real-time radioscopy provides immediate response imaging with the capability to follow motion of the inspected part. This includes radioscopy where the motion of the test object must be limited (commonly referred to as near real-time radioscopy).

Real-time radioscopy may be performed on materials including castings and weldments when the modified provisions to Article 2 as indicated herein are satisfied. SE-1255 shall be used in conjunction with this Appendix as indicated by specific references in appropriate paragraphs. SE-1416 provides additional information that may be used for radioscopic examination of welds.

II-220 GENERAL REQUIREMENTS

This radioscopic methodology may be used for the examination of ferrous or nonferrous materials and weldments.

II-221 Procedure Requirements

A written procedure is required and shall contain as a minimum the following (see SE-1255, 5.2):

(a) material and thickness range
(b) equipment qualifications
(c) test object scan plan
(d) radioscopic parameters
(e) image processing parameters
(f) image display parameters
(g) image archiving

II-230 EQUIPMENT AND MATERIALS

II-231 Radioscopic Examination Record

The radioscopic examination data shall be recorded and stored on videotape, magnetic disk, or optical disk.

II-235 Calibration Block

The calibration block shall be made of the same material type and product form as the test object. The calibration block may be an actual test object or may be fabricated to simulate the test object with known discontinuities.

II-236 Calibrated Line Pair Test Pattern and Step Wedge

The line pair test pattern shall be used without an additional absorber to evaluate the system resolution. The step wedge shall be used to evaluate system contrast sensitivity.

The step wedge must be made of the same material as the test object with steps representing 100%, 99%, 98%, and 97% of both the thickest and the thinnest material sections to be inspected. Additional step thicknesses are permissible.

II-237 Equivalent Performance Level

A system which exhibits a spatial resolution of 3 line pairs per millimeter, a thin section contrast sensitivity of 3%, and a thick section contrast sensitivity of 2% has an equivalent performance level of 3% — 2% — 3 lp/mm.

II-260 CALIBRATION

System calibration shall be performed in the static mode by satisfying the line pair test pattern resolution, step wedge contrast sensitivity, and calibration block discontinuity detection necessary to meet the IQI requirements of T-276.

II-263 System Performance Measurement

Real-time radioscopic system performance parameters shall be determined initially and monitored regularly with the system in operation to assure consistent results.

The system performance shall be monitored at sufficiently scheduled intervals to minimize the probability of time-dependent performance variations. System performance tests require the use of the calibration block, line pair test pattern, and the step wedge.

System performance measurement techniques shall be standardized so that they may be readily duplicated at the specified intervals.

II-264 Measurement With a Calibration Block

The calibration block shall also be placed in the same position as the actual object and manipulated through the same range and speed of motions as will be used for the actual object to demonstrate the system's response in the dynamic mode.

II-270 EXAMINATION

II-278 System Configuration

The radioscopic examination system shall, as a minimum, include the following:

(a) radiation source
(b) manipulation system
(c) detection system
(d) information processing system
(e) image display system
(f) record archiving system

II-280 EVALUATION

II-286 Factors Affecting System Performance

The radioscopic examination system performance quality is determined by the combined performance of the components specified in II-278. (See SE-1255, 6.1.)

When using wire IQIs, the radioscopic examination system may exhibit asymmetrical sensitivity, therefore, the wire diameter axis shall be oriented along the axis of the least sensitivity of the system.

II-290 DOCUMENTATION

II-291 Radioscopic Technique Information

To aid in proper interpretation of the radioscopic examination data, details of the technique used shall accompany the data. As a minimum, the information shall include the items specified in T-291 when applicable, II-221, and the following:

(a) operator identification
(b) system performance test data

II-292 Evaluation by Manufacturer

Prior to being presented to the Inspector for acceptance, the examination data shall be interpreted by the Manufacturer as complying with the referencing Code Section. The Manufacturer shall record the interpretation and disposition of each weldment examined on a radiographic interpretation review form accompanying the radioscopic data.

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MANDATORY APPENDIX

APPENDIX III — DIGITAL IMAGE ACQUISITION, DISPLAY, AND STORAGE FOR RADIOGRAPHY AND RADIOSCOPY

III-210 SCOPE

Digital image acquisition, display, and storage can be applied to radiography and radioscopy. Once the analog image is converted to digital format, the data can be displayed, processed, quantified, stored, retrieved, and converted back to the original analog format, for example, film or video presentation.

Digital imaging of all radiographic and radioscopic examination test results shall be performed in accordance with the modified provisions to Article 2 as indicated herein.

III-220 GENERAL REQUIREMENTS

III-221 Procedure Requirements

A written procedure is required and shall contain, as a minimum, the following system performance parameters:

(a) image digitizing parameters — modulation transfer function (MTF), line pair resolution, contrast sensitivity, and dynamic range;

(b) image display parameters — format, contrast, and magnification;

(c) image processing parameters that are used;

(d) storage — identification, data compression, and media (including precautions to be taken to avoid data loss);

(e) analog output formats.

III-222 Original Image Artifacts

Any artifacts that are identified in the original image shall be noted or annotated on the digital image.

III-230 EQUIPMENT AND MATERIALS

III-231 Digital Image Examination Record

The digital image examination data shall be recorded and stored on video tape, magnetic disk, or optical disk.

III-234 Viewing Considerations

The digital image shall be judged by visual comparison to be equivalent to the image quality of the original image at the time of digitization.

III-236 Calibrated Optical Line Pair Test Pattern and Optical Density Step Wedge

An optical line pair test pattern operating between 0.1 and 4.0 optical density shall be used to evaluate the modulation transfer function (MTF) of the system. The optical density step wedge shall be used to evaluate system contrast sensitivity.

III-250 IMAGE ACQUISITION AND STORAGE

III-255 Area of Interest

Any portion of the image data may be digitized and stored provided the information that is digitized and stored includes the area of interest as defined by the referencing Code Section.

III-258 System Configuration

The system shall, as a minimum, include the following:

(a) digitizing system

(b) display system

(c) image processing system

(d) image storage system

III-260 CALIBRATION

The system shall be calibrated for modulation transfer function (MTF), dynamic range, and contrast sensitivity.

III-263 System Performance Measurement

System performance parameters (as noted in III-221) shall be determined initially and monitored regularly with the system in operation to assure consistent results. The system performance shall be monitored at the beginning and end of each shift to minimize the probability of time-dependent performance variations.

III-280 EVALUATION

III-286 Factors Affecting System Performance

The quality of system performance is determined by the combined performance of the components specified in III-258.

III-287 System-Induced Artifacts

The digital images shall be free of system-induced artifacts in the area of interest that could mask or be confused with the image of any discontinuity in the original analog image.

III-290 DOCUMENTATION

III-291 Digital Imaging Technique Information

To aid in proper interpretation of the digital examination data, details of the technique used shall accompany the data. As a minimum, the information shall include items specified in T-291 and II-221 when applicable, III-221, III-222, and the following:

(a) operator identification

(b) system performance test data

III-292 Evaluation by Manufacturer

Prior to being presented to the Inspector for acceptance, the digital examination data from a radiographic or radioscopic image shall have been interpreted by the Manufacturer as complying with the referencing Code Section.

The digital examination data from a radiograph that has previously been accepted by the Inspector is not required to be submitted to the Inspector for acceptance.

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MANDATORY APPENDIX

APPENDIX IV — INTERPRETATION, EVALUATION, AND DISPOSITION OF RADIOGRAPHIC AND RADIOSCOPIC EXAMINATION TEST RESULTS PRODUCED BY THE DIGITAL IMAGE ACQUISITION AND DISPLAY PROCESS

IV-210 SCOPE

The digital image examination test results produced in accordance with Article 2, Mandatory Appendix II, and Article 2, Mandatory Appendix III, may be interpreted and evaluated for final disposition in accordance with the additional provisions to Article 2 as indicated herein.

The digital information is obtained in series with radiography and in parallel with radioscopy. This data collection process also provides for interpretation, evaluation, and disposition of the examination test results.

IV-220 GENERAL REQUIREMENTS

The digital image shall be interpreted while displayed on a cathode ray tube (soft display). The interpretation may include density and contrast adjustment, quantification, and pixel measurement, including digital or optical density values and linear or area measurement.

The interpretation of a digitized image is dependent upon the same subjective evaluation by a trained interpreter as the interpretation of a radiographic or radioscopic image. Some of the significant parameters considered during interpretation include: area of interest, image quality, IQI image, magnification, density, contrast, discontinuity shape (rounded, linear, irregular), and artifact identification.

The digital image interpretation of the radiographic and radioscopic examination test results shall be performed in accordance with the modified provisions to Article 2 as indicated herein.

After the interpretation has been completed, the interpretation data and the digital image, which shall include the unprocessed original full image and the digitally processed image, shall be recorded and stored on video tape, magnetic tape, or optical disk.

IV-221 Procedure Requirements

A written procedure is required and shall contain, as a minimum, the following system performance parameters:

(a) image digitizing parameters — modulation transfer function (MTF), line pair resolution, contrast sensitivity, dynamic range, and pixel size;

(b) image display parameters — monitor size including display pixel size, luminosity, format, contrast, and magnification;

(c) signal processing parameters — including density shift, contrast stretch, log transform, and any other techniques that do not mathematically alter the original digital data, e.g., linear and area measurement, pixel sizing, and value determination;

(d) storage — identification, data compression, and media (including precautions to be taken to avoid data loss). The non-erasable optical media should be used for archival applications. This is frequently called the WORM (Write Once Read Many) technology. When storage is accomplished on magnetic or erasable optical media, then procedures must be included that show trackable safeguards to prevent data tampering and guarantee data integrity.

IV-222 Original Image Artifacts

Any artifacts that are identified shall be noted or annotated on the digital image.

IV-230 EQUIPMENT AND MATERIALS

IV-231 Digital Image Examination Record

The digital image examination data shall be recorded and stored on video tape, magnetic disk, or optical disk.

IV-234 Viewing Considerations

The digital image shall be evaluated using appropriate monitor luminosity, display techniques, and room lighting to insure proper visualization of detail.

IV-236 Calibrated Optical Line Pair Test Pattern and Optical Density Step Wedge

An optical line pair test pattern operating between 0.1 and 4.0 optical density shall be used to evaluate the modulation transfer function (MTF) of the system. High spatial resolution with 14 line-pairs per millimeter (lp/mm) translates to a pixel size of 0.0014 in. (0.035 mm). Lesser spatial resolution with 2 lp/mm can be accomplished with a pixel size of 0.012 in. (0.3 mm). The optical density step wedge shall be used to evaluate system contrast sensitivity. Alternatively, a contrast sensitivity gage (step wedge block) in accordance with SE-1647 may be used.

IV-250 IMAGE ACQUISITION, STORAGE, AND INTERPRETATION

IV-255 Area of Interest

The evaluation of the digital image shall include all areas of the image defined as the area of interest by the referencing Code Section.

IV-258 System Configuration

The system shall, as a minimum, include:
(a) digital image acquisition system
(b) display system
(c) image processing system
(d) image storage system

IV-260 CALIBRATION

The system shall be calibrated for modulation transfer function (MTF), dynamic range, and contrast sensitivity. The electrical performance of the hardware and the quality of the digital image shall be measured and recorded.

IV-263 System Performance Measurement

System performance parameters (as noted in IV-221) shall be determined initially and monitored regularly with the system in operation to assure consistent results. The system performance shall be monitored at the beginning and end of each shift to minimize the probability of time-dependent performance variations.

IV-280 EVALUATION

IV-286 Factors Affecting System Performance

The quality of system performance is determined by the combined performance of the components specified in IV-258.

IV-287 System-Induced Artifacts

The digital images shall be free of system-induced artifacts in the area of interest that could mask or be confused with the image of any discontinuity.

IV-290 DOCUMENTATION

IV-291 Digital Imaging Technique Information

To aid in proper interpretation of the digital examination data, details of the technique used shall accompany the data. As a minimum, the information shall include items specified in T-291 and II-221 when applicable, III-221, III-222, IV-221, IV-222, and the following:
(a) operator identification
(b) system performance test data
(c) calibration test data

IV-292 Evaluation by Manufacturer

Prior to being presented to the Inspector for acceptance, the digital examination data from a radiographic or radioscopic image shall have been interpreted by the Manufacturer as complying with the referencing Code Section.

The digitized examination data that has previously been accepted by the Inspector is not required to be submitted to the Inspector for acceptance.

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MANDATORY APPENDIX

APPENDIX V — GLOSSARY OF TERMS FOR RADIOGRAPHIC EXAMINATION

V-210 SCOPE

This Mandatory Appendix is used for the purpose of establishing standard terms and definitions of terms relating to radiographic examination.

V-220 GENERAL REQUIREMENTS

(a) The Standard Terminology for Nondestructive Examinations (ASTM E 1316) has been adopted by the Committee as SE-1316.

(b) SE-1316 Section 7 provides the definitions of terms listed in V-230(a).

(c) For general terms, such as *Indication, Flaw, Discontinuity, Evaluation*, etc., refer to Article 1, Mandatory Appendix I.

(d) Paragraph V-230(b) provides a list of terms and definitions that are Code specific. Paragraph V-230(c) provides a list of terms and definitions that are specific to Section V, Article 2, Appendix VI.

V-230 REQUIREMENTS

(a) The following SE-1316 terms are used in conjunction with this Article: *composite viewing, contrast sensitivity, contrast stretch, densitometer, density* (film), *digital image acquisition system, erasable optical medium, focal spot, intensifying screen, IQI sensitivity, line pair test pattern, location marker, luminosity, magnetic storage medium, optical density, pixel, pixel size, screen, source, step wedge, system-induced artifacts, transmission densitometer,* and *transmitted film density.*

(b) The following Code terms are used in conjunction with this Article.

annotate — to provide an explanatory note on the digital image

calibrated line pair test pattern — see *optical line pair test pattern*

calibrated step wedge film — a radiograph with discrete density steps, which is traceable to a national standard

cathode ray tube (soft display) — a device that produces an image by exciting a fluorescent substance with a magnetically guided beam

data compression — a reduction in the size of a digital data set to a smaller data set

density shift — a function that raises or lowers all density/greyscale values equally such that contrast is maintained within the data set

designated wire — the specific wire that must be discernible in the radiographic image of a wire-type image quality indicator

diaphragm — an aperture (opening) in a radiation opaque material that limits the usable beam size of a radiation source

digital — of, or relating to, data in the form of numerical digits (e.g., binary)

digitizing — the act of converting an analog measurement of a quantity to a digital value

display pixel size — the length and width dimensions of the smallest element of a displayed image

display system — a system that can display an array of pixels on a screen (CRT)

dynamic range — the range of operation of a device between its upper and lower limit; this range can be given as a ratio (e.g., 100:1) of the maximum signal level capability to its noise level, the number of measurable steps between the upper and lower limits, the number of bits needed to record this number of measurable steps, or the maximum and minimum measurable values

equivalent IQI sensitivity — that thickness of hole-type IQI, expressed as a percentage of the part thickness, in which 2*T* hole would be visible under the same radiographic conditions

essential hole — the specific hole that must be discernible in the radiographic image of a hole-type IQI

image processing system — a system that uses mathematical algorithms to manipulate digital image data

image quality indicator

hole type — a rectangular plaque, made of material radiographically similar to that of the object being radiographed, with small diameter holes (1*T*, 2*T*, and 4*T*) used to check the image quality of the radiograph

wire type — a set of small diameter wires, made of material radiographically similar to that of the object being radiographed, used to check the image quality of the radiograph

image storage system — a system that can store digital image data for future use

IQI — image quality indicator

line pair resolution — the number of line pairs per unit distance that are detectable in an image

log transform — a function that applies a logarithmic mapping to all density/greyscale values in an image; this operation is often performed when the resulting distribution is normal, or if the resulting relationship with another variable is linear

modulation transfer function (MTF) — a measure of spatial resolution as a function of contrast; a plot of these variables (spatial resolution and contrast) yields a curve representing the frequency response of the system

national standard step tablet — an x-ray film with discrete density steps produced and certified by a nationally recognized standardizing body

nonerasable optical media (optical disk) — a storage media that prevents the erasure or alteration of digital data after it is stored

optical density step wedge — a radiographic image of a mechanical step wedge with precise thickness increments and may be used to correlate optical film density to the thickness of material, also known as a step tablet

penetrameter — no longer used in Article 2; see *image quality indicator*

quantification — the act of determining or expressing a quantity (i.e., giving a numerical value to a measurement of something)

radiographic examination — a nondestructive method for detecting discontinuities in materials and components using penetrating radiation to produce an image on a recording medium

sensitivity — the smallest discernible detail and/or contrast change (e.g., IQI hole or wire) in a radiographic image

shim — a material, radiographically similar to the object being radiographed, that is placed between a hole-type IQI and the object in order to reduce the radiographic density through the image of the hole-type IQI

source side — that surface of the area of interest being radiographed for evaluation nearest the source of radiation

WORM (write once read many) — a term relating to a type of digital storage media where the data can be stored only once but accessed (nondestructively) many times

(c) The following Code terms are used in conjunction with Article 2, Appendix VI:

contrast sensitivity — the size of the smallest detectable change in optical density

dynamic range — the extent of measurable optical density obtained in a single scan

image — the digital representation of a target on the reference film used to evaluate both the digitization and display aspects of a film digitization system

reference film — a single industrial radiographic film that encompasses the targets necessary for the evaluation and quantification of the performance characteristics of a film digitization system

spatial linearity — the accuracy to which a digitization system reproduces the physical dimensions of information on the original film [both in the horizontal (along a single scan line) and vertical (from one scan line to another) directions]

spatial resolution — the size of the smallest detectable element of the digitized image

step wedge calibration film — a processed film with discrete density steps that have been verified by comparison with a national standard step tablet

step wedge comparison film — a processed film with discrete density steps that have been verified by use of a calibrated densitometer, which is used to determine if production radiographs meet density limits

target — a physical pattern on a reference film used to evaluate the performance of a film digitization system

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MANDATORY APPENDIX

APPENDIX VI — DIGITAL IMAGE ACQUISITION, DISPLAY, INTERPRETATION, AND STORAGE OF RADIOGRAPHS FOR NUCLEAR APPLICATIONS

VI-210 SCOPE

Digital imaging process and technology provide the ability to digitize and store the detailed information contained in the radiograph (analog image), thus eliminating the need to maintain and store radiographs for permanent record.

VI-220 GENERAL REQUIREMENTS

VI-221 Supplemental Requirements

VI-221.1 Additional Information. Article 2, Mandatory Appendices III and IV, contain additional information that shall be used to supplement the requirements of this Appendix. These supplemental requirements shall be documented in the written procedure required by this Appendix.

VI-221.2 Reference Film. Supplement A contains requirements for the manufacture of the reference film.

VI-222 Written Procedure

A written procedure is required. The written procedure shall be the responsibility of the owner of the radiographs and shall be demonstrated to the satisfaction of the Authorized Nuclear Inspector (ANI). When other enforcement or regulatory agencies are involved, the agency approval is required by formal agreement. The written procedure shall include, as a minimum, the following essential variables:

VI-222.1 Digitizing System Description

(a) manufacturer and model no. of digitizing system;

(b) physical size of the usable area of the image monitor;

(c) film size capacity of the scanning device;

(d) spot size(s) of the film scanning system;

(e) image display pixel size as defined by the vertical/horizontal resolution limits of the monitor;

(f) luminance of the video display; and

(g) data storage medium.

VI-222.2 Digitizing Technique

(a) digitizer spot size (in microns) to be used (see VI-232);

(b) loss-less data compression technique, if used;

(c) method of image capture verification;

(d) image processing operations;

(e) time period for system verification (see VI-264);

(f) spatial resolution used (see VI-241);

(g) contrast sensitivity (density range obtained) (see VI-242);

(h) dynamic range used (see VI-243); and

(i) spatial linearity of the system (see VI-244).

VI-223 Personnel Requirements

Personnel shall be qualified as follows:

(a) Level II and Level III Personnel. Level II and Level III personnel shall be qualified in the radiographic method as required by Article 1. In addition, the employer's written practice shall describe the specific training and practical experience of Level II and Level III personnel involved in the application of the digital imaging process and the interpretation of results and acceptance of system performance. Training and experience shall be documented in the individual's certification records.

(b) As a minimum, Level II and III individuals shall have 40 hours of training and 1 month of practical experience in the digital imaging process technique.

(c) Other Personnel. Personnel with limited qualifications performing operations other than those required for the Level II or Level III shall be qualified in accordance with Article 1. Each individual shall have specified training and practical experience in the operations to be performed.