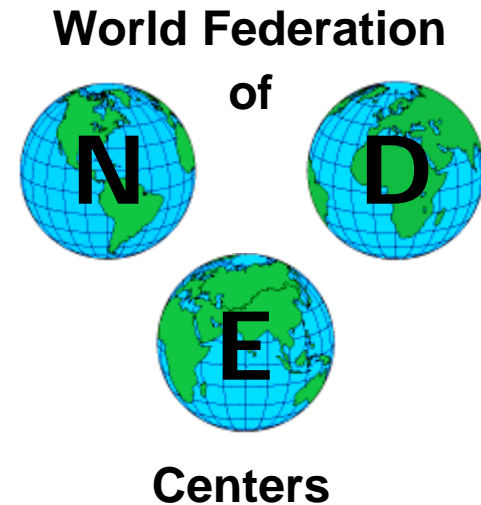


2008 ULTRASONIC BENCHMARKS



Problems for 2008

This year we have two components of the ultrasonic benchmark study. The first component is very similar to the studies we performed in 2007 on the pulse-echo responses of flat-bottom holes through curved interfaces. We have repeated this study in order to better understand the responses seen last year.

The second component of the benchmark study is a study of the ultrasonic response of side-drilled holes at various depths in a steel block.

The experimental data for both these studies have been obtained by the Commissariat à l'énergie atomique (CEA) in France. We would like to thank the researchers at CEA for their efforts in designing these benchmarks and for obtaining the responses.

2008 Benchmark Problems

Surface Curvature Effects Study

In this study (see Fig. 1) we examine the on-axis P-wave response of seven flat-bottom holes positioned at different depths under a reference planar surface and under 4 curved surfaces (2 concave and 2 convex cylindrical surfaces).

A **spherically focused transducer** having a nominal diameter of 12.7 mm was used in all the cases. The properties of this transducer have been examined carefully at both the Center for NDE, Iowa State University and by CEA. A summary of the CNDE results are given below. For more details of the CNDE study see the file Probe306400 on the CNDE ftp site (details of access to that site are given at the end of this announcement).

Measured Transducer Characteristics (under broadband excitation)

Response from flat surface in water:

- peak response at 4.7 inches
- center frequency: 4.5 MHz
- frequency bandwidth (FWHM): 2.2 – 6.8 MHz

Response from ball reflector in water:

- peak response at 3.84 inches
- center frequency: 5.3 MHz
- frequency bandwidth (FWHM): 2.8 – 7.7 MHz
- beam spot diameter (FWHM): 0.089 inches

Fit of on-axis radiation pattern to that of an ideal focused piston probe:

- effective diameter: 0.491 inches
- effective geometric focal length: 6.807 inches

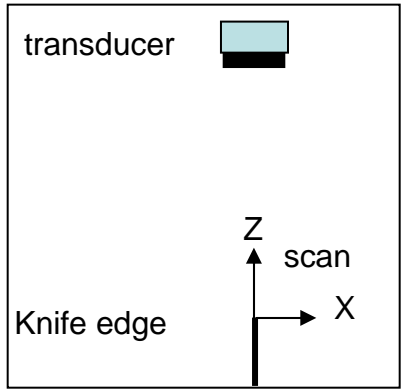
The best fit effective diameter and effective geometric focal length values given above are the values that best match an ideal focused piston probe over the bandwidth of the transducer. Thus, it is suggested that one use those values in all the model calculations.

One obviously also needs to specify the spectral characteristics of the transducer (and the corresponding measurement system) in order to simulate pulse responses. The CNDE results given above show the results obtained for bandwidth and center frequency when using a ball reflector in water. Similarly, CEA has measured these same parameters for this transducer when using a knife edge reflector, as shown on the following page. It is suggested that one use the CEA spectral values in the model calculations as those would likely correspond closer to the conditions under which the FBH response data were taken.

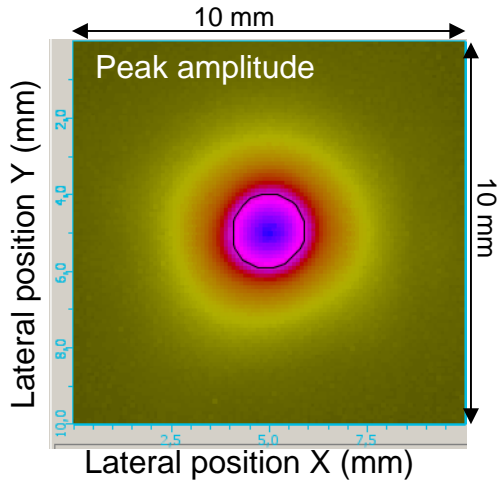
In summary, we would suggest that the transducer modeling parameters be taken as:

effective diameter: 0.491 inches (12.47 mm)
effective geometrical focal length: 6.807 inches (172.9 mm)
center frequency: 4.8 MHz
-6 dB bandwidth: 88%(of center frequency)

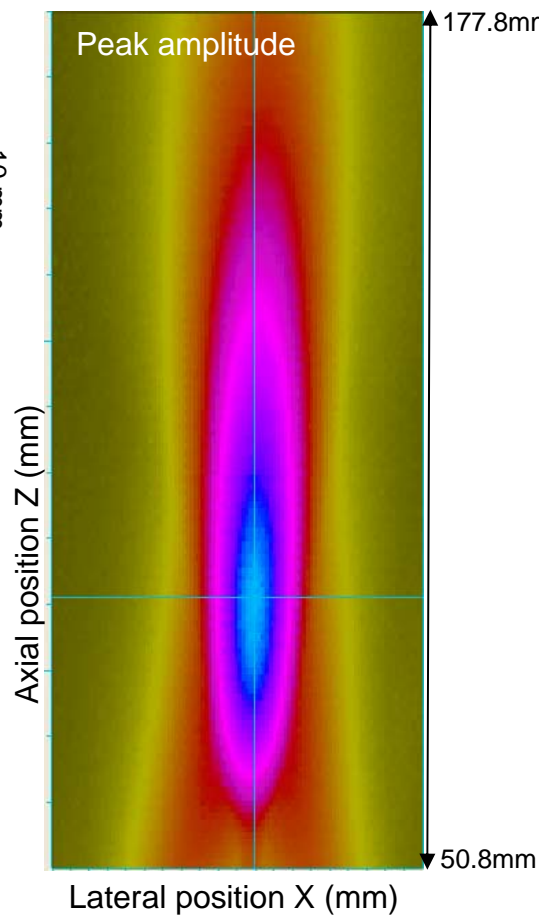
Response of the transducer from a knife edge in water



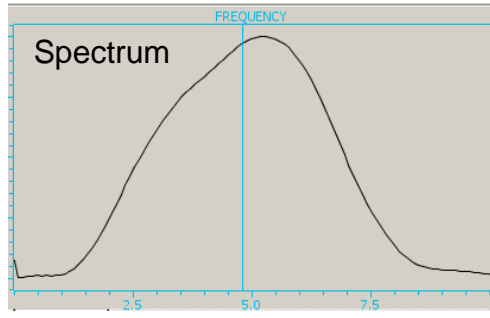
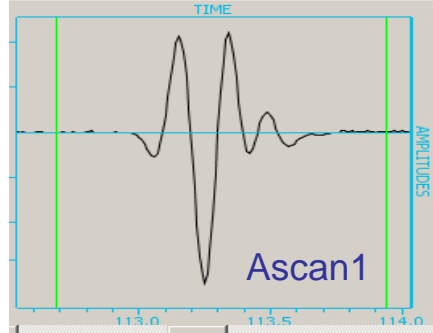
Cscan at 89 mm depth



XZ Cscan



Wave form at the maximum amplitude



Measured characteristics:

- Peak response at Z=90 mm
- Beam spot average diameter at -6dB: 2.2mm
- Width at half maximum extends from 2.7 to 6.9MHz
- Center frequency = $0.5(2.7+6.9)=4.8\text{MHz}$
- Bandwidth = $6.9-2.7=88\%$

Transducer nominal characteristics

Waves	Shape	Dimension (diameter)	Central frequency	Focal length
P-waves	circular	12.7 mm	5MHz	3.5 PTF

For the surface curvature study, the water path length, « d », is 75 mm, the transducer was oriented to produce 0° refracted P waves in each block.

The **blocks** used for this study are five aluminum blocks (see Fig.1) with different surface curvatures (one block with a planar surface, two blocks with concave surfaces (radius 50.8 mm and 203.2 mm), and two blocks with convex surfaces (radius 50.8 mm and 203.2 mm)).

Each block contains seven 0.8 mm diameter **flat-bottom holes** (FBHs) at following depths « D »:
1/4 inch; 1/2 inch; 3/4 inch; 1 inch; 1.5 inch; 2 inch; 3 inch.

The transducer was moved in two perpendicular directions over each FBH. The waveform received from the FBH was recorded at each position of the transducer and the maximum amplitude of the rectified echo was stored for each FBH. The **reference amplitude** for all the echoes is the amplitude of the echo received from the 1/2 inch depth FBH under the planar surface. The ratio of the FBH amplitudes and reference amplitude were calculated (in dB), taking into account any differences in gain settings and the results placed in a table (see Table 1)

For this curvature study, use appropriate beam models and flaw scattering models to determine the corresponding amplitude ratios (in dB) given in Table 1. Also, generate a table of the same cases showing the difference in dB from the model predictions and the experimental results.

Response from flat bottomed holes at different depths under various surfaces (1)

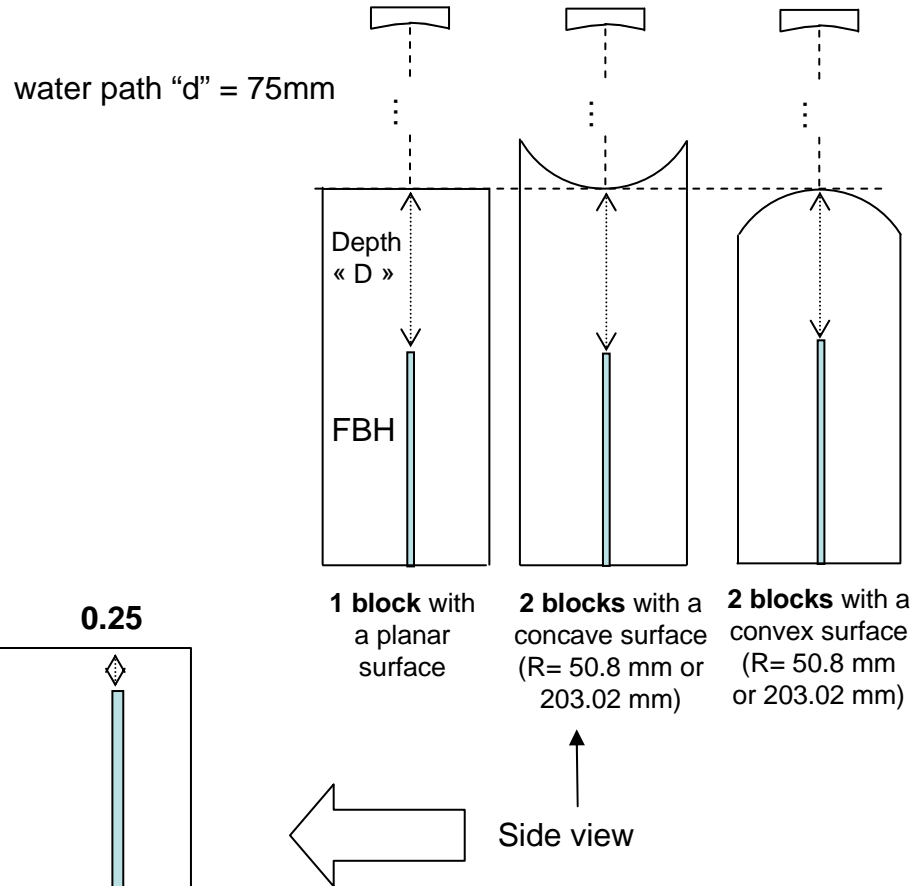
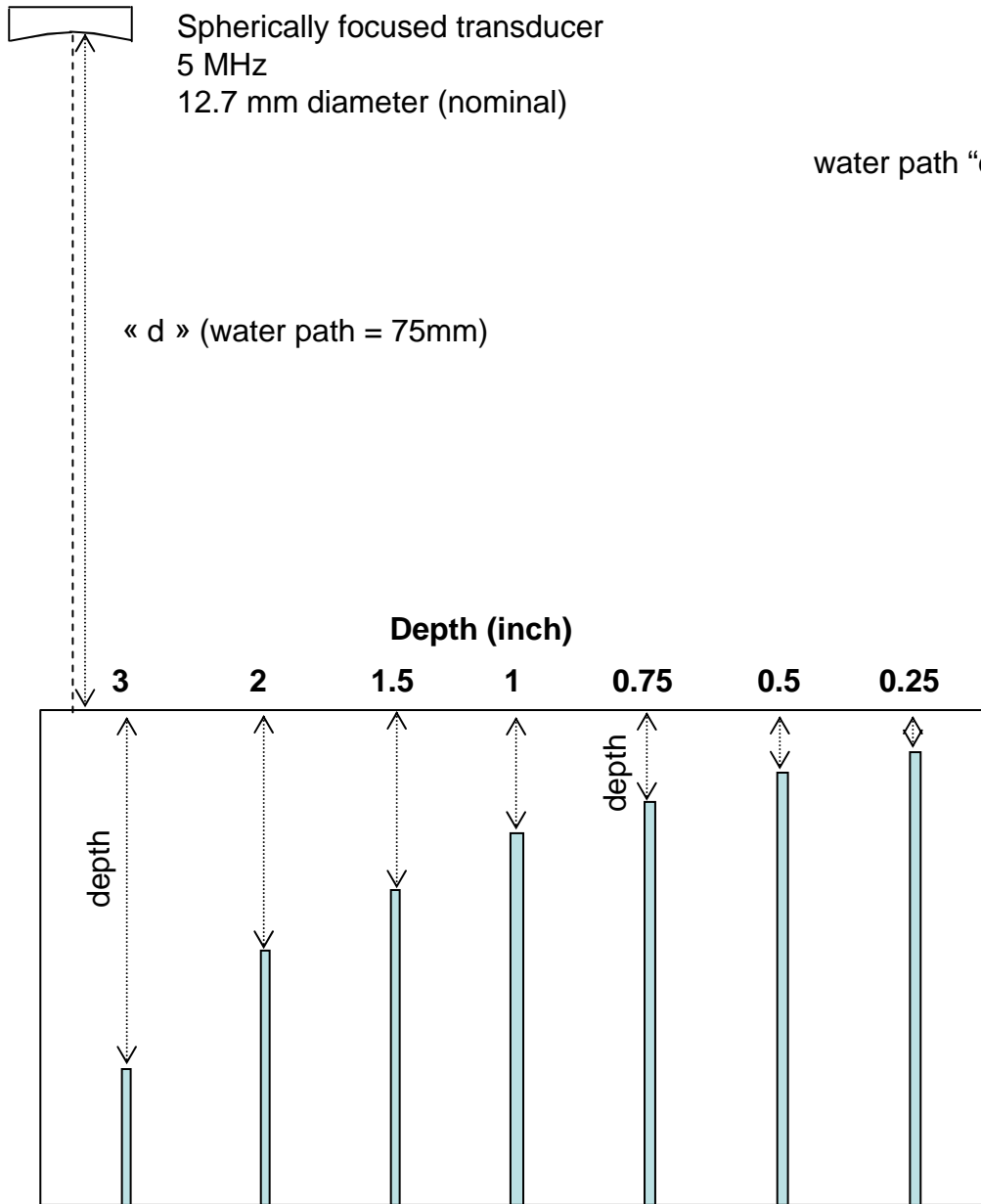


Fig. 1
FBH and blocks

Response from flat-bottom holes at different depths under various surfaces (2)

block \ depth of the FBH (mm)	6.35	12.7	19.05	25.4	38.1	50.8	76.2
Planar surface	1.3	0	-2.3	-4.9	-11	-14.5	-22.4
R = 50.8 mm, concave surface	5.2	2.8	-4.8	-8.9	-16.3	-24.2	-29.7
R = 50.8 mm, convex surface	-2.9	-4.6	-7.6	-10.6	-15.5	-20.4	-27.6
R = 203 mm concave surface	0.6	0.2	-2.1	-4.9	-10.8	-14.7	-21.4
R = 203 mm, convex surface	0.3	-1.4	-4.0	-6.9	-11.3	-14.8	-21.0

Table 1. Relative amplitudes in dB of the P-wave direct echo of the FBH

The amplitude of reference A_{ref} = amplitude maximum of the echo of the FBH at 12.7mm depth under the planar surface.

The relative amplitude A_R of the FBH printed in table 1 is in dB: $A_R = 20\log(A_{FBH} / A_{REF}) - (G_{FBH} - G_{REF})$ where G_{FBH} and G_{REF} are the gains in dB.

Response from flat bottom holes at different depths under various surfaces (3)

	Density	c_L	c_T
water	1g.cm^{-3}	1486 ms^{-1}	
Aluminum	2.7g.cm^{-3}	6381.2 ms^{-1}	3000 ms^{-1}

Acoustical properties of material and water

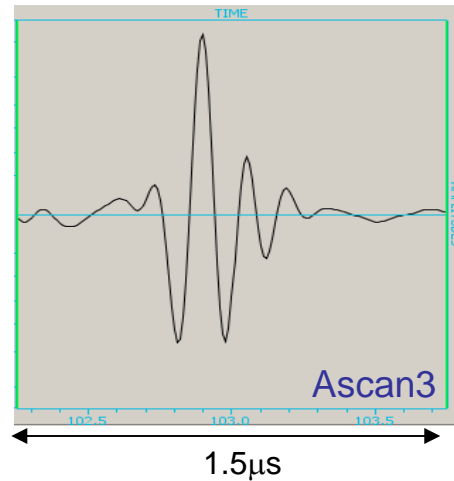
Defects	Diameter:	Distances from surface (see Fig. 1) :	Orientation
9 Flat Bottom Holes	0.8 mm	6.35 to 76.2 mm (0.25 to 3 inches)	Normal axis of the FBH perpendicular to the surface

Flaw characteristics

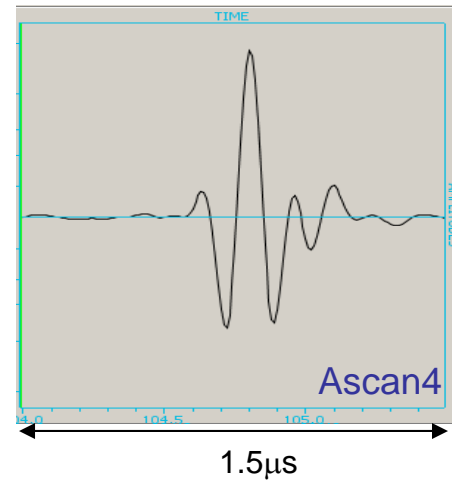
Response from flat-bottom holes at different depths under various surfaces (5) Concave surface R=50.8mm

The waveforms of the echos of 4 FBHs positioned under the concave surface (radius 50.8mm) are also presented below because they allow one to observe a shift in the phase of the echoes at a given depth, due to a caustic phenomena.

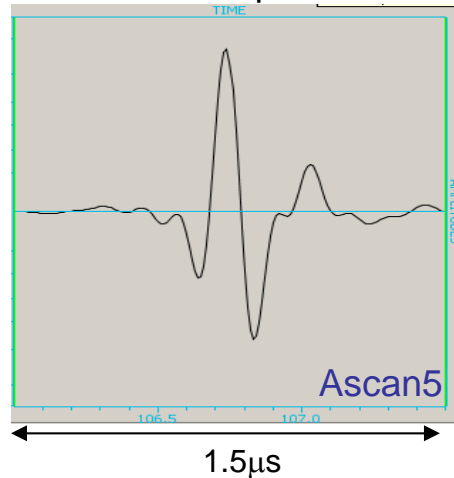
FBH depth 6.35mm



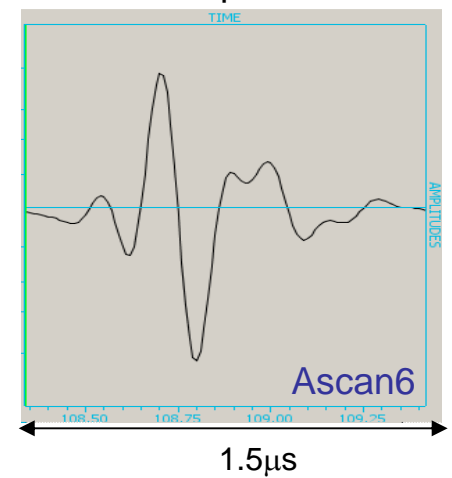
FBH depth 12.7mm



FBH depth 19.05mm



FBH depth 25.4mm



2008 Benchmark Problems

Side-drilled Hole Study

In this study, the response of **side-drilled holes** at various depths **in a steel block** were obtained, as shown in Fig. 2. The same focused transducer used in the flat-bottom hole study was used in this study. The water path length, « d », was again 75 mm, and the transducer was oriented to produce 0° refracted P waves in the block.

The transducer was scanned parallel to the surface of the block as shown in Fig. 2 and the amplitude of the rectified A-scan signal was recorded as a function of scan position. The **reference amplitude** for all the echoes is the amplitude of the echo received from side-drilled hole at a depth of 8 mm. The ratio of the SDH amplitudes and reference amplitude were calculated (in dB) and the results are given in Table 2.

For this side-drilled hole study, use appropriate beam models and flaw scattering models to determine the corresponding amplitude ratios (in dB) given in Table 2. Also, generate a table of the same cases showing the difference in dB from the model predictions and the experimental results.

Response from side drilled holes (SDH) at different depths (1)

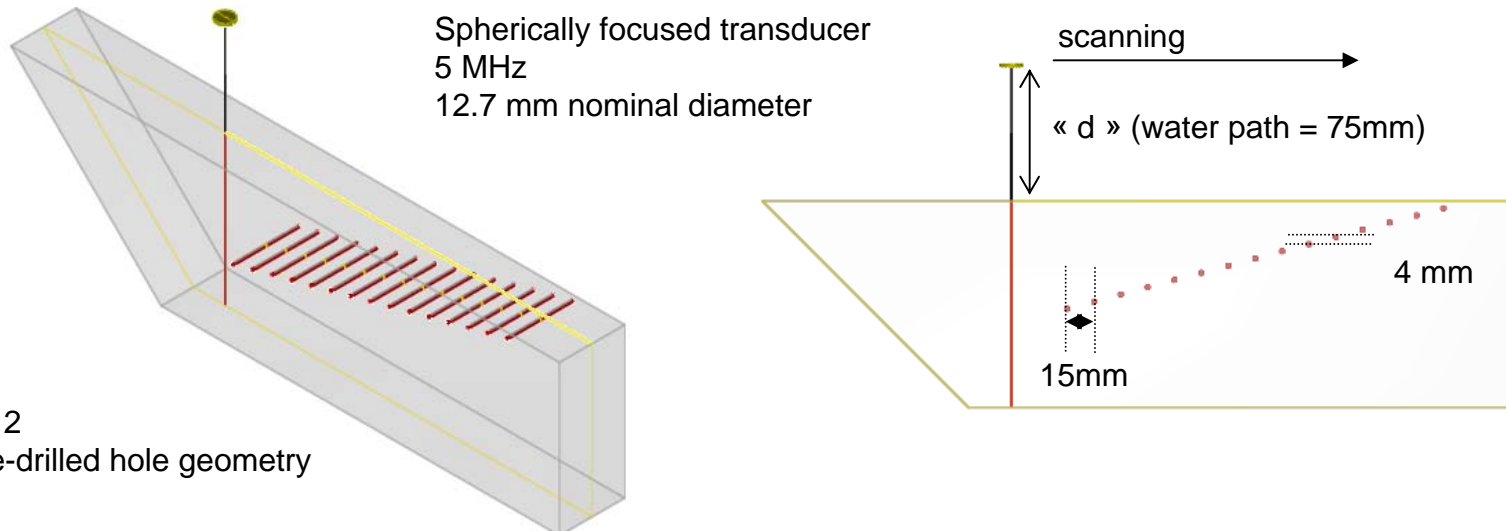


Fig. 2
Side-drilled hole geometry

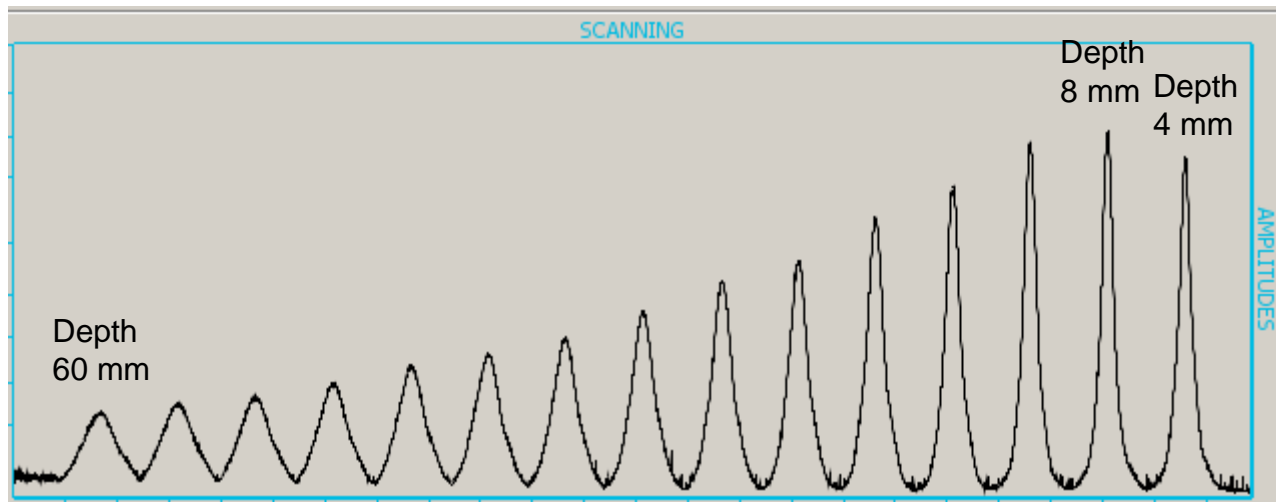
	Density	c_L	c_T
water	1g.cm ⁻³	1486 ms ⁻¹	
Steel	7.8g.cm ⁻³	5900 ms ⁻¹	3230ms ⁻¹

Acoustical properties of material and water

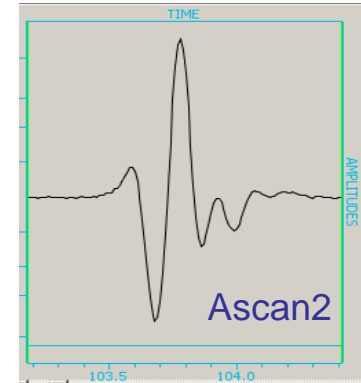
Defects	Diameter	Length	Distances from the surface (mm):	Orientation
Side Drilled Holes	2 mm	50 mm	4 to 60 mm (step 4 mm)	Axis of the SDH parallel to the surface

Flaw characteristics

Response from side drilled holes (SDH) at different depths (2)



SDH response
at maximum amplitude
(depth 8 mm)



depth of the SDH (mm)	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
Peak amplitude (dB)	-0.7	0 (ref)	-0.3	-1.4	-2.4	-3.8	-4.6	-5.8	-7.2	-8.1	-9	-10.1	-11.1	-11.8	-12.7

Table 2. Relative amplitudes in dB of the P-wave direct echo of the SDH

There are several supplemental data files for the benchmark problems available at the CNDE ftp site listed below. These are all in Excel spreadsheet format. These include the response of the focused transducer to the knife edge described as part of the transducer characterization study, the four A-scan responses of the FBHs shown previously for the 50.8 mm concave radius case, showing phase changes in the FBH signal, and the A-scan for the reference SDH case (SDH located at a depth of 8 mm).

PARTICIPATION IN THE STUDY

The files for this benchmark study have been placed on the CNDE ftp site <ftp://cnde:Bruce@ftp.cnde.iastate.edu>. They are in the directory pub in the folder named 2008 UT Benchmark. The results of these benchmark studies will be presented at the 35th Annual Review of Progress in Quantitative Nondestructive Evaluation (RPQNDE) meeting, which will be held July 20-25, 2008 at the University of Illinois – Chicago. We plan to hold an ultrasonics benchmark session at that meeting for these problems. To present your benchmark results at that session, please note that the deadline for submitting an abstract is May 2, 2008 (mark on your abstract that it is for the UT benchmark session). However, feel free to work on these problems even if you are not presenting at that meeting. Also, the advance registration deadline for the conference is June 27, 2008. For more details of the RPQNDE conference, visit the website at www.cnde.iastate.edu/qnde/qnde.html.

If you are willing to share your tabulated results for Tables 1 and 2, we will include those in a summary comparison that will be part of a paper written for the RPQNDE proceedings by a World Federation representative. All benchmark participants who provide such data will be listed as co-authors on this summary paper and will have an opportunity to review its contents.

For any questions, please e-mail Prof. Schmerr at lschmerr@cnde.iastate.edu.

Les Schmerr
Permanent Secretary, World Federation of NDE Centers
April, 2008