AFFORDABLE UT TRAINING

# SOUND REFLECTIONS

*"SOUND REFLECTIONS" is a free monthly newsletter presenting basic UT math & theory plus inspection tips for anyone wishing to gain more insight into applied ultrasonic inspection. We hope that your UT problem solving curiosity will help you develop more UT knowledge.*

## Dual Media Velocity vs Distance on an A-Scan

STARTING POINTS required to understand Dual Media Testing:

1. An A-Scan displays the sound beam DISTANCE traveled between the inspected part surface to any reflector within the part.

2. The basic calculation that the A-Scan follows to accomplish this is:

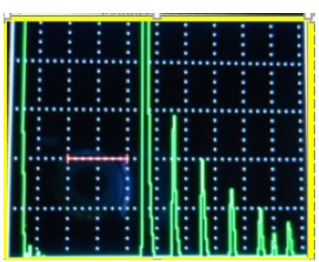
   Distance=Velocity of sound in the tested material x Time measured to the reflector

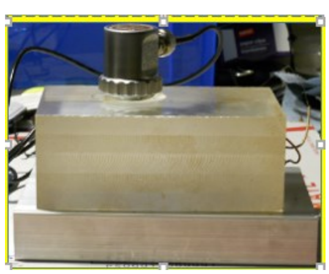
   distance=velocity X time or $d=v$ X $t$

3. The A-Scan requires that you enter **only one sound velocity**, that velocity will be the velocity for the material being inspected. This velocity will not be the correct velocity for the material between the transducer and the inspected material.

4. When you perform an inspection using an incorrect velocity for a water path or a delay line material between the transducer and the inspected material, the displayed distance of the delay coupling material will not be correct.

**Definition:** *dual media UT inspection is simply applying sound energy to a part through another media or material to create a delay path to the inspected part.*





Using a typical A-Scan screen plus the UT test as shown below, let's look at this example of a test with a block of acrylic resin between a contact transducer and an aluminum plate UT inspected with a normal incident transducer on the surface of the acrylic resin.

True thickness of the acrylic resin block is 1.9 inches & sound velocity 1.07 X 10^5 IPS

True thickness of the aluminum plate is 1 inch & sound velocity is 2.5 X 10^5 IPS

Again, note distance=velocity X time.

This mathematical statement means that TIME allows you to measure the TRUE DISTANCE ONLY if you are using the ACTUAL TRAVEL VELOCITY.

An A-Scan measures the sound path distance traveled in both materials above (acrylic resin and aluminum) by using an electronic time clock. The only correct distance displayed is for aluminum because you entered aluminum's sound velocity. The delay media's distance will NOT be correct because its velocity (1.07 X 10^5 IPS) is different than sound velocity of aluminum. The velocity of sound in acrylic is also slower than that of aluminum, roughly half that of aluminum. Please note that each different material has its own characteristic sound velocity.

Keep in mind that the A-Scan measures time of sound travel, NOT the velocity of sound. This means the A-Scan is essentially a Stopwatch that monitors the TIME to and from each reflector in any material. Let us dig deeper into the relationship:

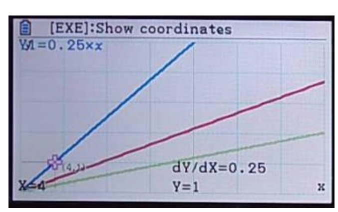
distance=velocity X time or *($d = v$ X $t$)*

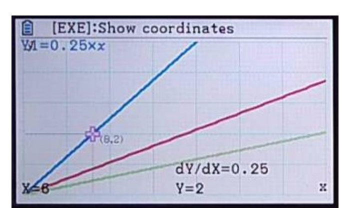
The A-Scan electronics must somehow make this calculation to measure the true tested distance. To help understand the A-Scan electronic math process, we will further examine the algebra and physics of this measurement.

First, let us look at the algebra: $d = v$ X $t$. In the original algebra format, this relationship is the same as the equation for a line: $y = mx + b$, where $b$=0.

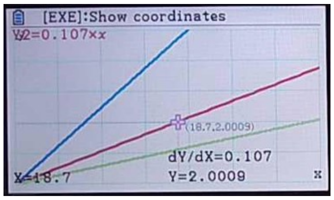
When viewed in this manner "$v$" from $d = v$ X $t$ *plays the same role as m. which is a constant slope for the line that can be plotted by d = v X t.* And......that is exactly what $v$ = velocity is when ENTERED into the A-Scan. It is the constant used along with the variable $x$ = "$t$ " measuring elapsed time as the sound beam travels to each reflector.

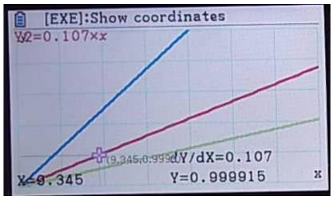
Let's compare the plots of sound travel distances in water, acrylic resin and aluminum using $y = mx$. Each of the 6 graphic plots below shows these plots.



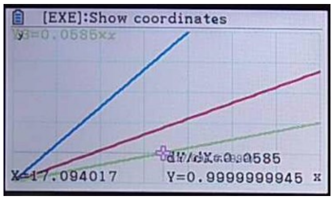



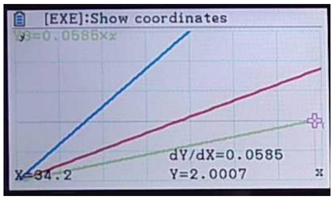
*The cross cursor on the blue plot shows 4µs travel time to 1 inch in aluminum and 8µs for 2 inches round trip distance.*



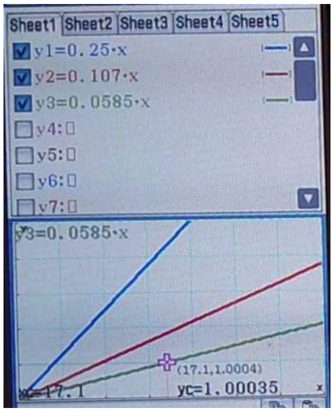

*The cross cursor on the red plot shows 9.345µs travel time to 1 inch in Lucite and 18.7µs for 2 inches round trip distance.*

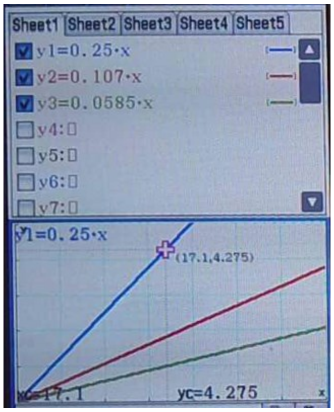



*The cross cursor on the green plot shows 17.09µs travel time to 1 inch in water and 34.2µs for 2 inches round trip distance.*

Whenever sound travels through water it always takes 17.09 µsecs to travel through 1 inch of water, no matter what velocity setting you enter into the A-Scan instrument. The only problem is that any sound velocity value other than 0.585 X 10^5 IPS that you enter into the A-Scan will not provide the correct distance value of water path distance on the display.




The two linear plots directly above compare distances obtained on an A-Scan display when using two different velocity settings (0.0585 X 10^5 IPS & 0.25 inch/µsec). The lefthand plot shows the red cross cursor on the green sloped line at (17.1, 1.0), which represents the measured distance of 1.0 inch at a time of 17.1 µsec in water when using the true velocity of sound in water, 0.0585 inch/µsec.

The adjacent righthand plot shows the red cross cursor on the blue sloped line at (17.1, 4.275), which represents the aluminum equivalent distance for 1 inch of water, 4.275 inches. On the righthand graph trace the horizontal axis to the right. When you reach 17.1, stop and then trace directly upward until you cross the blue sloped line. At the point of intersection of the blue sloped line move directly to the LEFT until you cross the vertical axis at the point of 4.275 inches.

With any pair of sloped lines, you can move to the desired point in time on the horizontal axis. Then trace a vertical line directly upwards, noting the two points on the vertical axis at which you cross each sloped line.

The previous algebraic plots were used only demonstrate the mathematical origin of the operation of the distance measuring capability of a UT A-Scan instrument. There was no intent to suggest that you plot curves and trace them to determine equivalent distance values. As a note, the original analog electronic UT instruments used repetitive time voltage sloped waveforms to generate distance measurements.

A quick way to determine the dual media equivalent of one or the media in a UT inspection when using an A-Scan during an A-Scan test is the following equations of two ratios.

$d_{RDG}$ = The resultant A−Scan display reading of the delay material length.

$d_{ACT}$ = The actual length of the delay path material\media (fluid or plastic).

$V_M$ = The velocity of sound in the inspected material\media (solids or metals).

$V_{DELAY}$ = The velocity of sound in the delay material\media (fluid or plastic).

*The proportional relationship and several solutions are shown:*

$$\frac{d_{RDG}}{d_{ACT}} = \frac{V_M}{V_{DELAY}}; \quad d_{RDG} = \frac{V_M \times d_{ACT}}{V_{DELAY}}; \quad \& \quad d_{ACT} = \frac{V_{DELAY} \times d_{RDG}}{V_M}$$

Let's use the relationships above to determine the Aluminum equivalent water path distance for the actual 1-inch water path distance. The aluminum plate is 1-inch thick. Aluminum velocity is 2.5 X 10^5 IPS; Water velocity is 0.585 X 10^5 IPS.

$$d_{RDGWP} = \frac{V_{AL} \times d_{ACTWP}}{V_{WP}} = \frac{2.5 \times 1.0}{0.585} = 4.27$$

$\cong$ *4.3 inches on display*

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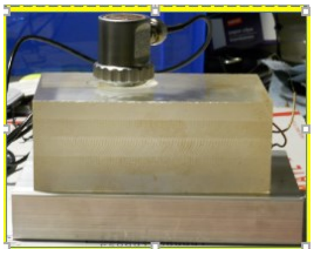
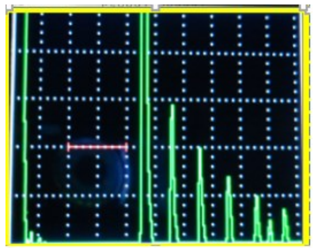
SOUND REFLECTIONS

### Another Delay Material Distance Calculation



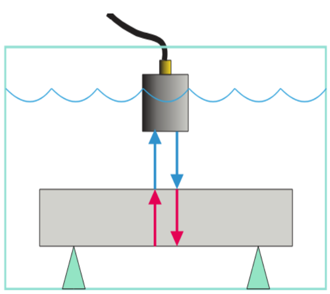


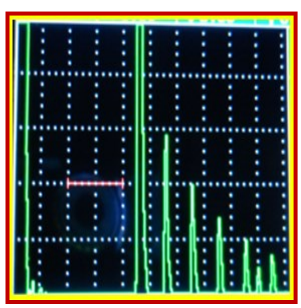
Here we determine the Aluminum equivalent Lucite path distance for the actual 1.9-inch Lucite path distance. The aluminum plate is 1-inch thick. Aluminum velocity is 2.5 X 10^5 IPS; Lucite velocity is 1.07 X 10^5 IPS.

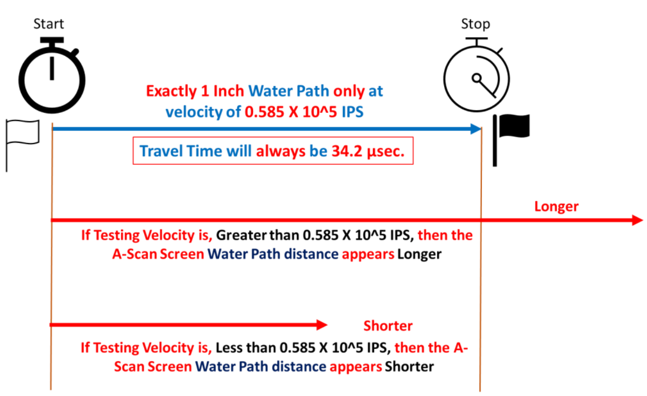
$$d_{RDGLu} = \frac{V_{AL} \times d_{ACTLu}}{V_{Lu}} = \frac{2.5 \times 1.9}{1.07} = 4.439$$

$\cong$ *4.4 inches on display*

### The Stop Watch Diagram Analogy








The **immersed transducer and plate image** above the **stop-watch-diagram** represents a dual media UT test. **The stop-watch-diagram,** itself, represents a **1-inch water path distance** over which the sound energy travels to and from the front surface of this **1-inch metal plate**. The basic ***"take away"*** from this stop-watch diagram should be that the sound energy round trip travel time for 1 inch of water will **ALWAYS BE 34.2 µsecs per inch of water** because it is mathematically related to the characteristic **Round Trip Time (RTT) of water** based solely upon the **characteristic sound velocity** (**0.585 X 10^5 IPS**) of water. The metal plate characteristic sound velocity will be greater that water causing the distance between echoes to be less that the distance for water, ***even though the distances are the same.***

Note, every material has its own unique characteristic sound velocity.

## *Importance of Sound Beam Energy Time of Flight*

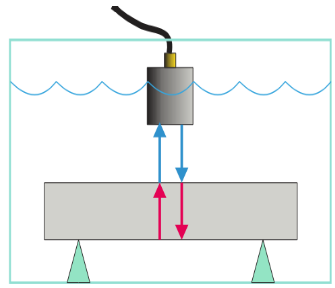
$$d = v \ X \ t$$

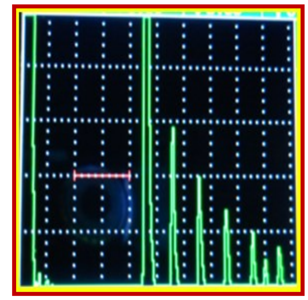
*In our first issue, our initial topic was travel time of sound energy in different materials. As you can see, this issue's topic depends on understanding sound energy travel time for determining the sound path distance by an ultrasonic A-Scan Instrument.*

# UT PUZZLE

## (Last Issue's) "UT PUZZLE"

*"R U A UT MATH PRO?"* You are inspecting a 1 inch thick aluminum plate through a water path using an A-Scan instrument calibrated with the sound velocity in aluminum. The distance of the water path read on the screen graticule, initial pulse to interface echo, is 4.5 inches. The velocity of sound in Aluminum is 2.5 x 10^5 IPS and the velocity of sound in water is 0.585 x 10^5 IPS.





The SOLUTION to the "**UT PUZZLE**" in the last issue of ***Sound Reflections*** is based on this issue's front page discussion of Dual Media UT inspections using an A-Scan instrument.

$d_{ACT} = ?$

$d_{RDG} = 45$ inch

$V_{AL} = 2.5X\ 10^5\ IPS$

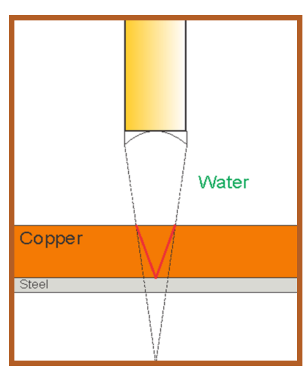
$V_{DELAY} = 0.585\ X\ 10^5\ IPS$

$$d_{ACT} = \frac{V_{DELAY} \times d_{RDG}}{V_M} = \frac{0.585 \times 4.5}{2.5} = 1.05\ inches$$

## *"R U A UT PRO?"*

You are required to inspect the bond line of a steel reinforced copper electrical bus bar with the dimensions shown in the adjacent diagram. You will be using a spot focused transducer with a focal distance of 5 inches in water. Assume water velocity is 0.0585µs/in & copper velocity is 0.183µs/in.

***What is the required water path to place the focal point on the bond line?***




The adjacent diagram shows a 1 inch piece of copper busbar reinforced by 1/8 inch strip of carbon steel.

A UT test is required to ensure that there is ZERO LACK of bond between the copper bar and the steel strip.

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