APPENDIX C

ROUND ROBIN REPORTED AMPLITUDE

Previous studies [1]–[4] have found that there is large scatter in reported amplitude between different technicians scanning the same flaw for conventional UT. As expected, the round robin data from this study showed the same trend. The average range between the maximum and minimum Indication Rating for all flaws scanned with conventional UT was 10 decibels (dB). This variability is much larger than the 3 dB difference used in the AWS D1.5 tension criteria for classification as either a Class A (Rejectable) or Class D (Acceptable) indication for welds up to 1.5” thick or the 5 dB difference for welds greater than 1.5” thick. If more technicians participated in the round robin study, the extremes in the difference in reported indication ratings would have only increased. Therefore, it should be expected that a flaw with amplitude close to the rejection limit would be found to be acceptable to some conventional UT technicians and rejectable to others.

It was found that lack of fusion indications have the greatest range (i.e., difference in maximum and minimum) in Indication Ratings, while porosity had the smallest range. This is likely due to the mirror-like quality of lack of fusion flaws where only a small movement of the probe results in a large change in amplitude while porosity is much less affected by adjustments in the probe location. Table C-1 summarizes the average range in reported indication rating by different flaw types.

Figure C-1 through Figure C-4 display the scatter in reported Indication Rating (amplitude) for each flaw. The figures are sorted by flaw type, similar to the height and length scatter plots. While there was a very large amount of scatter for each flaw, the Indication Rating was typically well into the Class A category for LOF and cracks. Flaw 1 in Figure C-1 and Flaw 4 in Figure C-2 had flaw classifications ranging from Class A to Class D which demonstrates how the scatter in reported amplitude can result in scatter in flaw rejection rate.

Table C-1. Average Range in Reported Conventional UT Indication Rating

Flaw Type	Avg. Range
LOF	12 dB
Crack	11 dB
Porosity	3 dB
Slag	9 dB

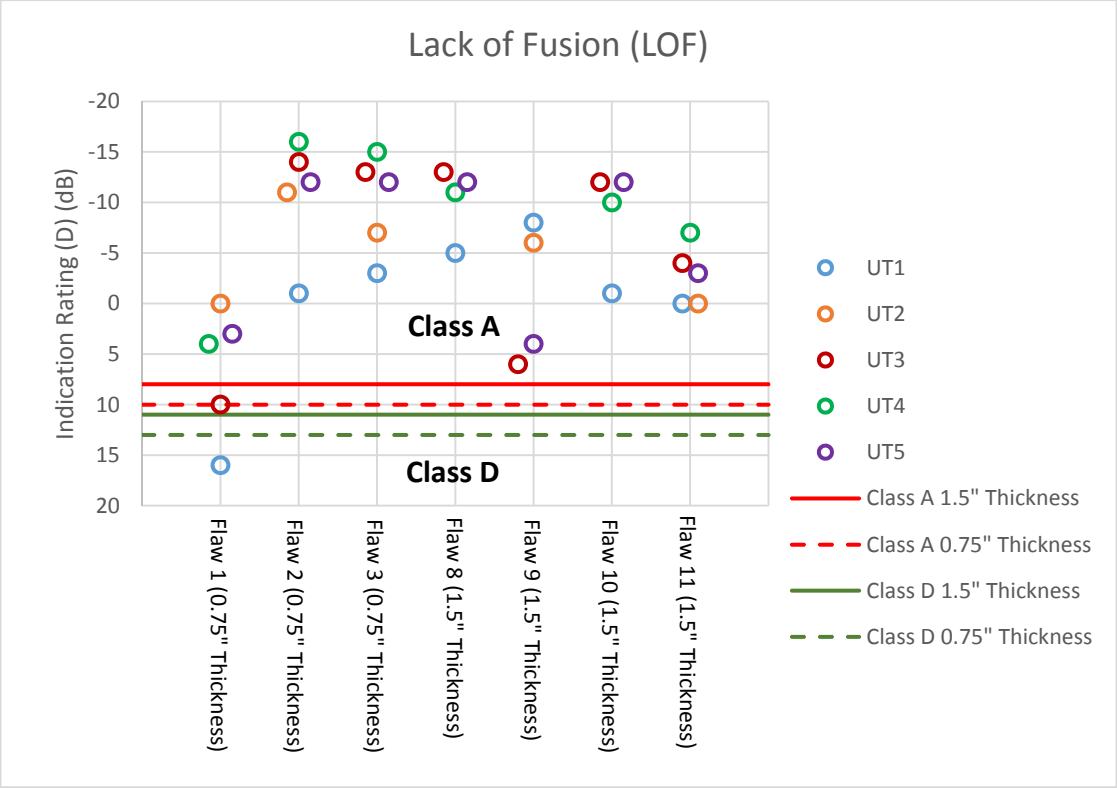

Figure C-1. Conventional UT Amplitude Scatter for LOF Flaws

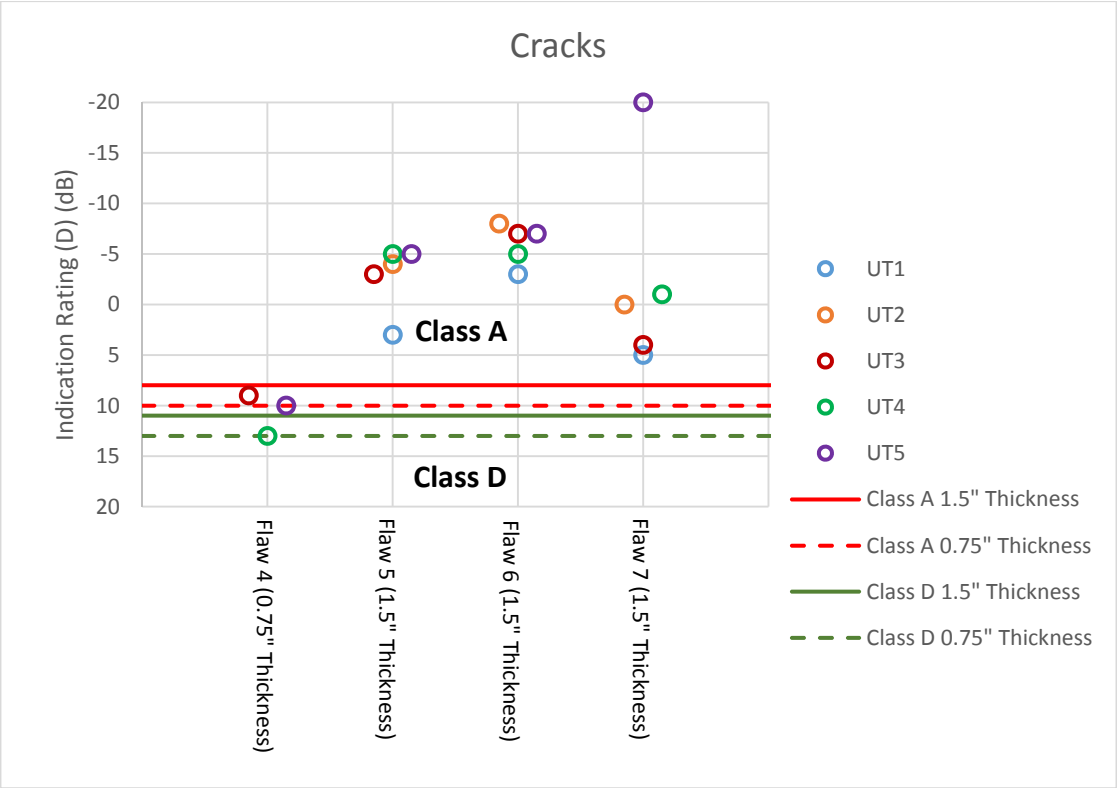

Figure C-2. Conventional UT Amplitude Scatter for Cracks

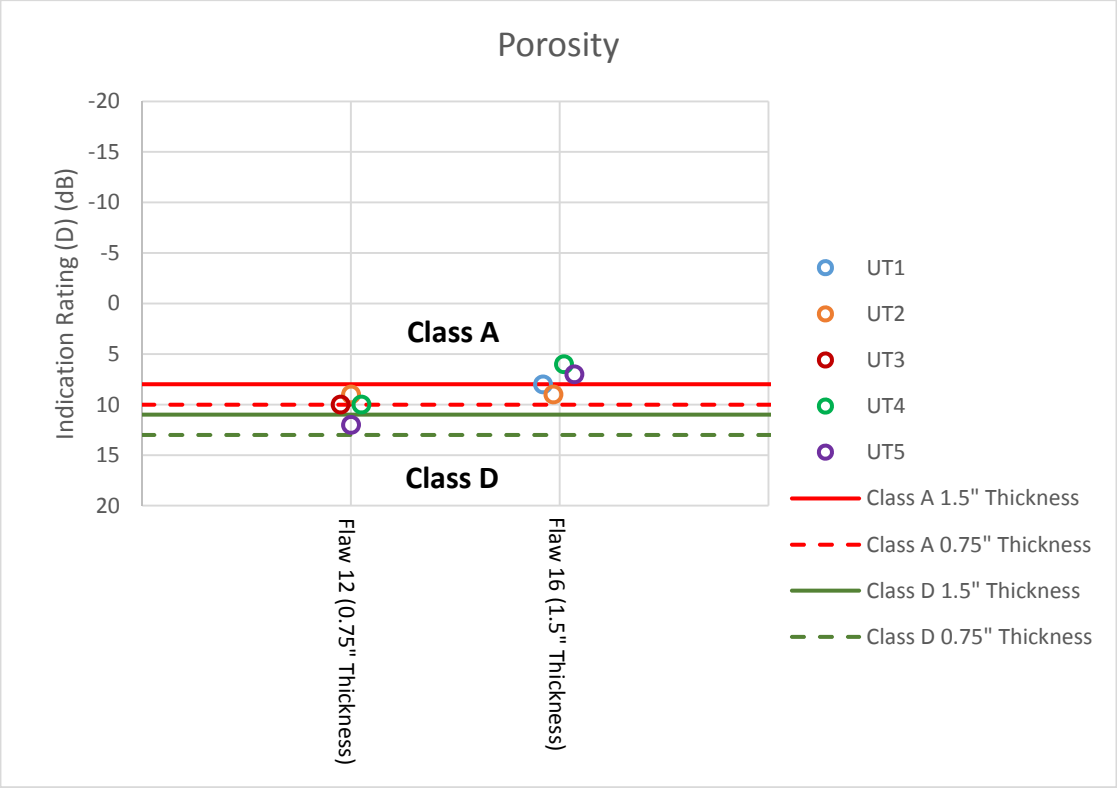

Figure C-3. Conventional UT Amplitude Scatter for Porosity

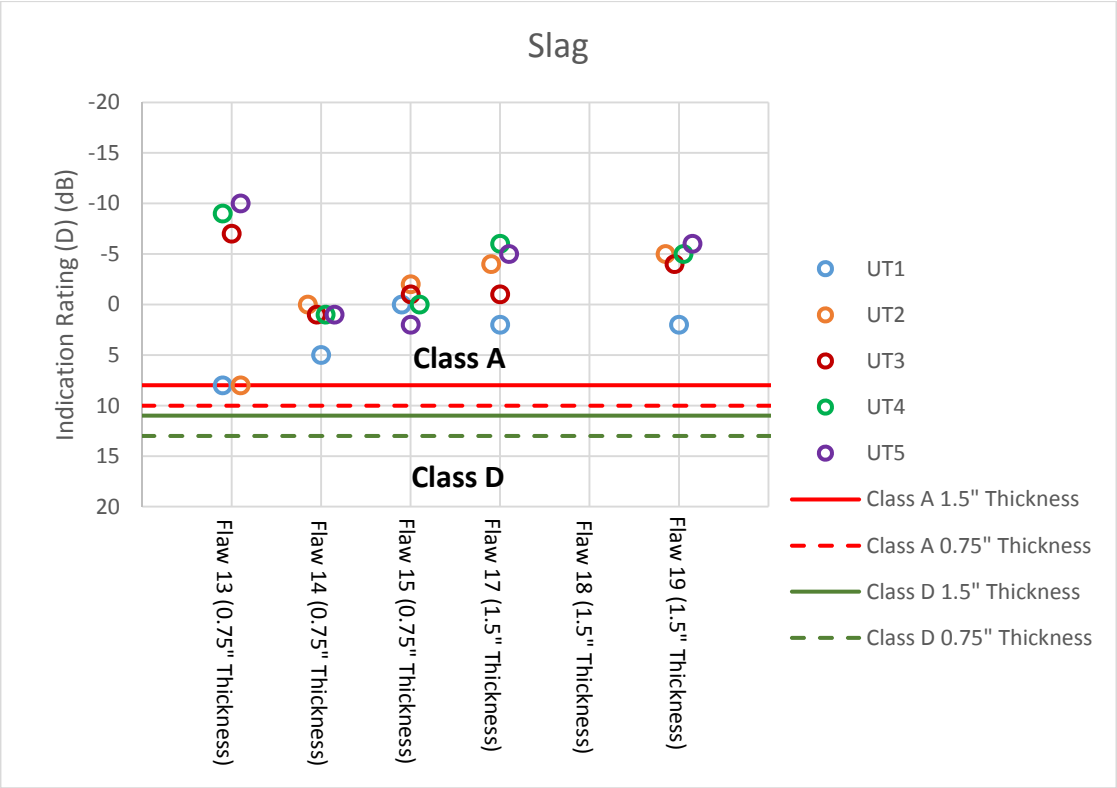

Figure C-4. Conventional UT Amplitude Scatter for Slag

A similar comparison was made for PAUT Annex K to investigate the range in reported amplitude, but one issue is that some PAUT technicians truncated the amplitude at 100% full screen height (FSH) while others reported amplitude readings up to 200% FSH. Therefore, comparing the maximum and minimum reported amplitude for each flaw is not as straightforward with PAUT since the truncated amplitude readings can give the appearance of a high range in amplitude due to the same flaw being reported as 100% and 200% FSH by different technicians or low range if all of the readings are at 100% FSH.

It was noted that the flaws that had a high amplitude with conventional UT also typically had a high amplitude with PAUT, but PAUT tended to have more outliers below the ARL (Class A) than conventional UT. This is thought to be caused by the lack of raster scanning to determine the maximum reported amplitude, but it also could be due to the differences in the acceptance criteria amplitude limits. Due to the truncation of the PAUT data, it was difficult to compare the difference in the magnitude of scatter between PAUT and conventional UT scans.

The amplitude was plotted against the flaw size (i.e., flaw height, flaw length, and flaw cross-sectional area) for both PAUT and conventional UT. As expected, the amplitude increases as the size of planar flaws increase (height, length, or cross-sectional area) for both PAUT and conventional UT. This shows that amplitude is appropriate for use in an ultrasonic acceptance criteria since an amplitude cut-off can be set such that large planar flaws are rejectable, if detected.

All planar flaws greater than 0.20” high x 0.40” length (cross-sectional area 0.08 in^2) had PAUT amplitude greater than 50% FSH (Class B). Recall that 50% FSH is equal to the reference amplitude for the 2015 version of Annex K. Conventional UT indication ratings for these planar flaws were greater than or equal to +6 dB (Class A up to 1.5” thickness and Class B for 1.5” to 2.5” thickness). Recall that this is equivalent to an amplitude of 6 dB below reference for PAUT. The maximum reported amplitude for PAUT would likely have been higher if the peak amplitude was determined by additional raster scanning rather than just reporting the maximum measured along the line scans.

Volumetric flaws did not have a correlation between size (height, length, or cross-sectional area) and amplitude for PAUT or conventional UT using the size of the overall grouping of flaws. It should be noted that the flaw size for porosity was taken to be the overall group of pores rather than the individual pore dimensions. It is likely that the individual pore dimensions also affect the ultrasonic response. The amplitude from volumetric flaws is likely more influenced by the flaw type (slag vs. porosity) and local differences in shape than the overall size of the grouped flaw.

C.1 List of References

[1] E. A. Ginzel, R. Thomson, and R. K. Ginzel, “A Qualification Process for Phased-Array UT using DNV RP-F118 Guidelines,” *NDT.net*, pp. 1–12, 2011.

[2] G. Washer, R. Connor, and D. Looten, “Performance Testing of Inspectors to Improve the Quality of Nondestructive Testing,” *Transp. Res. Rec. J. Transp. Res. Board*, vol. 2408, pp. 107–116, Dec. 2014.

[3] R. E. Shaw Jr., “Ultrasonic Testing Procedures, Technician Skills, and Qualifications,” *J. Mater. Civ. Eng.*, vol. 14, no. 1, pp. 62–67, 2002.

[4] T. J. Jessop, P. J. Mudge, and J. D. Harrison, *NCHRP Report 242: UT Measurement of Weld Flaw Size*. Washington, DC: National Research Council, 1981.