

Applying Volumetric NDE in ASME Section VIII, Division 1

Volumetric nondestructive examinations detect hidden flaws in welds and materials. The volumetric examination methods currently accepted for use in ASME Section VIII, Division 1 are radiographic (RT) and ultrasonic (UT) examination. Each examination method has multiple techniques. Construction codes specify **when** to perform these examinations and their acceptance criteria, and then reference the detailed technical requirements of Section V for **how** to apply these examinations. For the purposes of this discussion, we will focus on the application of these examination methods under the rules of ASME Section VIII, Division 1.

Paragraph **UW-11** describes when volumetric examinations are required, where it states in **UW-11(a)(1)**:

UW-11(a): Full Radiography. The following welded joints shall be examined radiographically for their full length in the manner prescribed in UW-51:

(1) all butt welds in the shell and heads of vessels used to contain lethal substances [see UW-2(a)];

This clearly requires full radiographic examination of all longitudinal (Category A) and circumferential (Category B) butt welds in the shells and heads of pressure vessel in lethal service as defined by **UW-2(a)**. Paragraph **UW-11(a)(2)** describes another set of conditions under which radiographic examinations are required, where it states:

(2) all butt welds in the shell and heads of vessels in which the nominal thickness [see (g) below] at the welded joint exceeds 1-1/2 in. (38 mm), or exceeds the lesser thicknesses prescribed in UCS-57, UNF-57, UHA-33, UCL-35, or UCL-36 for the materials covered therein, or as otherwise prescribed in UHT-57, ULW-51, ULW-52(d), ULW-54, or ULT-57;

In **UW-11(g)** it states:

UW-11(g): For radiographic and ultrasonic examination of butt welds, the definition of nominal thickness at the welded joint under consideration shall be the nominal thickness of the thinner of the two parts joined. Nominal thickness is defined in Mandatory Appendix 3, 3-2.

Full radiography as described above is required when:

1. the nominal thickness of the thinner of the two parts joined exceeds 1-1/2 in. (38 mm), or
2. when lesser thicknesses given in the cited paragraphs are exceeded.

Unfired steam boilers [defined in U-1(g)(1)] also have radiographic examination requirements, which are described in UW-11(a)(3) as follows:

(3) all butt welds in the shell and heads of unfired steam boilers having design pressures

(-a) exceeding 50 psi (350 kPa) [see UW-2(c)];

(-b) not exceeding 50 psi (350 kPa) [see UW-2(c)] but with nominal thickness at the welded joint exceeding the thickness specified in (2) above;

These requirements are similar to lethal service for the conditions stated in UW-11(a)(3)(-a), but under the rules of UW-11(a)(3)(-b) the requirements revert to the conditions described in UW-11(a)(2) when the design pressure does not exceed 50 psi (350 kPa).

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A set of conditions under which a broad exemption from radiographic examination of certain welds is given in paragraph UW-11(a)(4), which states:

(4) all butt welds in nozzles, communicating chambers, etc., with the nominal thickness at the welded joint that exceeds the thickness in (2) above or attached to the shell or heads of vessels under (1) or (3) above that are required to be fully radiographed; however, except as required by UHT-57(a), Category B and C butt welds in nozzles and communicating chambers that neither exceed NPS 10 (DN 250) nor 11/8 in. (29 mm) wall thickness do not require any radiographic examination;

This is an extremely long run-on sentence, so let's break it down into simpler terms. Radiographic examinations of butt welds which are normally required to be examined as described in **UW-11(a)(1)** (lethal service), **(2)** (thickness requirements), or **(3)** (unfired steam boilers) are **NOT** required for:

1. Category B or C butt welds in nozzles or communicating chambers,
2. when they exceed neither NPS 10 (an OD of 10.75 in.) (DN 250) nor a thickness of 1-1/8 in. (29 mm).

However, this exemption does not apply to Type 1 full penetration butt welds in Part UHA materials of any diameter or thickness.

In addition to the full radiographic examination requirements discussed above, spot radiographic examinations shall also be applied under the rules of **UW-52** when the conditions described in **UW-11(a)(5)** apply:

(5) all Category A and D butt welds in the shell and heads of vessels where the design of the joint or part is based on a joint efficiency permitted by UW-12(a), in which case:

(-a) Category A and B welds connecting the shell or heads of vessels shall be of Type No. (1) or Type No. (2) of Table UW-12;

(-b) Category B or C butt welds [but not including those in nozzles and communicating chambers except as required in (4) above] which intersect the Category A butt welds in the shell or heads of vessels or connect seamless vessel shell or heads shall, as a minimum, meet the requirements for spot radiography in accordance with UW-52.

Here we have another long string of words linking these requirements to another paragraph that needs some explanation. In the first phrase of paragraph **UW-12(a)** it states that for butt welds in shells or heads of Category A (long seams and hemispherical head attachment welds) and Category D (nozzle or communicating chamber attachment welds) to be assigned a joint efficiency from column (a) of **Table UW-12**, they must:

1. be fully radiographed, and
2. the spot radiography requirements of **UW-52** must be met for any of the following welds which intersect these welds.
 - a. **UW-11(a)(5)(-a)**: Category A (hemispherical head attachment) and Category B (other dished heads, and shell section to shell section attachment) butt welds which shall be limited to Type 1 (full penetration butt welds) or Type 2 (full penetration butt welds with backing strips); and
 - b. **UW-11(a)(5)(-b)**: Category B or Category C (flange to nozzle or shell, and flat head to shell) butt welds that are not exempt from radiographic examination due to their diameter or thickness by the provisions of **UW-11(a)(4)**.

The second phrase of **UW-12(a)** states that when the spot radiography requirements of **UW-11(a)(5)(b)** are **NOT** met, that a joint efficiency found in column (b) of **Table UW-12** must be applied. Those fully radiographed butt welds do not automatically receive the higher joint efficiency of column (a) unless the addition spot radiography is applied. The last sentence of **UW-11(a)(5)(b)** is a significant restriction that needs to be recognized, though:

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Spot radiographs required by this paragraph shall not be used to satisfy the spot radiography rules as applied to any other weld increment.

This means a spot radiograph is only acceptable for satisfying a single requirement, and cannot serve multiple requirements. This sentence primarily applies to the spot radiography requirements of **UW-12(d)** for welds joining seamless shell sections and seamless heads. A separate document addressing weld joint efficiencies describes these rules in detail. Full radiography is also required for the following welds:

(6) all butt welds joined by electrogas welding with any single pass greater than 1-1/2 in. (38 mm) and all butt welds joined by electroslag welding;

The examination requirements of **UW-11(a)(6)** are further expanded in **UW-11(d)**, where it states:

UW-11(d): Electrogas welds in ferritic materials with any single pass greater than 1-1/2 in. (38 mm) and electroslag welds in ferritic materials shall be ultrasonically examined throughout their entire length in accordance with the requirements of [Mandatory Appendix 12](#). This ultrasonic examination shall be done following the grain refining (austenitizing) heat treatment or postweld heat treatment.

Take note that these expanded requirements invoking ultrasonic examination of these welds in addition to the required radiographic examination includes some subtle but significant considerations that may not be obvious:

1. There is no maximum thickness limit above which the rule applies to electroslag welds, meaning it applies to all thicknesses; and
2. The rules invoke the **Appendix 12** ultrasonic examination method, which is the shear wave or distance-amplitude type of examination technique. If a Manufacturer wants to apply ultrasonic examinations in lieu of radiographic examination (discussed a little later) using the examination technique specified for that option [see **UW-51(a)(4)**], that technique could be used alone instead of applying both RT and UT.

All Category A welds in tubesheets must be fully radiographed under the rules of **UW-11(a)(7)**, but the use of a Type 1 weld joint from **Table UW-12** is also required:

(7) all Category A welds in a tubesheet shall be of Type (1) of [Table UW-12](#);

The rules of **UW-11(a)(4)** that exempt butt welds in nozzles and communicating chambers from radiographic examination due to their outside diameter and thickness are intended to override any other requirements for examinations that may be found in the various Parts of **Subsection C**. This is clearly stated in **UW-11(a)(8)**:

(8) exemptions from radiographic examination for certain welds in nozzles and communicating chambers as described in (2), (4), and (5) above take precedence over the radiographic requirements of [Subsection C](#) of this Division.

Spot radiography may be applied in accordance with **UW-52** when full radiography is not required under the rules of **UW-11(b)**, and allows exemption from radiographic examination as discussed in **UW-11(a)(4)** for nozzles and communicating chambers based upon their diameter and thickness when spot radiography is specified for the entire vessel.

UW-11(b): Spot Radiography. Except when spot radiography is required for Category B or C butt welds by (a)(5)(-b) above, butt-welded joints made in accordance with Type No. (1) or (2) of [Table UW-12](#) which are not required to be fully radiographed by (a) above, may be examined by spot radiography. Spot radiography shall

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be in accordance with UW-52. If spot radiography is specified for the entire vessel, radiographic examination is not required of Category B and C butt welds in nozzles and communicating chambers that exceed neither NPS 10 (DN 250) nor 1-1/8 in. (29 mm) wall thickness.

This option simply improves the joint efficiency as described in UW-12(b):

UW-12(b): *A value of E not greater than that given in column (b) of Table UW-12 shall be used in the design calculations for spot radiographed butt-welded joints [see UW-11(b)].*

Then there is the option of applying no radiographic examination at all, as described in UW-11(c) and UW-12(c):

UW-11(c): No Radiography. *Except as required in (a) above, no radiographic examination of welded joints is required when the vessel or vessel part is designed for external pressure only, or when the joint design complies with UW-12(c).*

UW-12(c): *A value of E not greater than that given in column (c) of Table UW-12 shall be used in the design calculations for welded joints that are neither fully radiographed nor spot radiographed [see UW-11(c)].*

Welds made with the Electron Beam or Laser Beam welding processes require ultrasonic examination and surface examination in addition to any required radiographic examinations described in UW-11(a) and (b).

UW-11(e): *In addition to the requirements in (a) and (b) above, all welds made by the electron beam or laser beam process shall be ultrasonically examined for their entire length in accordance with the requirements of Mandatory Appendix 12. Ultrasonic examination may be waived if the following conditions are met:*

- (1) The nominal thickness at the welded joint does not exceed 1/4 in. (6 mm).*
- (2) For ferromagnetic materials, the welds are either examined by the magnetic particle examination technique in accordance with Mandatory Appendix 6 or examined by the liquid penetrant examination technique in accordance with Mandatory Appendix 8.*
- (3) For nonferromagnetic materials, the welds are examined by the liquid penetrant examination technique in accordance with Mandatory Appendix 8.*

This rule also includes some subtle but significant considerations that may not be obvious:

1. There is a minimum thickness of 1/4 in. (6 mm) when applying ultrasonic examinations, but there is no maximum thickness above which the rule applies, meaning it applies to all thicknesses; and
2. The rules invoke the **Appendix 12** ultrasonic examination method, which is the shear wave or distance-amplitude type of examination technique. If a Manufacturer wants to apply ultrasonic examinations in lieu of radiographic examination (discussed a little later) using the examination technique specified for that option [see UW-51(a)(4)], that technique could be used alone instead of applying both RT and UT.

Welds made by the inertia and continuous drive friction welding processes also require ultrasonic examination in addition to any required radiographic examinations described in UW-11(a) and (b).

UW-11(f): *When radiography is required for a welded joint in accordance with (a) and (b) above, and the weld is made by the inertia and continuous drive friction welding processes, the welded joints shall also be ultrasonically examined for their entire length in accordance with Mandatory Appendix 12.*

The code words do not specifically state a minimum thickness of 1/4 in. (6 mm). However, the generally recognized minimum acceptable thickness for any ultrasonic examination is 1/4 in. (6 mm).

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Now that we understand **when** radiographic examinations are required, we need to look at **how** they are applied. Paragraph **UW-51** contains the rules for applying full radiography, and specifies a number of details starting in **UW-51(a)** where it states:

UW-51(a): All welded joints to be radiographed shall be examined in accordance with Section V, Article 2, except as specified below.

Section V, Article 2 describes the technical details for applying radiographic examination methods. This Article includes several **Mandatory Appendices** describing additional technical details for using the various radiographic examination techniques. **Section V, Article 2**, paragraph **T-210** requires compliance with **Article 1**, which describes rules for examination personnel qualification. **Section V, Article 1** invokes rules for examination personnel qualifications.

T-120: The radiographic method described in this Article for examination of materials including castings and welds shall be used together with Article 1, General Requirements.

Section V, Article 2, paragraph **T-221.1** requires performing radiographic examinations in accordance with a written procedure.

T-221.1: Written Procedure. Radiographic examination shall be performed in accordance with a written procedure.

Section V, Article 2, paragraph **T-274.1** requires that the geometric unsharpness of a radiograph be determined, with the resulting value not to exceed the maximum values given in **T-274.2**.

T-274.1 Geometric Unsharpness Determination. Geometric unsharpness of the radiograph shall be determined in accordance with

It is important to remember that since Section V is a reference code and only applies to the extent to which the construction code references it. The construction code also has the ability to take exception to, and apply alternatives to, any of the rules of a reference code. Paragraph **UW-54** specifically references the subparagraphs in **T-120** invoked by Section VIII, Division 1 rather than referencing the entire Article.

“Personnel performing nondestructive examinations in accordance with UW-51, UW-52, or UW-53 shall be qualified and certified in accordance with the requirements of Section V, Article 1, T-120(e), T-120(f), T-120(g), T-120(i), T-120(j), or T-120(k), as applicable.”

We do not address the detailed requirements for the qualification and certification of examination personnel in this document. They are topics for separate discussion. Additional details of radiographic examination requirements in the subparagraphs of UW-51(a) are as follows:

UW-51(a)(1): A complete set of radiographic images and examination records, as described in Section V, Article 2, for each vessel or vessel part shall be retained by the Manufacturer, as follows:

- (-a) radiographic images until the Manufacturer’s Data Report has been signed by the Inspector**
- (-b) examination records as required by this Division (see [Mandatory Appendix 10, 10-13](#))**

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Mandatory Appendix 10, paragraph **10-13(b)(8)** requires retention of the NDE Interpretation Report for a minimum of three years.

UW-51(a)(2): Demonstration of acceptable density on radiographic films and the ability to see the prescribed image quality indicator (IQI) image and the specified hole or the designated wire of a wire IQI shall be considered satisfactory evidence of compliance with Section V, Article 2.

Though not specifically stated in this paragraph, this means that a written procedure is **NOT** required when performing radiographic examinations under Section VIII, Division 2 rules. **UW-51(a)(3)** also states that geometric unsharpness values are only to be used as a guide for film based radiography.

UW-51(a)(3): The requirements of Section V, Article 2, T-274.2, are to be used only as a guide for film-based radiography.

An option for the Manufacturer to apply ultrasonic examinations in lieu of radiographic examinations is provided in paragraph **UW-51(a)(3)**:

UW-51(a)(4): As an alternative to the radiographic examination requirements above, all welds in which the thinner of the members joined is 1/4 in. (6 mm) thick and greater may be examined using the ultrasonic (UT) method specified by [UW-53\(b\)](#) or [UW-53\(c\)](#).

(A discussion of **UW-53(b)** and **UW-53(c)** will be included later.)

Paragraph **UW-51(b)** describes the radiographic examination acceptance criteria.

(b) Indications revealed by radiography within a weld that exceed the following criteria are unacceptable and therefore are defects. Defects shall be repaired as provided in [UW-38](#), and the repaired area shall be reexamined. In lieu of reexamination by radiography, the repaired weld may be ultrasonically examined in accordance with [Mandatory Appendix 12](#) at the Manufacturer's option. For material thicknesses in excess of 1 in. (25 mm), the concurrence of the user shall be obtained.

This ultrasonic examination shall be noted under Remarks on the Manufacturer's Data Report Form:

(1) any indication characterized as a crack or zone of incomplete fusion or penetration;

(2) any other elongated indication on the radiograph which has length greater than:

(-a) 1/4 in. (6 mm) for t up to 3/4 in. (19 mm)

(-b) 1/3t for t from 3/4 in. (19 mm) to 2-1/4 in. (57 mm)

(-c) 3/4 in. (19 mm) for t over 2-1/4 in. (57 mm)

Where:

t = the thickness of the weld excluding any allowable reinforcement.

For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t.

(3) any group of aligned indications that have an aggregate length greater than t in a length of 12t, except when the distance between the successive imperfections exceeds 6L where L is the length of the longest imperfection in the group;

(4) rounded indications in excess of that specified by the acceptance standards given in [Mandatory Appendix 4](#).

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This is a “workmanship” acceptance criteria, as opposed to a “fracture mechanics” acceptance criteria. Fracture mechanics acceptance criteria applies to the more advanced ultrasonic examination techniques that are capable of accurately determining the flaw size, orientation, location and depth. The acceptance criteria for rounded indications in Appendix 4 has dimensional limits, as well as considering their grouping. The grouping criteria requires a comparative judgment between the film image indications as compared to the graphic examples shown in the code. It is worth mentioning that aligned indications are often the result of a lack of sidewall fusion or slag inclusions. These indications should be evaluated carefully along with considering their dimensional acceptance criteria.

Paragraph **UW-52** describes the requirements for spot radiography examinations. It starts with an explanatory Note describing the intent of spot radiography, and its limitations:

UW-52 SPOT EXAMINATION OF WELDED JOINTS

***NOTE:** Spot radiographing of a welded joint is recognized as an effective inspection tool. The spot radiography rules are also considered to be an aid to quality control. Spot radiographs made directly after a welder or an operator has completed a unit of weld proves that the work is or is not being done in accordance with a satisfactory procedure. If the work is unsatisfactory, corrective steps can then be taken to improve the welding in the subsequent units, which unquestionably will improve the weld quality. Spot radiography in accordance with these rules will not ensure a fabrication product of predetermined quality level throughout. It must be realized that an accepted vessel under these spot radiography rules may still contain defects which might be disclosed on further examination. If all radiographically disclosed weld defects must be eliminated from a vessel, then 100% radiography must be employed.*

(a) Butt-welded joints that are to be spot radiographed shall be examined locally as provided herein.

(b) Minimum Extent of Spot Radiographic Examination

(1) One spot shall be examined on each vessel for each 50 ft (15 m) increment of weld or fraction thereof for which a joint efficiency from column (b) of [Table UW-12](#) is selected. However, for identical vessels or parts, each with less than 50 ft (15 m) of weld for which a joint efficiency from column (b) of [Table UW-12](#) is selected, 50 ft (15 m) increments of weld may be represented by one spot examination.

(2) For each increment of weld to be examined, a sufficient number of spot radiographs shall be taken to examine the welding of each welder or welding operator. Under conditions where two or more welders or welding operators make weld layers in a joint, or on the two sides of a double-welded butt joint, one spot may represent the work of all welders or welding operators.

(3) Each spot examination shall be made as soon as practicable after completion of the increment of weld to be examined. The location of the spot shall be chosen by the Inspector after completion of the increment of welding to be examined, except that when the Inspector has been notified in advance and cannot be present or otherwise make the selection, the Manufacturer may exercise his own judgment in selecting the spots.

(4) Radiographs required at specific locations to satisfy the rules of other paragraphs, such as [UW-9\(d\)](#), [UW-11\(a\)\(5\)\(-b\)](#), and [UW-14\(b\)](#), shall not be used to satisfy the requirements for spot radiography.

It is important to emphasize that:

1. selecting the location of the spot to be examined, and performance of the spot radiographic examination, shall be performed after completing the increment the examination is intended to evaluate, and
2. we once again see that this spot serves a singular purpose, and cannot be used to satisfy any other spot radiography requirements mentioned by the cited reference paragraphs.

Paragraph **UW-51(c)** describes the acceptance criteria for spot radiography:

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(c) Standards for Spot Radiographic Examination. Spot examination by radiography shall be made in accordance with the technique prescribed in [UW-51\(a\)](#). The minimum length of spot radiograph shall be 6 in. (150 mm). Spot radiographs may be retained or be discarded by the Manufacturer after acceptance of the vessel by the Inspector. The acceptability of welds examined by spot radiography shall be judged by the following standards:

(1) Welds in which indications are characterized as cracks or zones of incomplete fusion or penetration shall be unacceptable.

(2) Welds having indications characterized as slag inclusions or cavities are unacceptable when the indication length exceeds $2/3t$, where t is defined as shown in [UW-51\(b\)\(2\)](#). For all thicknesses, indications less than 1/4 in. (6 mm) are acceptable, and indications greater than 3/4 in. (19 mm) are unacceptable. Multiple aligned indications meeting these acceptance criteria are acceptable when the sum of their longest dimensions does not exceed t within a length of $6t$ (or proportionally for radiographs shorter than $6t$), and when the longest length L for each indication is separated by a distance not less than $3L$ from adjacent indications.

(3) Rounded indications are not a factor in the acceptability of welds not required to be fully radiographed.

The general acceptability of rounded indications with no set criteria of acceptance in spot radiography causes some concern and confusion. Even when the dimensional requirements are satisfied, aligned indications can be a characteristic of lack of sidewall fusion or slag inclusions. These indications should be evaluated carefully along with considering their dimensional acceptance criteria. Paragraph [UW-52\(d\)](#) includes rules for handling spot radiographs that are unacceptable:

(d) Evaluation and Retests

(1) When a spot, radiographed as required in [\(b\)\(1\)](#) or [\(b\)\(2\)](#) above, is acceptable in accordance with [\(c\)\(1\)](#) and [\(c\)\(2\)](#) above, the entire weld increment represented by this radiograph is acceptable.

(2) When a spot, radiographed as required in [\(b\)\(1\)](#) or [\(b\)\(2\)](#) above, has been examined and the radiograph discloses welding which does not comply with the minimum quality requirements of [\(c\)\(1\)](#) or [\(c\)\(2\)](#) above, two additional spots shall be radiographically examined in the same weld increment at locations away from the original spot. The locations of these additional spots shall be determined by the Inspector or fabricator as provided for the original spot examination in [\(b\)\(3\)](#) above.

(-a) If the two additional spots examined show welding which meets the minimum quality requirements of [\(c\)\(1\)](#) and [\(c\)\(2\)](#) above, the entire weld increment represented by the three radiographs is acceptable provided the defects disclosed by the first of the three radiographs are removed and the area repaired by welding. The weld repaired area shall be radiographically examined in accordance with the foregoing requirements of [UW-52](#).

(-b) If either of the two additional spots examined shows welding which does not comply with the minimum quality requirements of [\(c\)\(1\)](#) or [\(c\)\(2\)](#) above, the entire increment of weld represented shall be rejected. The entire rejected weld shall be removed and the joint shall be rewelded or, at the fabricator's option, the entire increment of weld represented shall be completely radiographed and only defects need be corrected.

(-c) Repair welding shall be performed using a qualified procedure and in a manner acceptable to the Inspector. The rewelded joint, or the weld repaired areas, shall be spot radiographically examined at one location in accordance with the foregoing requirements of [UW-52](#).

Most Manufacturers prefer to fully examine the entire increment and repair those areas found unacceptable, as it saves time and reduces costs.

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Paragraph **UW-53** describes the requirements for ultrasonic examination:

UW-53 ULTRASONIC EXAMINATION OF WELDED JOINTS

(a) Ultrasonic examination of welded joints whose joint efficiency is not determined by ultrasonic examinations may be performed and evaluated in accordance with [Mandatory Appendix 12](#).

The **Appendix 12** rules referenced in **UW-53(a)** apply the “shear wave” or “pulse echo distance-amplitude” technique for ultrasonic examination. It is an early technique that is being rapidly replaced by the Phased Array (PAUT) and Time of Flight Diffraction (TOFD) ultrasonic examination techniques in recent years. The **Appendix 12** ultrasonic examination technique is capable of finding and sizing flaws, but not as accurately and effectively as PAUT and TOFD. This is why it is not an acceptable examination technique for determining the joint efficiency of a weld. The acceptance criteria for the **Appendix 12** ultrasonic examination technique applies the exact same “workmanship” flaw dimension criteria that applies to radiographic examination.

UW-53(b): Ultrasonic examination of welds per [UW-51\(a\)\(4\)](#) shall be performed and evaluated in accordance with the requirements of Section VIII, Division 2, 7.5.5.

The rules in **UW-53(b)** send the code user to **Section VIII, Division 2**, paragraph **7.5.5** for the detailed requirements for applying ultrasonic examinations when a joint efficiency is to be determined. These rules apply when using ultrasonic examinations in lieu of radiographic examinations of welds in materials whose thickness is not less than 1/4 in. (6 mm) as referenced in **UW-51(a)(4)**.

Section VIII, Division 2, paragraph **7.5.5** describes rules for performing ultrasonic examinations in lieu of required radiographic examinations:

7.5.5 ULTRASONIC EXAMINATION USED IN LIEU OF RADIOGRAPHIC EXAMINATION

7.5.5.1 When used in lieu of the radiographic examination requirements of [7.5.3](#), automated or semi-automated ultrasonic examination shall be performed in accordance with a written procedure conforming to the requirements of Section V, Article 4, Mandatory Appendix VIII or Mandatory Appendix XI, as applicable, and the following additional requirements. For SAW welds in 2-1/4Cr-1Mo-1/4V vessels, additional ultrasonic examination is required and shall be in accordance with [7.5.4.1\(e\)](#).

(a) The ultrasonic examination area shall include the volume of the weld, plus 50 mm (2 in.) on each side of the weld for material thickness greater than 200 mm (8 in.). For material thickness 200 mm (8 in.) or less, the ultrasonic examination area shall include the volume of the weld, plus the lesser of 25 mm (1 in.) or t on each side of the weld. Alternatively, examination volume may be reduced to include the actual heat-affected zone (HAZ) plus 6 mm (1/4 in.) of base material beyond the heat-affected zone on each side of the weld, provided the following requirements are met:

(1) The extent of the weld HAZ is measured and documented during the weld qualification process; and

(2) The ultrasonic transducer positioning and scanning device is controlled using a reference mark (paint or low stress stamp adjacent to the weld) to ensure that the actual HAZ plus an additional 6 mm (0.25 in.) of base metal is examined.

(b) The initial straight beam material examination (Section V, Article 4, T-472) for reflectors that could interfere with the angle beam examination shall be performed

(1) Manually,

(2) As part of a previous manufacturing process, or

(3) During the automated or semi-automated UT examination, provided detection of these reflectors is demonstrated.

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(c) Personnel performing and evaluating UT examinations shall be qualified and certified in accordance with 7.3. Only UT Level II or or Level III personnel shall analyze the data or interpret the results. In addition, UT personnel shall meet the requirements of Section V, Article 4, Mandatory Appendix VIII, VIII-423 prior to performing production scans.

(d) Contractor qualification records of certified personnel shall be approved by the Certificate Holder and maintained by their employer.

(e) Qualification of the procedure shall be performed per Section V, Article 1, T-150(d), and Section V, Article 4, Mandatory Appendix VIII, VIII-421.2.

(f) Application of automated or semi-automated ultrasonic examinations shall be noted on the Manufacturer's Data Report, as well as the extent of its use.

NOTE: Sectorial scans (S-scans) with phased arrays may be used for the examination of welds, provided they are qualified satisfactorily in accordance with (e). S-scans provide a fan beam from a single emission point, which covers part or all of the weld, depending on transducer size, joint geometry, and section thickness. While S-scans can demonstrate good detectability from side drilled holes, because they are omnidirectional reflectors, the beams can be mis-oriented for planar reflectors (e.g., lack of fusion and cracks.) This is particularly true for thicker sections, and it is recommended that multiple linear passes with S-scans be utilized for components greater than 25 mm (1 in.) thick. An adequate number of flaws should be used in the demonstration block to ensure detectability for the entire weld volume.

7.5.5.2 Flaw Sizing. *The dimensions of the flaw shall be determined by the rectangle that fully contains the area of the flaw, and the flaw shall be classified as either a surface or subsurface flaw (see Figures 7.11 through 7.17).*

(a) The length, l , of the flaw shall be drawn parallel to the inside pressure-retaining surface of the component.

(b) The measured flaw through-wall dimension shall be drawn normal to the inside pressure-retaining surface and shall be defined as a for a surface flaw or $2a$ for a subsurface flaw.

(c) Subsurface flaw(s) close to a surface shall be considered surface flaw(s) if the distance between the flaw and the nearest surface is equal to or less than one-half the flaw through-wall dimension, as shown in Figures 7.11 through 7.17.

7.5.5.3 Flaw Evaluation and Acceptance Criteria. *Flaws shall be evaluated for acceptance using the applicable criteria of Tables 7.8, 7.9, 7.10, or 7.11, and with the following additional requirements. Unacceptable flaws shall be repaired and the repaired welds shall be re-evaluated for acceptance.*

(a) For surface connected flaws, the measured through-wall dimension, a , shall be compared to the value of a as determined from the applicable flaw acceptance criteria table.

(b) For subsurface flaws, the measured through-wall dimension, $2a$, shall be compared to twice the value of a as determined from the applicable flaw acceptance criteria table.

(c) Surface Flaws - Flaws identified as surface flaws during the UT examination may or may not be surface connected, as shown in Figures 7.11 through 7.17. Therefore, unless the UT data analysis confirms that the flaw is not surface connected, it shall be considered surface connected or a flaw open to the surface, and is unacceptable unless surface examination is performed. If the flaw is surface connected, the requirements above still apply. However, in no case shall the flaw length, l , exceed the acceptance criteria in this Division. Acceptance surface examination techniques are as follows:

(1) Magnetic particle examination (MT) in accordance with 7.5.6,

(2) Liquid penetrant examination (PT) in accordance with 7.5.7,

(3) Eddy Current examination (ET) in accordance with 7.5.8.

(d) Multiple Flaws

(1) Discontinuous flaws shall be considered a singular planar flaw if the distance between adjacent flaws is equal to or less than the dimension S as shown in Figure 7.14.

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(2) Discontinuous flaws that are oriented primarily in parallel planes shall be considered a singular planar flaw if the distance between the adjacent planes is equal to or less than 13 mm (1/2 in.) (see Figure 7.15).

(3) Discontinuous flaws that are coplanar and nonaligned in the through-wall thickness direction of the component shall be considered a singular planar flaw if the distance between adjacent flaws is equal to or less than S as shown in Figure 7.16).

(4) Discontinuous flaws that are coplanar in the through-wall direction within two parallel planes 13 mm (1/2 in.) apart (i.e., normal to the pressure-retaining surface of the component) are unacceptable if the additive flaw depth dimension of the flaws exceeds those shown in Figure 7.17.

(e) Subsurface Flaws - the flaw length, l , shall not exceed $4t$.

Some standout features are:

1. Use of an automatic or semiautomatic ultrasonic examination is required. This means the ultrasonic scanning technique requires a mechanical scanning device, which may be manually or self-propelled.
2. Automated data acquisition and retention in an unaltered raw form is required during qualification of the written procedure and during production scans.
3. The examination shall be performed in accordance with a written procedure for the applicable examination techniques in accordance with the requirements of Section V, Article 4, Mandatory Appendix VIII or Mandatory Appendix XI.
4. The written procedure shall be qualified in accordance with Section V, Article 4, Mandatory Appendix VIII or Mandatory Appendix XI as appropriate.
5. Examination personnel shall be qualified by their performance during the procedure qualification demonstration examination, in addition to meeting the requirements of Section V, Article 1, T-120 as referenced in paragraph 7.3 of Section VIII, Division 2.
6. Acceptance criteria is not dimensionally specified, and must be calculated from the indications received during the examination, and differs depending on the depth, dimensions, and orientation of the indications.

The rules in **UW-53(c)** replace the former rules that allowed ultrasonic examination of final closure seams under **Appendix 12** when radiographic examinations were not practicable due to accessibility or other issues. The newer rules permit applying ultrasonic examination using PAUT and TOFD techniques with a manual scanning plan and transducer arrangement. The technical details for performing these examinations are essentially the same as those for the automatic and semiautomatic ultrasonic examinations described in paragraph 7.5.5 of **Section VIII, Division 2**.

UW-53(c): Phased array manual raster ultrasonic examinations may be used to establish the joint efficiency of the final closure seam of a pressure vessel whose construction, geometric configuration, or accessibility prohibits obtaining interpretable radiographs in accordance with UW-51(a) and the ultrasonic examination requirements of (b) when all of the following conditions are met: ... (additional details are clipped)

The former rules were deleted when the use of ultrasonic examination in lieu of radiographic examination was introduced into the code in **UW-51(a)(4)**. It was determined that the “old” ultrasonic examination of **Appendix 12** was inadequate for applying a joint efficiency. However, there were some situations where it was not possible to apply the automated scanning techniques of PAUT or TOFD.

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Paragraph **UW-54** describes the requirements for nondestructive examination personnel qualification and certification:

UW-54 QUALIFICATION OF NONDESTRUCTIVE EXAMINATION PERSONNEL

Personnel performing nondestructive examinations in accordance with [UW-51](#), [UW-52](#), or [UW-53](#) shall be qualified and certified in accordance with the requirements of Section V, Article 1, T-120(e), T-120(f), T-120(g), T-120(i), T-120(j), or T-120(k), as applicable.

These are the basic requirements. Personnel performing ultrasonic examinations as described in UW-53(b) and UW-53(c) are also subject to the additional qualification requirements for those examination techniques.

The incorporation of rules for using ultrasonic examination in lieu of radiographic examination needs further integration and refinement in future code Editions.