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Air pressure transient generation, propagation and alleviation in tall buildings.

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- Background
- Theoretical Approaches
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The Problem

- Increasing evidence of very large pressure transients associated with tall buildings.

- Anecdotal evidence of pressure surges capable of lifting manhole covers in prestigious buildings

- Evidence of toilet traps being completely blown out in 50 storey buildings.

Tall Buildings

- The number of tall buildings being constructed around the world is growing rapidly.
- more than 50 m (or 14 floors) in height is typically used as the lower threshold.

- A building over 300 m (or 84 floors) in height is classed as a “supertall building”, and over 600 m (or 168 floors) in height is classed as a “megatall building”.

- In 2016, 128 buildings of 200 m height or greater were completed, 10 of which were classed as supertall.

- The total number of buildings of 200 m height or greater around the world is now 1,168 (a 441% increase from the year 2000, when just 256 existed), with numbers expected to grow each year.

Air pressure Transients in BDS

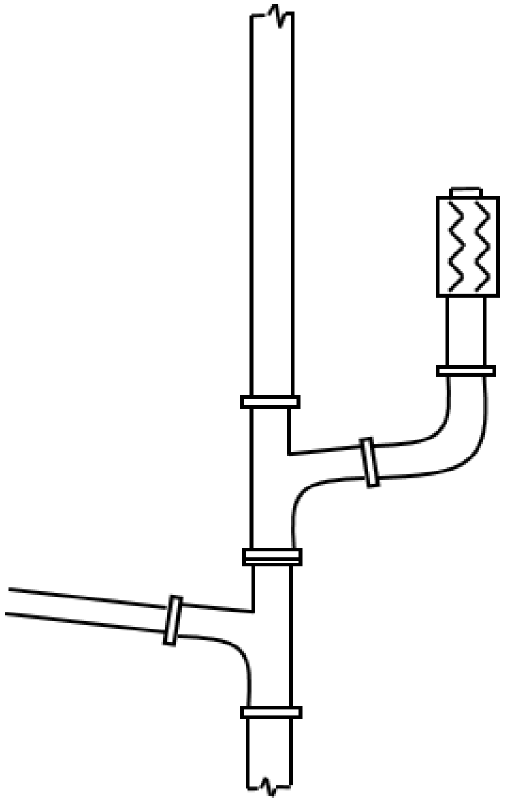
Air pressure transients in BDS are due to sudden changes in airflow brought about by some occlusion of the route available for the passage of air. The magnitude of these transients can be determined from the Joukowsky expression;

$$\Delta p = \rho c V$$

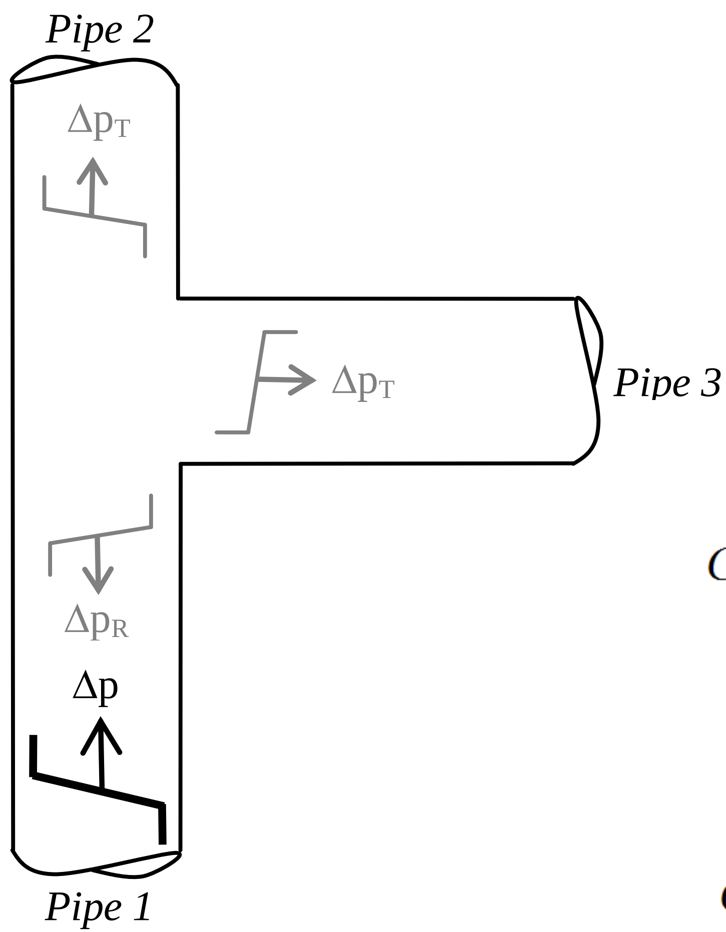
Pressure transient levels

Existing attenuators (P.A.P.A.™) invented at Heriot-Watt University and developed in association with STUDOR in the early 2000s were designed to deal with low amplitude air pressure transients in the region of 100 mm wg (1000Pa)

Typical arrangement for attenuator installation



Air pressure wave propagation – one of the basis for existing attenuation techniques.



$$C_T^{junction} = \frac{\frac{2A_1}{c_1}}{\frac{A_1}{c_1} + \frac{A_2}{c_2} + \frac{A_3}{c_3} + \ldots + \frac{A_n}{c_n}}$$

$$C_R^{junction} = \frac{\frac{A_1}{c_1} - \frac{A_2}{c_2} - \frac{A_3}{c_3} - \ldots - \frac{A_n}{c_n}}{\frac{A_1}{c_1} + \frac{A_2}{c_2} + \frac{A_3}{c_3} + \ldots + \frac{A_n}{c_n}}$$

Division of an incoming air pressure wave (Δp) at a three-pipe junction into its transmitted (Δp_T) and reflected (Δp_R) parts

Significance of wave speed (c) on attenuation

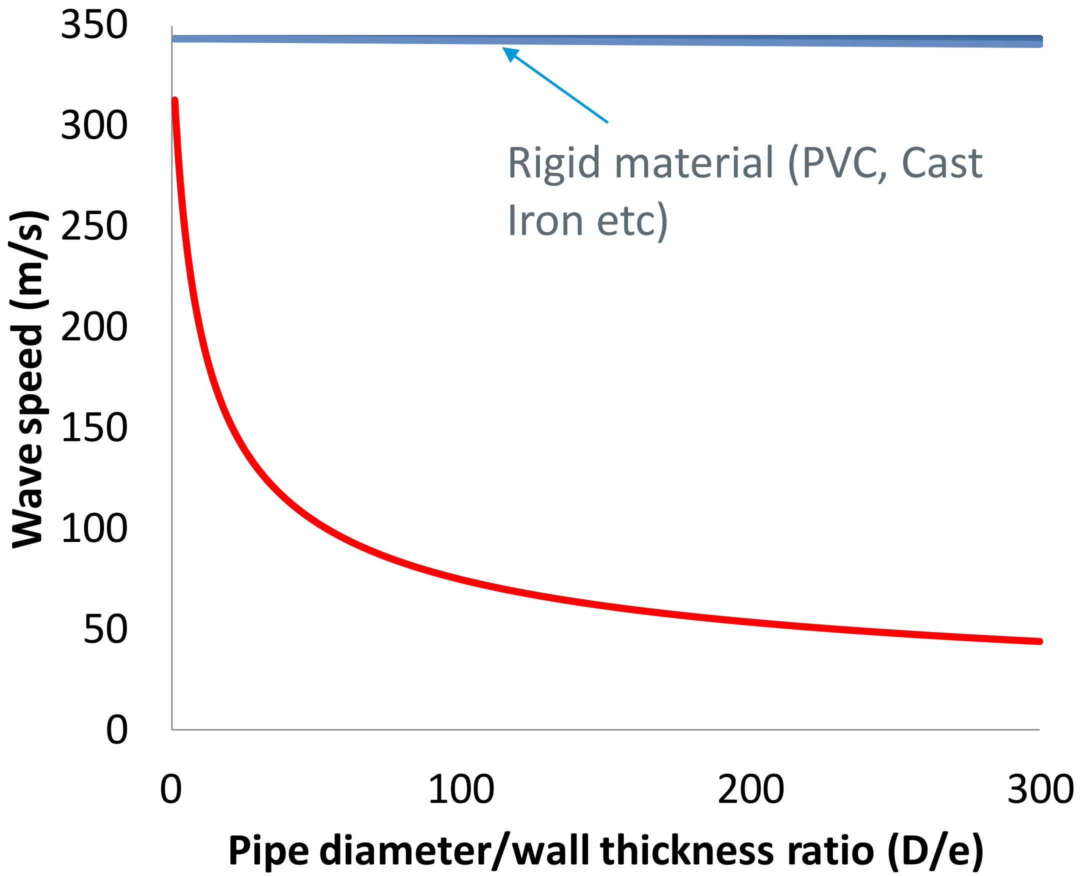
$$c = \sqrt{\frac{\gamma P}{\rho\left[1 + \frac{\gamma P D}{E e}\right]}}$$

c	wave speed
γ	ratio of specific heat
P	pressure
ρ	fluid density
D	pipe diameter
E	Young's Modulus
e	pipe wall thickness

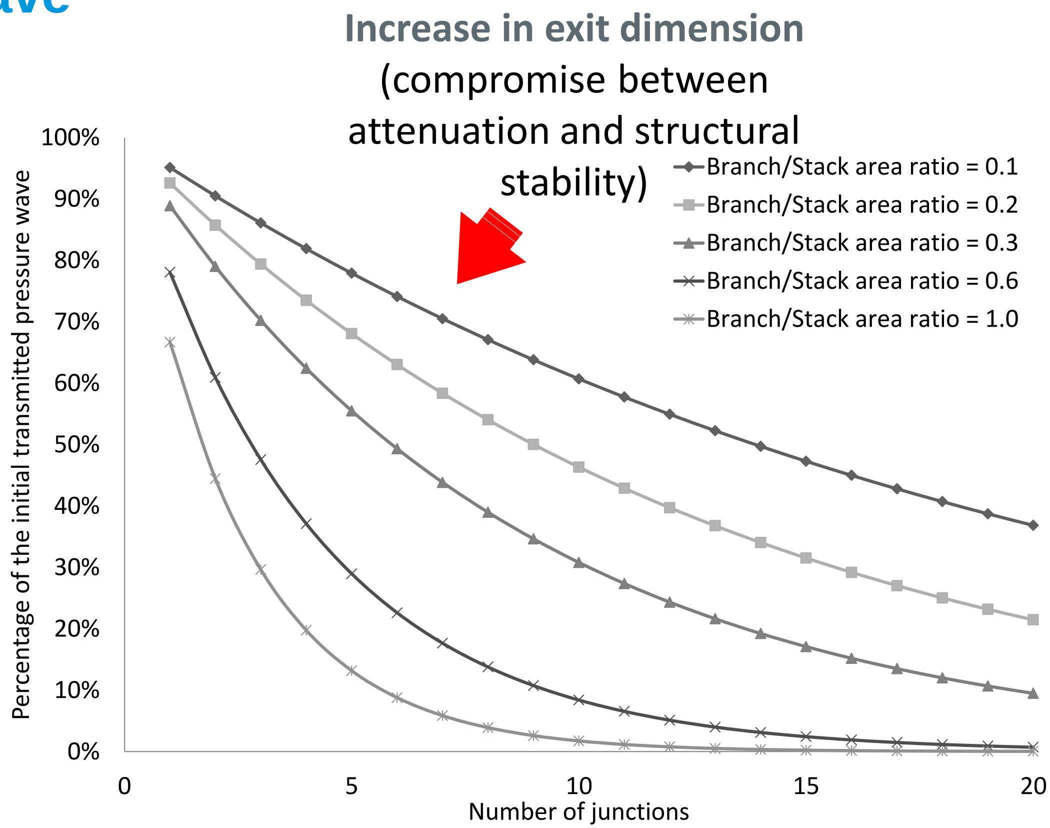
Table 1: Values of Young's modulus for a range of materials

Material	Range (GPa)
Stainless steel	200-215
Cast Iron	80-160
Copper	107-130
Aluminium	69-70
Glass	68
Reinforced concrete	30-60
PVC Plastic	2.4-3.3
Synthetic rubber	0.0007-0.0083

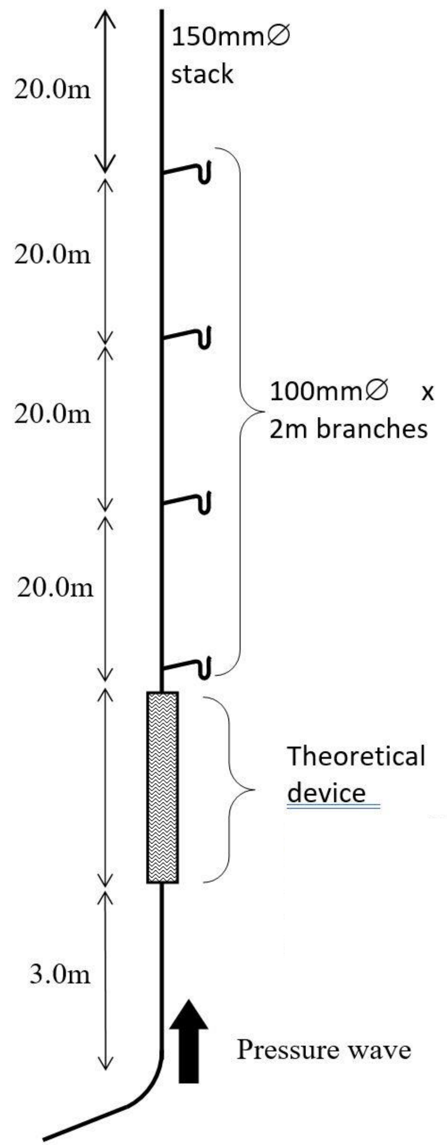
Influence of pipe wall thickness



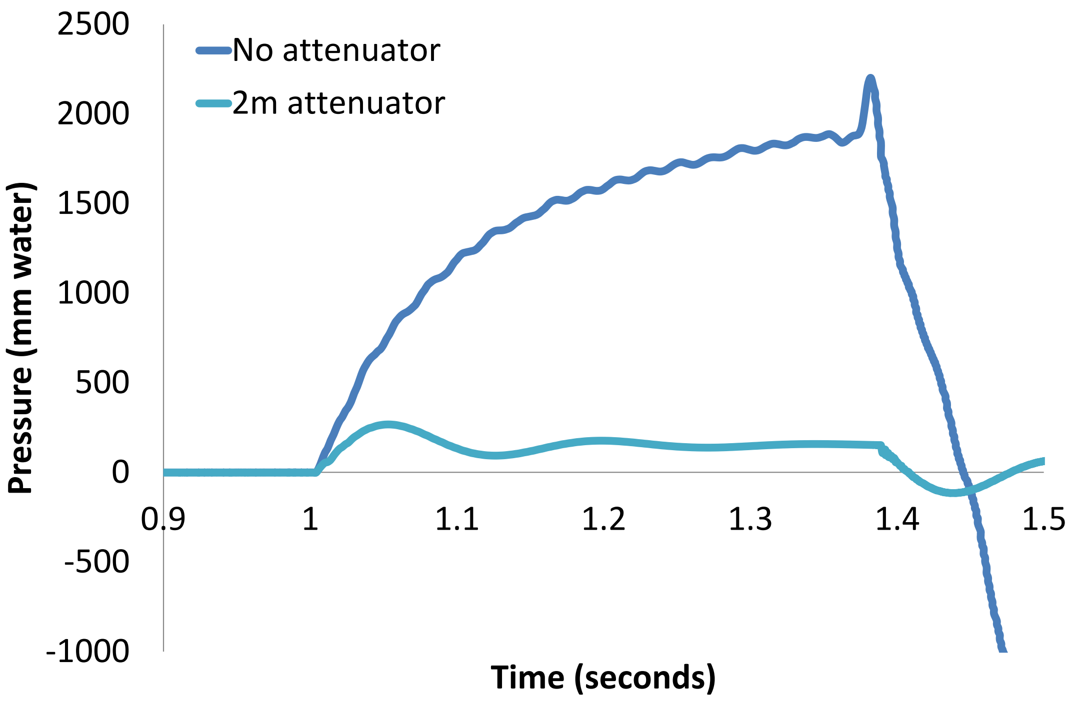
The relationship between branch to stack area ratio, number of junctions traversed, and the resultant proportion of transmitted pressure wave



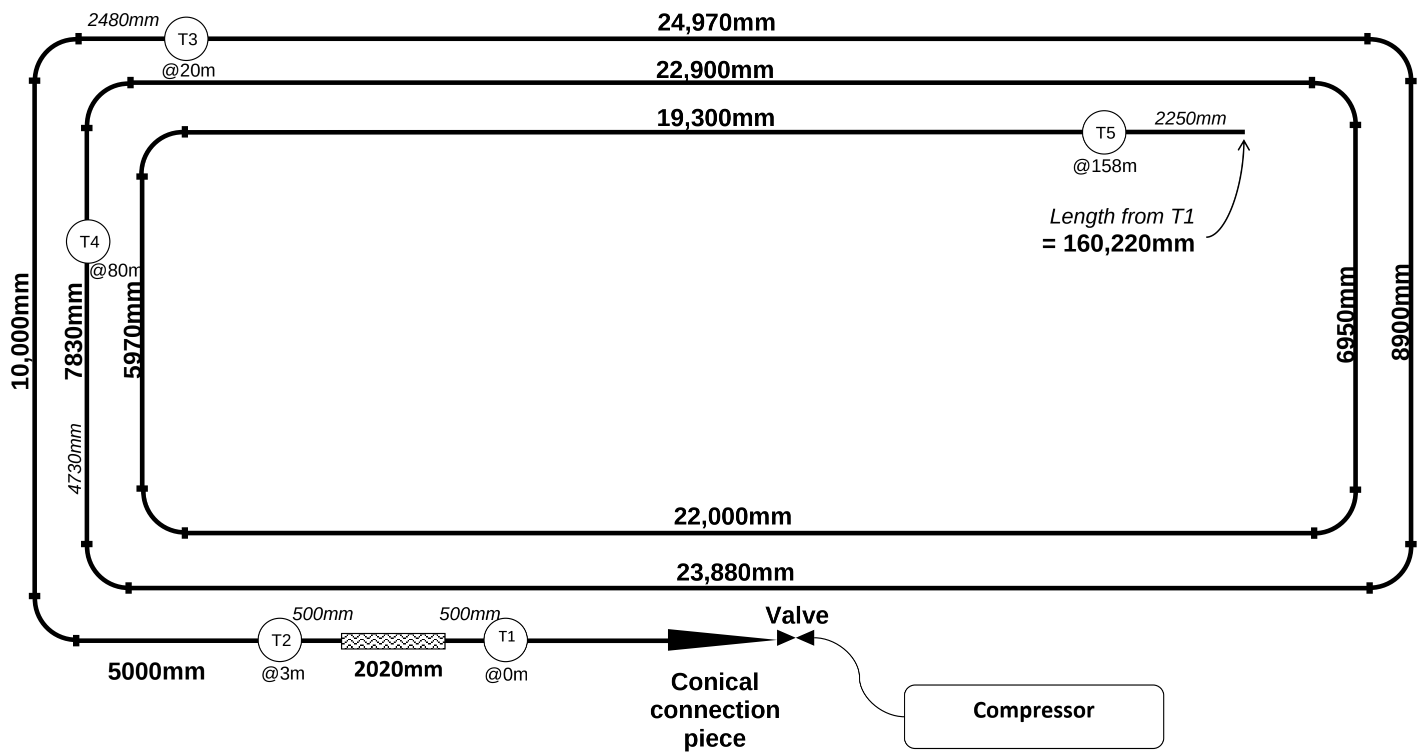
Evaluating a novel ‘in-line’ attenuator



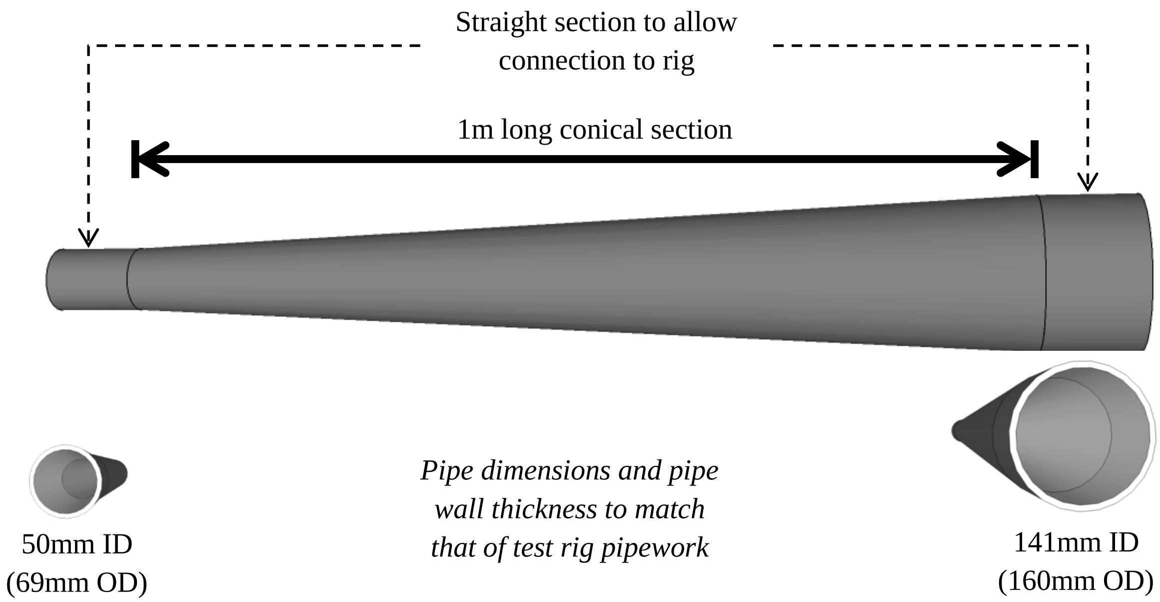
Simulated system in AIRNET


No attenuator
2m attenuator
2500
2000
1500
1000
500
0
-500
-1000
0.9
1
1.1
1.2
1.3
1.4
1.5
Pressure (mm water)
Time (seconds)

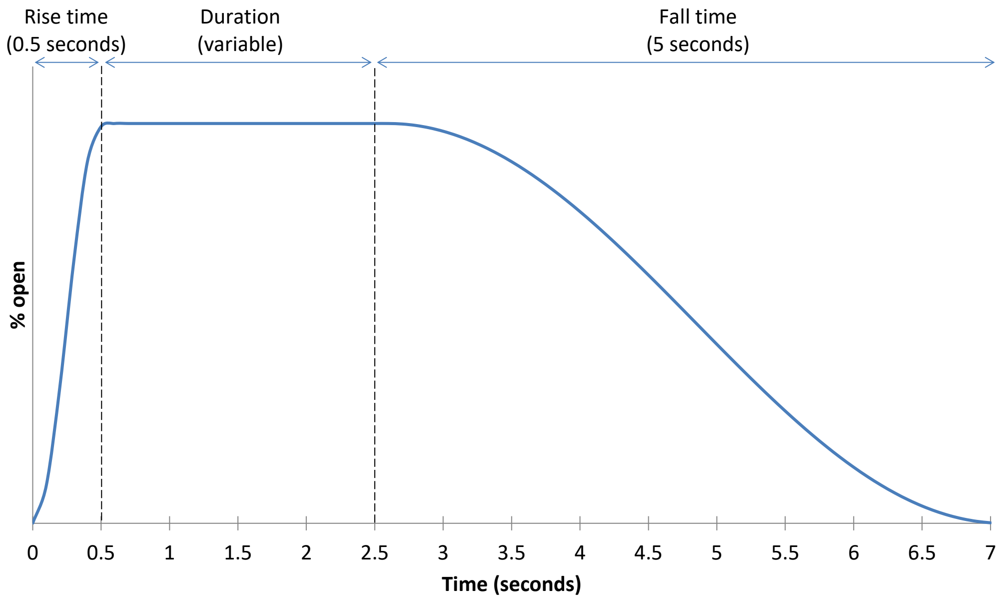
Full scale test system showing instrumentation

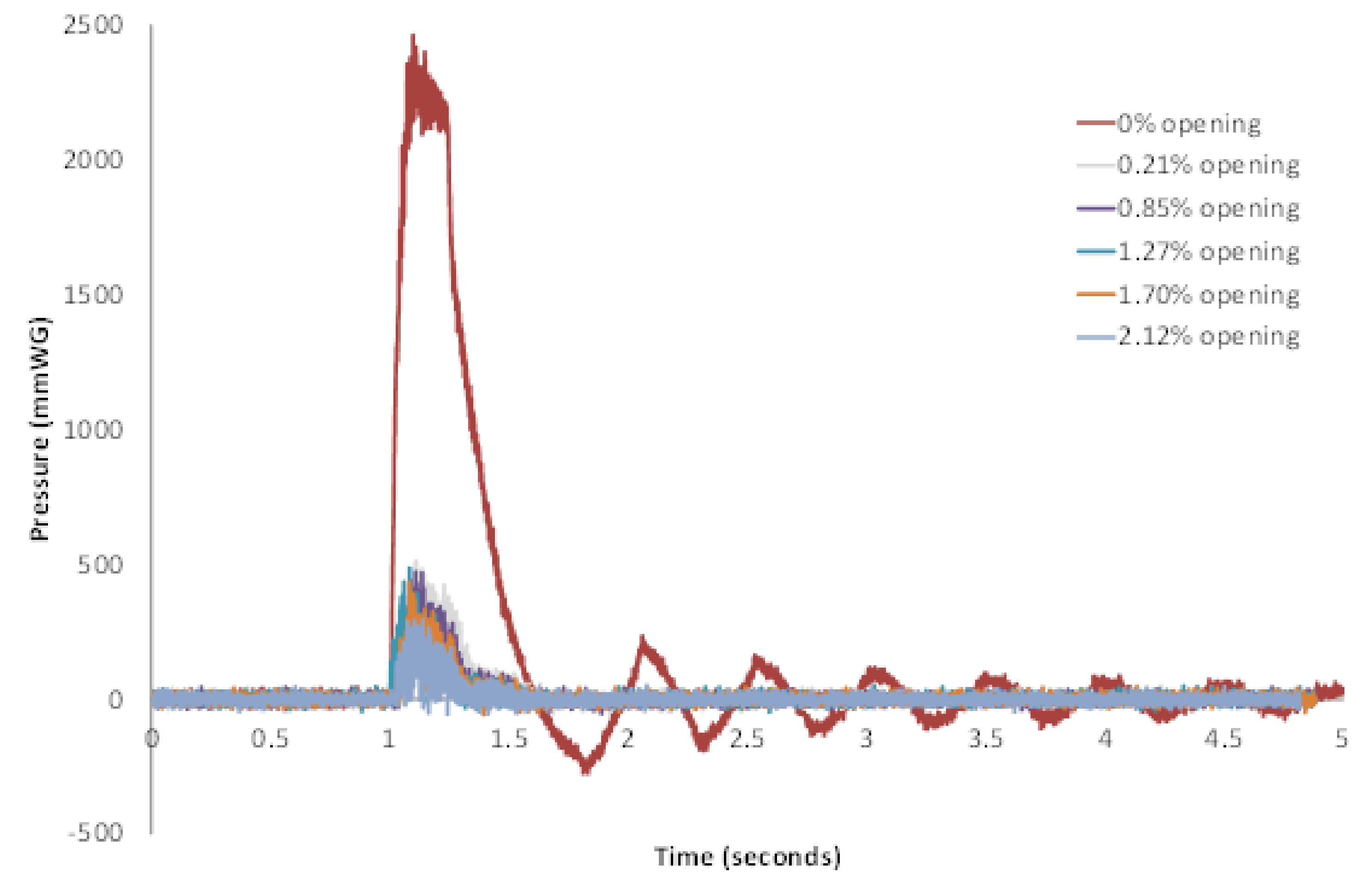


Control of pressure wave inlet to avoid reflection.



Adjustment of control to minimize pressure ‘bounce’ during fall time.





2500
2000
1500
1000
500
0
-500
Pressure (mmWG)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (seconds)
0% opening
0.21% opening
0.85% opening
1.27% opening
1.70% opening
2.12% opening

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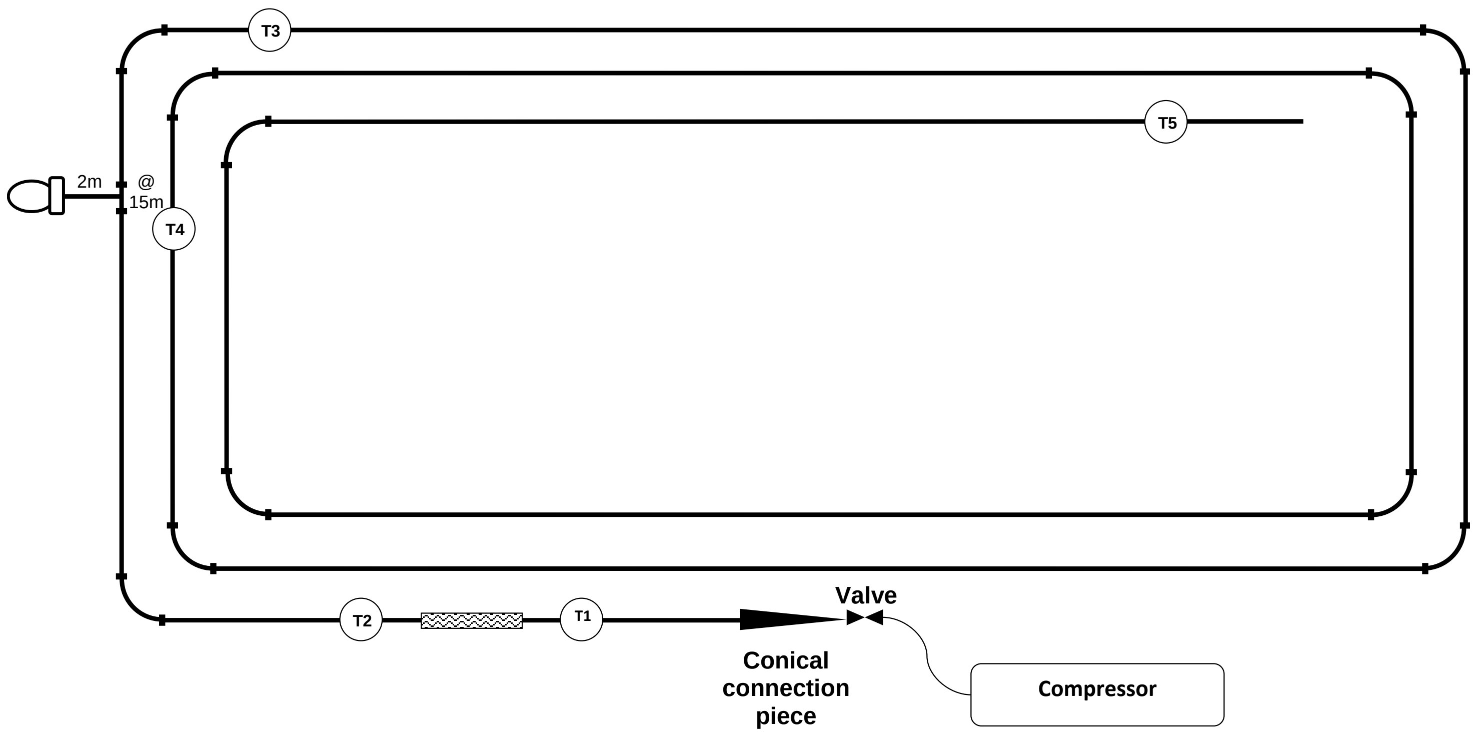
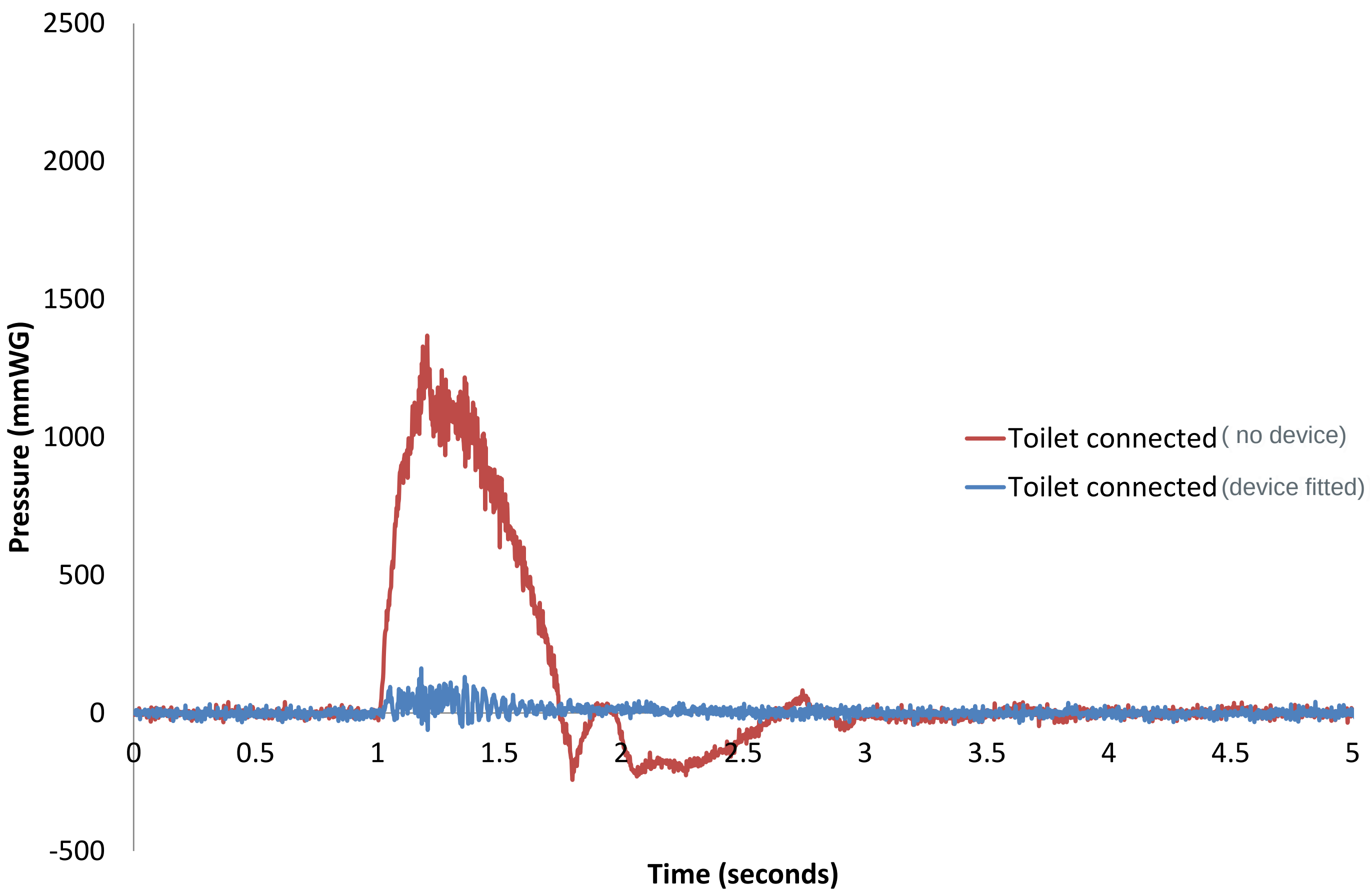


Full-scale test rig showing branch and WC connection.

The WC is installed near the base of the stack (floor 3 approx).


only a small movement of trap water and
a bubble emerges



Comparison of the measured pressure response from the test rig with a toilet fitted 15m from pressure transducer T1 with and without a contained Inline attenuator fitted.

Conclusions

- Pressure transients are inevitable in building drainage systems, particularly in tall building.

- Nearly two decades of work on pressure transient alleviation in tall buildings have shown that positive pressures can be much larger than existing devices can handle. (in excess of 1.5 m wg)

- A new in-line device capable of destroying 1.5 m pressure surges is presented in this work, and represents a step change in technology.

- Attenuation of up to 90% of the air pressure wave is possible.
- Air pressure wave volumes of approx. 135 litres can be destroyed. (4 litres currently typical)
- Devices can also attenuate negative transients.
- Since the device is in-line with the vertical stack, it is unobtrusive and saves valuable space in service ducts.
- Current trials in wet systems show similar results and no adverse affects on system flow and pressure regime.

Thank you for listening