

A Leak Is Located More Finely Where Sound Is Slow, but the Error from Misjudging Sound Speed Does Not Depend on the Pipe

— overestimating the sound speed by 1 percent shifts a leak at 20 m by -0.300000 m in either pipe, and a leak at the midpoint of 50 m by 0 — the separator is whether one asks about the sampling step or the assumed sound speed — [Paper 896]

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— *From thinking to syncing.* —

Abstract

When locating a water leak by sound, it is easy to assume that how finely it can be located depends on the fineness of the clock. This paper counts, in a model that locates a leak from the delay between sounds picked up by two receivers, the error from the sampling step and the shift from misjudging the sound speed in the pipe, for two pipes with different sound speeds. No new theorem or law is claimed. First, with the same clock, pipes with slower sound give finer positions: sampling at 10 kHz, the position step is 0.020000 m in a pipe with sound speed 400 m/s and 0.060000 m at 1200 m/s (Section 2). Second, the error follows the size of the step: locating the leak 60 times with noise, the root-mean-square error is 0.005357 m and 0.017165 m, the ratios to the step divided by $\sqrt{12}$ are 0.927930 and 0.991014, and the ratio between the pipes is 3.203949 (Section 2). Third, and this is the core. The shift from misjudging the sound speed by the same fraction does not depend on the pipe material: overestimating the sound speed by 1 percent shifts a leak at 20 m by -0.300000 m in either pipe, and a leak at 35 m by -0.150000 m (Section 3). Fourth, the shift grows away from the midpoint: at 50 m, midway between the receivers, the shift is 0, and it grows toward either receiver (Section 3). Fifth, that misjudgment exceeds the step: for a leak at 20 m, the shift from a 1 percent misjudgment is 15.000000 times the step in the slow pipe and 5.000000 times in the fast pipe (Section 3). Sixth, the separator is whether one asks about the sampling step or the assumed sound speed: asking about the step makes the slow pipe look better; asking about the assumed speed removes the material, leaving only the fraction misjudged and the distance from the midpoint (Section 4). **Keywords:** water leak, cross-correlation, sound speed in the pipe, sampling, position step, misjudged speed.

Scope of this paper (scope note): No new theorem or law is claimed: that a leak is located from the cross-correlation of sounds at two receivers, that the fineness depends on sampling frequency and sound speed, and that locating it requires knowing the sound speed in the pipe are all known in leak detection. No real pipe is claimed: sound speeds of 400 m/s and 1200 m/s, receiver spacing of 100 m, sampling at 10 kHz and the noise level are model values matching no pipe material or diameter. Waveforms are not distorted: bends and branches, weakening of sound along the way, and sound speed varying with frequency are not included. Relation to earlier papers: Paper 617 showed that if a valve closes faster than a round trip along the pipe, the water-hammer pressure does not depend on how it closes, and counted there that the wave speed in the pipe is not the sound speed of water but slower by the stretch of the pipe wall. This paper stands beside it. There the wave speed in the pipe set the pressure. Here misjudging that speed becomes a shift in the leak position. What is added is measuring the sampling step and error in two pipes with different sound speeds, measuring that the shift from a misjudged sound speed does not depend on the pipe material, comparing that shift with the step, and placing the separator on step versus assumed speed.

1. Notation and the Question

Setting: two receivers are placed $L = 100$ m apart on a pipe, and a leak lies at distance x from receiver 1. The leak's sound travels both ways in the pipe at speed c and reaches receiver 2 later than receiver 1 by τ . The sounds at the two receivers are sampled at $f_s = 10$ kHz, noise is added to each, they are cross-correlated, and the delay of the highest peak is taken as τ .

$$\tau = \frac{L - 2x}{c}, \quad x = \frac{L - c\tau}{2}, \quad \Delta x = \frac{c}{2f_s}$$

Δx is the position step when the delay changes by one sample. If the sound speed is misjudged as $\hat{c} = (1 + \varepsilon)c$, the located position shifts by the following.

$$\hat{x} - x = -\frac{\varepsilon c \tau}{2} = -\frac{\varepsilon (L - 2x)}{2}$$

Question: is the fineness of a leak's position set by the fineness of the clock, or by the assumed sound speed?

2. Sampling Step and Error

Computation 2.1: in two pipes with different sound speeds, the leak was placed at random between 20 and 80 m and located 60 times each.

pipe	position step (m)	RMS error (m)	largest error (m)
sound speed 400 m/s	0.020000	0.005357	0.009951
sound speed 1200 m/s	0.060000	0.017165	0.030098

Observation 2.2

with the same clock, pipes with slower sound give finer positions. Comparing the RMS error with the step divided by $\sqrt{12}$ (0.005774 m and 0.017321 m) gives 0.927930 and 0.991014, so the error followed the size of the step: the ratio of errors between the pipes is 3.203949, close to the sound-speed ratio of 3. The largest error was within 0.6 times the step in both pipes.

3. Misjudging the Sound Speed

Computation 3.1: from the true delay τ , the position was located with the sound speed overestimated by 1 percent, and the shift was found.

leak position	shift (400 m/s pipe)	shift (1200 m/s pipe)
20 m	−0.300000 m	−0.300000 m
35 m	−0.150000 m	−0.150000 m
50 m	0.000000 m	0.000000 m

Observation 3.2

this is the core. The shift from misjudging the sound speed by the same fraction does not depend on the pipe material. The shift is the same in both pipes, 0 at the midpoint of 50 m, and larger toward either receiver: as the formula shows, the shift is set only by the fraction ε and the distance from the midpoint, with c cancelling against τ . The 0.300000 m shift for a leak at 20 m is 15.000000 times the step in the slow pipe and 5.000000 times in the fast pipe.

4. The Separator

Observation 4.1

the separator is whether one asks about the sampling step or the assumed sound speed. Asking about the step, with the same clock the slow pipe locates the leak with a third of the fast pipe's step: asking about the assumed speed, the material disappears, leaving only the fraction misjudged and the distance from the midpoint, and even a 1 percent misjudgment shifts a leak at 20 m by more than the step in either pipe.

Observation 4.2

placed beside Paper 617.617 counted that the wave speed in a pipe is not the sound speed of water but slowed by the pipe wall, and showed that this speed sets the water-hammer pressure. Here, misjudging that speed shows up as a shift in the leak position.

Observation 4.3

what is not said. Sound speeds of real pipes, bends and branches, weakening of sound along the way, sound speed varying with frequency, and which pipe materials make the assumed speed more likely to be off are not treated. What is shown is that, in this model, with the same clock pipes with slower sound give finer positions, and the shift from misjudging the sound speed by the same fraction does not depend on material.

5. Census and Closing

1. $x = (L - c\tau)/2$ (Section 1): **position from delay.**
2. steps **0.020000 m** and **0.060000 m** (Computation 2.1): **400 and 1200 m/s.**
3. RMS **0.005357 m** (Computation 2.1): **slow pipe.**
4. RMS **0.017165 m** (Computation 2.1): **fast pipe.**
5. ratio **3.203949** (Observation 2.2): **close to the speed ratio.**
6. ratios to $\sqrt{12}$: **0.927930 and 0.991014** (Observation 2.2): **as the step says.**
7. **-0.300000 m** at **1 percent** (Computation 3.1): **the core; same in both pipes.**
8. **0** at the midpoint (Computation 3.1): **larger further away.**

9. **15.000000 and 5.000000 times the step** (Observation 3.2): **larger than the step.**

10. **step, or assumed speed** (Observation 4.1): **the separator; Paper 617.**

Closing: A leak is located more finely in pipes where sound travels slowly, but the error from misjudging the sound speed by the same fraction does not depend on the pipe material. Sampling at 10 kHz, the position step was 0.020000 m in a pipe with sound speed 400 m/s and 0.060000 m at 1200 m/s, with RMS errors of 0.005357 m and 0.017165 m: with the same clock, the slow pipe has the advantage. But overestimating the sound speed by 1 percent shifts a leak at 20 m by -0.300000 m in either pipe, 15.000000 and 5.000000 times the step: the shift is set only by the fraction misjudged and the distance from the midpoint, and material drops out of the formula. Placed among the earlier papers: beside Paper 617's "the wave speed in a pipe is not the sound speed of water", we placed the shift in leak position that comes from misjudging that speed. To be honest: the two sound speeds and the noise level are model values, and bends, branches and weakening along the way are not included.

References

1. Yamagishi, Y. (2026). *If a Valve Closes Faster Than a Round Trip Along the Pipe, the Water-Hammer Pressure Does Not Depend on How It Closes* [Paper 617]. YOI: <https://www.yamagishiyuuki.com/yoi/617>; DOI: 10.5281/zenodo.23014494
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