Ultrasound weld inspection in accordance with AWS D1.1 is performed using the pulse-echo contact technique. Acceptance/rejection of weld imperfections is based on a comparison of the power of the ultrasound wave (amplitude on the screen of the UT scope) reflected from a standard/reference reflector—which is a 0.06 in. diameter side-drilled hole on the International Institute of Welding (IIW)-type calibration block—with the power of the ultrasound wave reflected from the inspected weld’s imperfection (obviously, the power of the initial sound wave impulse is the same in both cases).

The inspection process can be divided into three important steps.

1. **Properly obtain the parameters of the reference reflector (calibration).**
2. **Adjust the parameters of the signal from the inspected imperfection to the parameters of the reference signal.** This adjustment needs to take the following factors into account:
   a. A part of the wave energy, which is lost due to attenuation of the sound wave traveling from the transducer to the weld imperfection and back. This is the so-called distance amplitude correction (DAC) curve.
   b. The difference in the shape and surface conditions between the surface of the IIW-type calibration block and the scanning surface of the part to be inspected.
3. **Compare the results received from Step 1 and Step 2 and evaluate.**

The following is a review of the important points in each step. Step 2b will be explored in Part II of this article in the January 2016 issue of *The NDT Technician*.

**Step 1: Calibration**

Any UT scope that is working in pulse-echo mode actually measures only two parameters: the time needed for the ultrasound impulse to travel from the transducer to the reflector and back; and the energy of the reflected signal compared to the energy of the initial impulse.

All other data needed to evaluate the size and location of the reflector are calculated by the software of the UT scope on the basis of the data obtained from the calibration process. For example, the velocity of the sound wave is calculated from the wave travel times from the transducer’s active element to two fixed-distance reflectors on the IIW-type calibration block—9 and 4 in. on an IIW Type 1 calibration block. Determination of the transducer sound-path angle (which is found through calibration) allows for the calculation of the surface distance and depth of the reflector. Sensitivity calibration gives the sound wave energy reflected by the standard reflector (incident sound wave energy is constant during calibration and inspection). Therefore, the accuracy of the data during UT inspection strictly depends on the accuracy of the calibration process.

In addition, two important aspects related to sensitivity calibration should be pointed out due to their significant effect on the attenuation of the sound wave.

- The thickness of the couplant layer should be approximately the same during calibration and inspection. This means that the pressure put on the plastic shoe of the search unit should be the same during calibration and inspection.
- The difference between the temperature of the calibration block (during calibration process) and the temperature of the...
inspected detail (during UT inspection) should not exceed 25 °F. For example, the difference in the reference level (reflection from a 0.06 in. diameter side-drilled hole) obtained from an ITW calibration block at 60 versus 100 °F is 2 to 2.5 dB. The use of a temperature gun is recommended to determine the temperature of the calibration block (during the calibration procedure) as well as the inspected area (during inspection).

**Step 2a: Adjustment for Attenuation**

A typical DAC curve for mild steel (ASTM A709, grade 50) and a standard search unit with a 70° angle is shown in Figure 1 (ASTM, 2011). For simplifying reasons, *AWS D1.1* approximates the DAC curve using a straight line with a slope of 2 dB/in. and assumes that the near zone is located within the first inch of the sound-path distance. This approximation, named “attenuation factor” (subdivision 6.26.6.4 of *AWS D1.1*), means that the attenuation of the wave energy (decreasing amplitude on the screen) is 2 dB for each inch of sound-path distance, and the near zone is located within the first inch of the sound-path distance.

This assumption leads to the following important consequences. First, it means that (in terms of amplitude and length) a discontinuity cannot be evaluated if the sound-path is less than 1 in. In other words, the first leg of a 70° search unit cannot be used for inspecting a weld from the scanning surface up to a depth of 0.342 in. For example, for the inspection of a weld with a size

![Figure 1. Distance amplitude correction (DAC) and attenuation factor for a 70° search unit in ASTM A709 grade 50 steel.](image)

$S_p = \text{sound-path, in inches; } l = \text{sound energy loss due to attenuation, in decibels.}$
of 5/16 in. with a 70° search unit, the first leg cannot be used, but rather the second and third legs are used. It is a common technician’s mistake to inspect complete joint penetration joints with a weld thickness of 5/16 in. using the first and second legs only.

Second, due to different deviation of the real attenuation (DAC) from a straight line with a slope of 2 dB/in. (the “attenuation factor”) for different values of the sound-path, indication ratings (as defined in 6.26.6.5 of AWS D1.1) from the same reflector found using the first leg (from Face B, Figure 2) or the second leg (from Face A, Figure 2) can differ significantly. For definitions of Face A, B, and C, see Table 6.7 of AWS D1.1 (AWS, 2010). As an example, take a 1/16 in. diameter hole drilled in the middle of a 1.25 in. thick flat bar (see Figure 2) parallel to Face A and Face B. Reflections from this hole are equal if one uses the first leg from Face A and Face B. The amplitude of these reflections as well as the amplitude of the reflection of the second leg from Face A lie well on the DAC curve. This means that in all cases there are reflections from reflectors of the same size, but different results when using the “attenuation factor.” Reflection from the same side-drilled hole gives an indication rating of +1 dB when using the first leg (from Face A or from Face B), which is a rejectable (Class A, Table 6.2, AWS D1.1) indication regardless of length, but when using the second leg from Face A, one gets an indication rating (from the same reflector) of +6 dB, which is an acceptable indication regardless of length (Class D, Table 6.2, AWS D1.1).

This deviation is not the only limitation for using the second leg. To get correct results when using the second leg the following requirements need to be satisfied.

- The surfaces of Face A and Face B should be strictly parallel.
- The roughness of the surface on Face B should be small in comparison with the sound wavelength to avoid significant scattering of sound energy on the surface of Face B (more detail will be given in Part II of this article).

The refraction of the sound energy on the surface of Face B should be significantly lower in comparison to the reflection. For example, the presence of any liquid (water, oil, and even couplant) on the surface of Face B could pervert the results of the inspection when using the second leg.

Summarizing all of the preceding and the fact that the acceptance criteria in Table 6.2 and Table 6.3 in AWS D1.1 by default were found using the first leg, the following is recommended: complete covering of the weld and the heat-affected zone (HAZ) should be done using primarily the first leg, wherever possible. This means that butt joints should be scanned from Face A and Face B from both sides of the weld (see joint configurations in Table 6.7 of AWS D1.1); corner and T-joints should be scanned from Face A, Face B, and (possibly) from Face C. The second and third legs should be used only if the sound-path of the first leg is less than 1 in., or if some part of the weld and the HAZ cannot be covered by the first leg. For example, if there is no access to Face B in a butt joint, then the second leg should be used for inspection of the top part of weld.

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