The Experimental Facility for Wave-based Defect Detection at University of Perugia, Italy

B. Brunone, S. Meniconi, M. Ferrante, C. Capponi, E. Mazzetti

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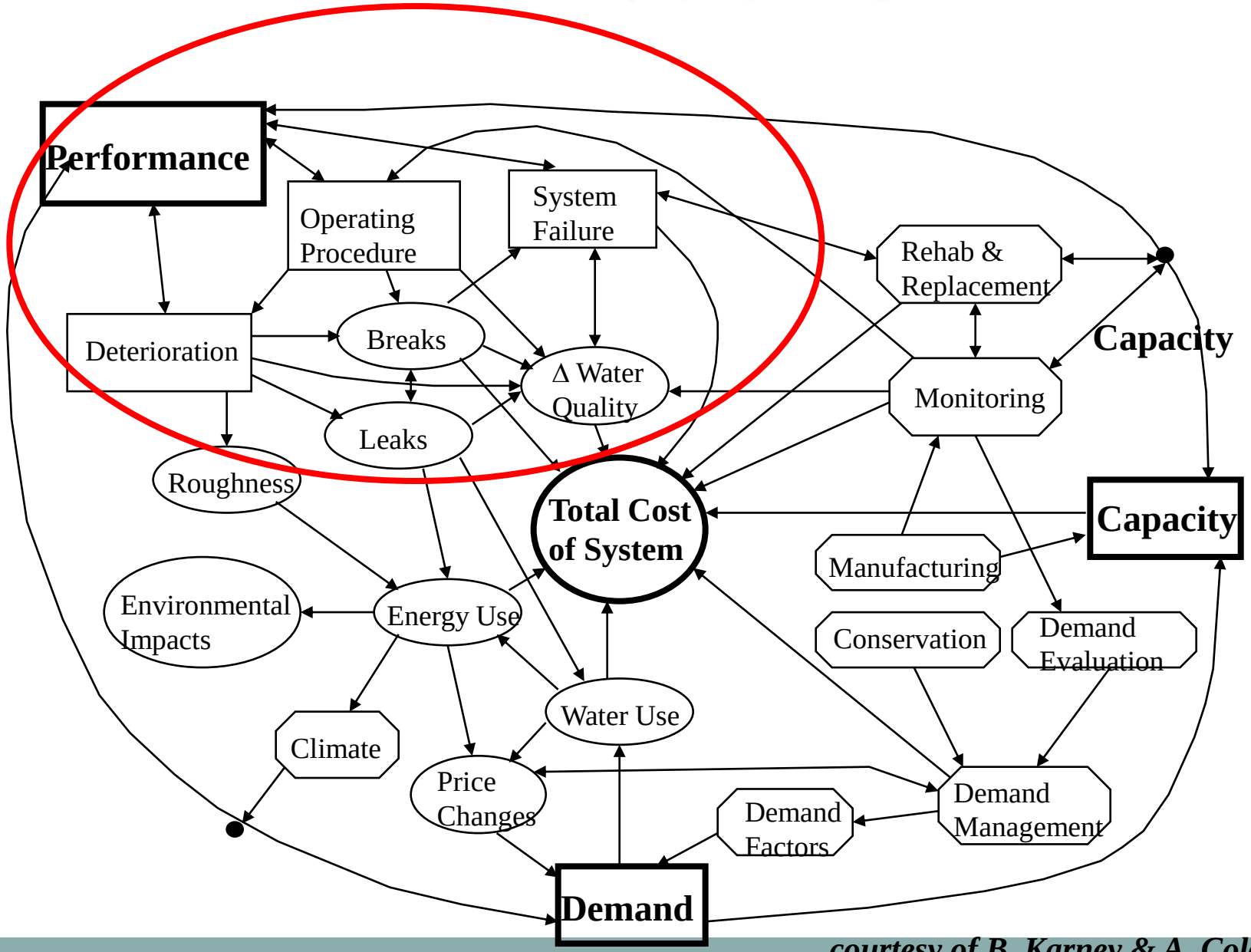
In the labyrinth of pipe systems…



courtesy of B. Karney & A. Colombo
University of Toronto, Canada

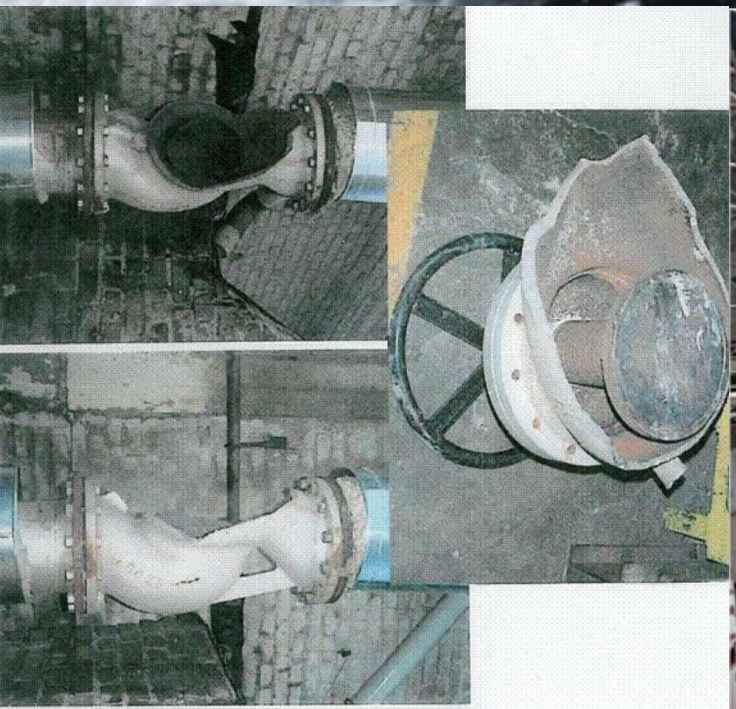
Waterhammer

Colpo d’ariete

Coup de belier

Arietenschlag

Golpe de ariete



The Experimental Facility for Wave-based Defect Detection at University of Perugia, Italy

Transient test-based techniques(TTBT)

Low frequency waves (LFW)

Time-domain approach

Short-period analysis

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Transient test-based techniques(TTBTs)

Unsteady-state tests are executed for detecting anomalies (e.g., leaks, partial blockages,…); pressure waves explore the systems

(from the practical point of view this implies a very short duration of tests and the fact that the well-known pipe system inaccessibility is overcome)

Only pressure data are acquired (pressure signal)

(from the practical point of view this implies the use of cheap probes quite "easy" to install with respect to flowmeters)

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Low frequency waves (LFW)

LFW ➔ 1 kHZ or less

(from the practical point of view this allows using 1-D hydraulic transient models but reduces spatial resolution)

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Time-domain approach

Pressure signals are analysed in the time-domain and all information are extracted by it without using directly the governing equations (i.e., properties of pressure waves are considered and the classical ITA approach in not followed)

(from the practical point of view this reduces computational efforts significantly also in terms of initial condition analysis and makes the analysis more intuitive at least for simple systems)

Short-period analysis

Attention is focused on the first pipe characteristic times

(from the practical point of view this reduces significantly the importance of both unsteady friction and, for polimeric pipes, viscoelasticity)

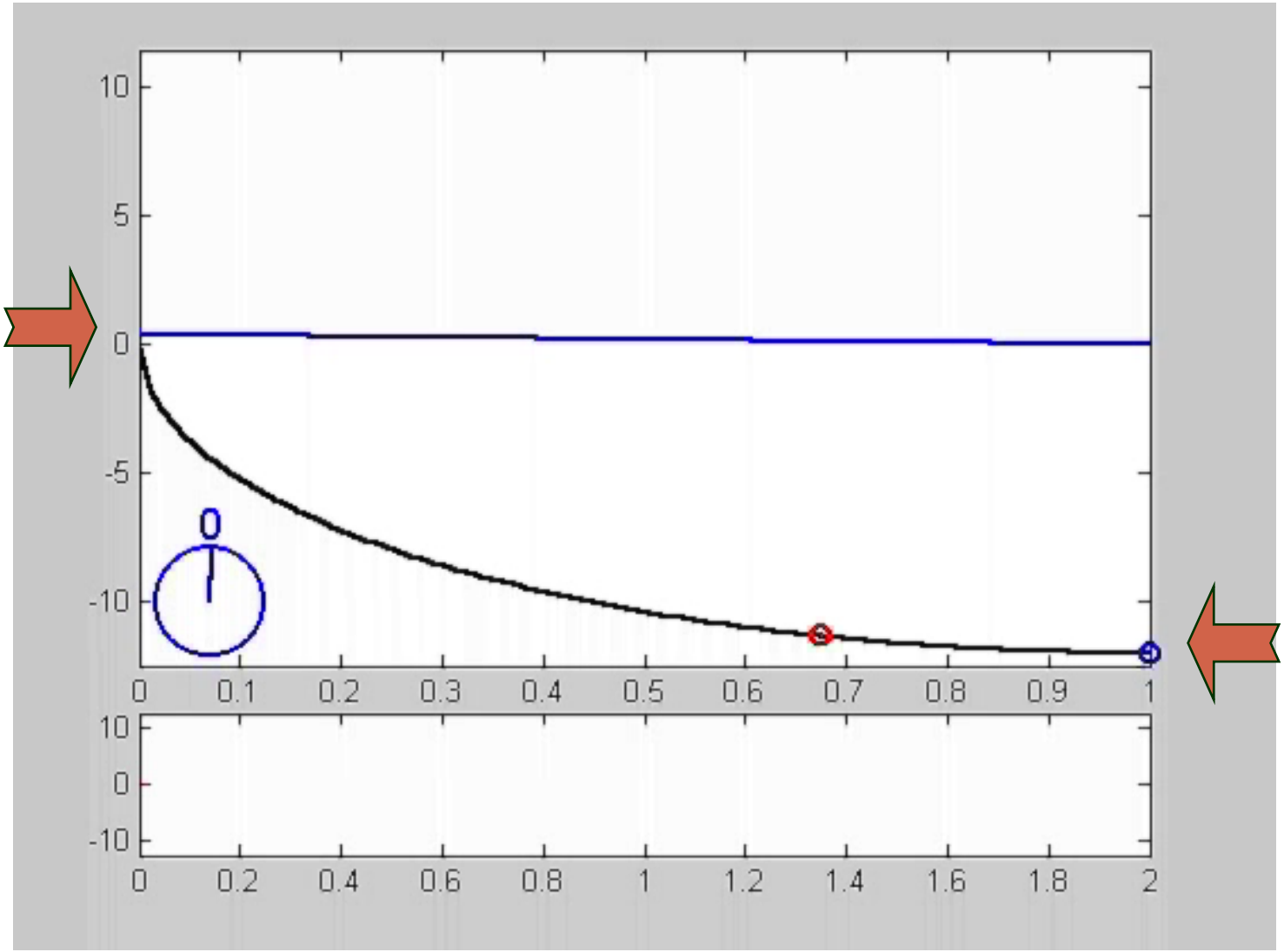
"SIMPLE" PIPE SYSTEMS

(i.e., classical transmission mains)

LABORATORY EXPERIMENTS

Transient in an intact pipe

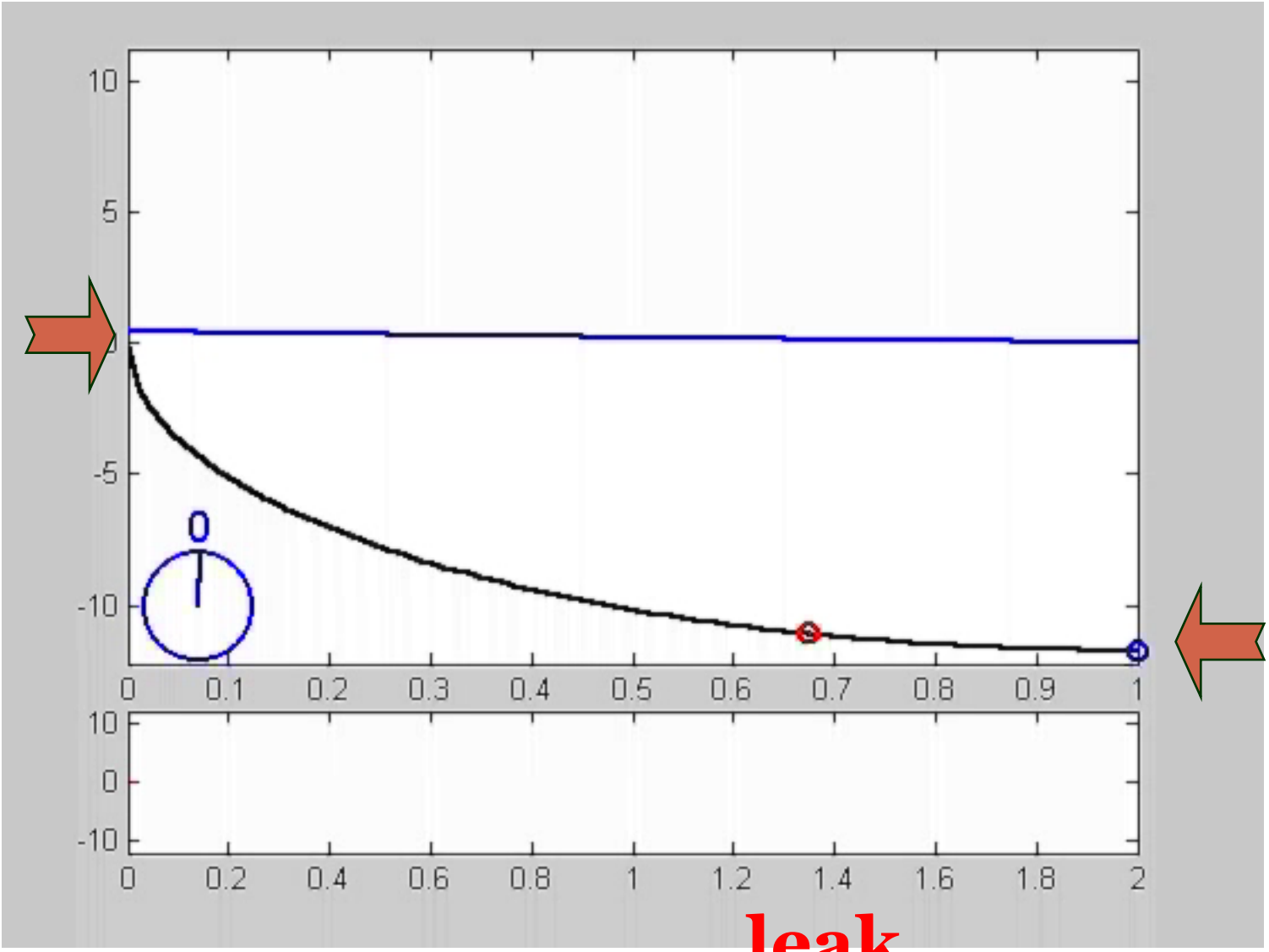
Supply reservoir



Manoeuver valve

Transient in an intact pipe

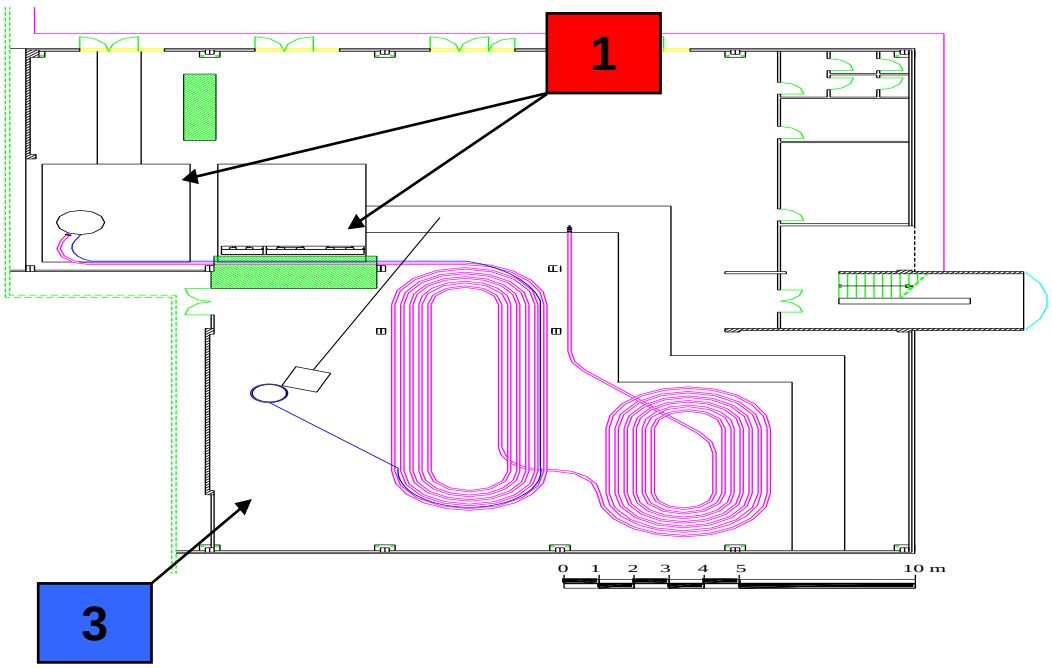
Supply reservoir



Manoeuver valve

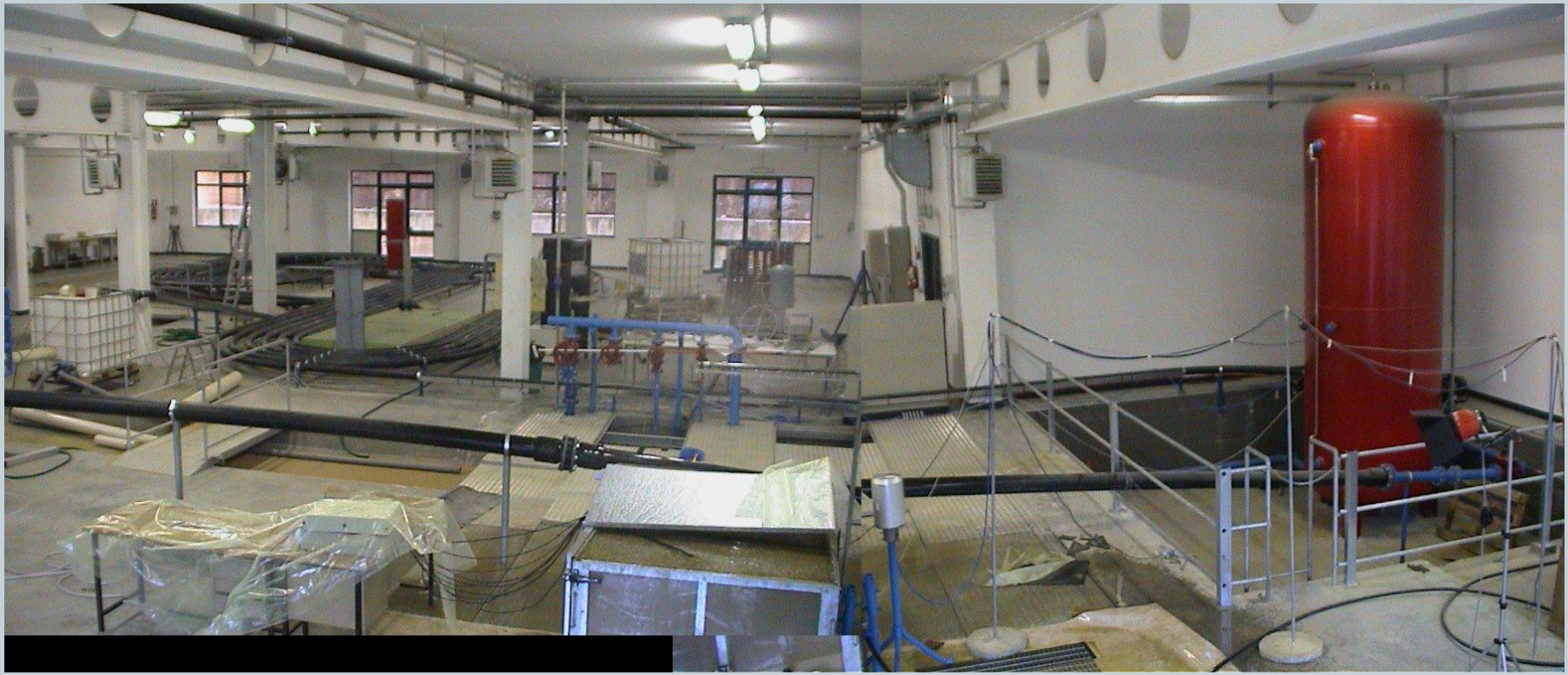
leak

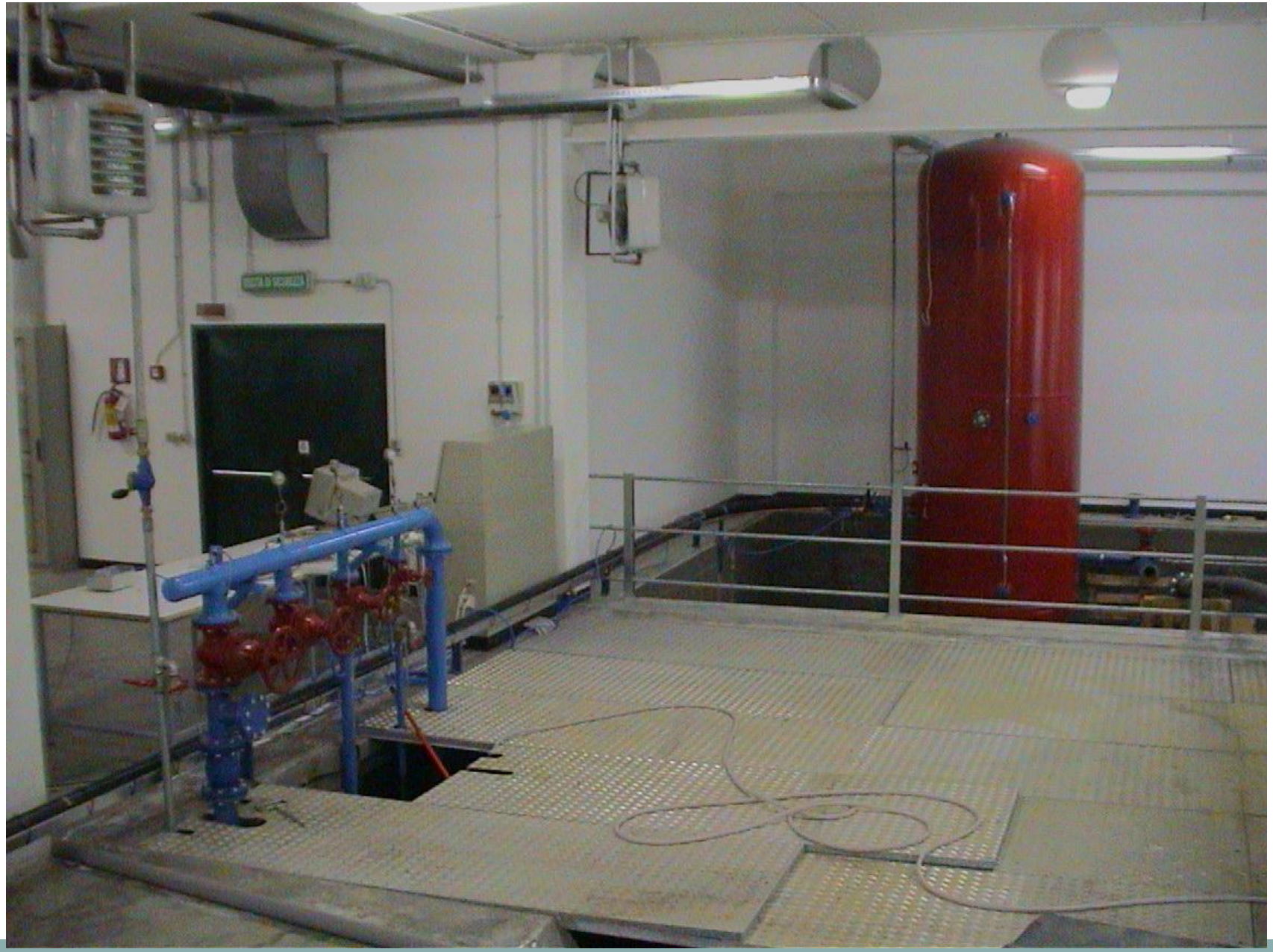
The Water Engineering Laboratory of the University of Perugia



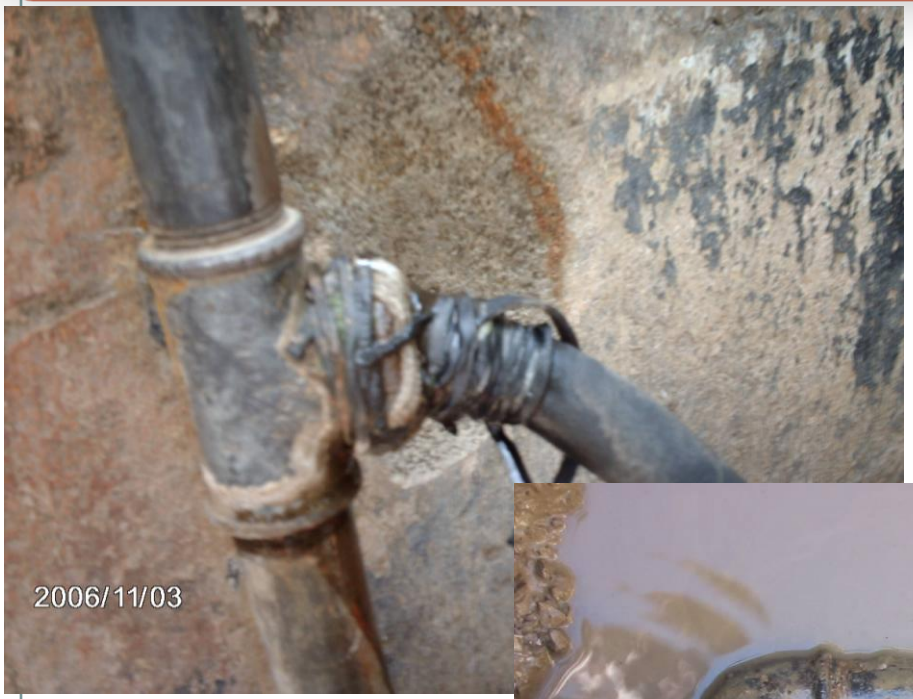
4

2



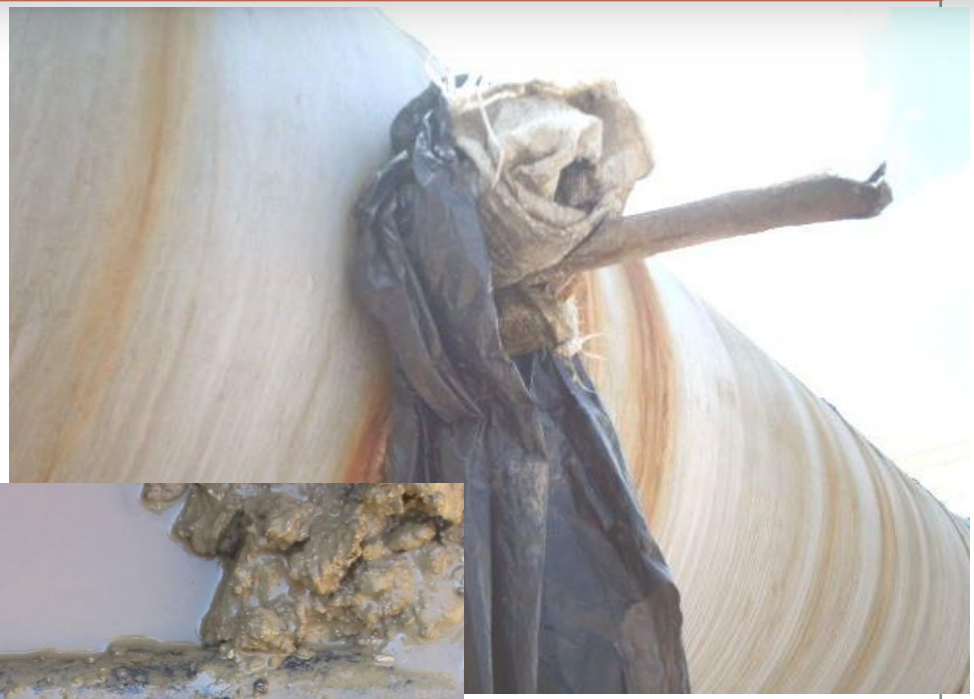


Leaks and illegal connections



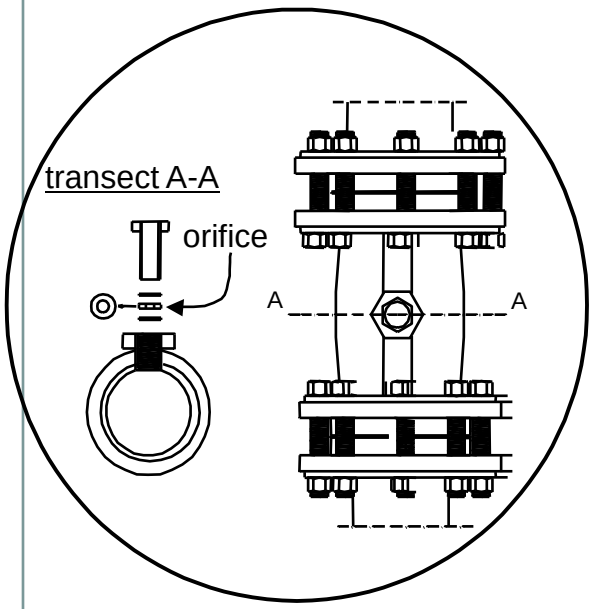
Illegal branche in Zambia (Mfula, 2007)

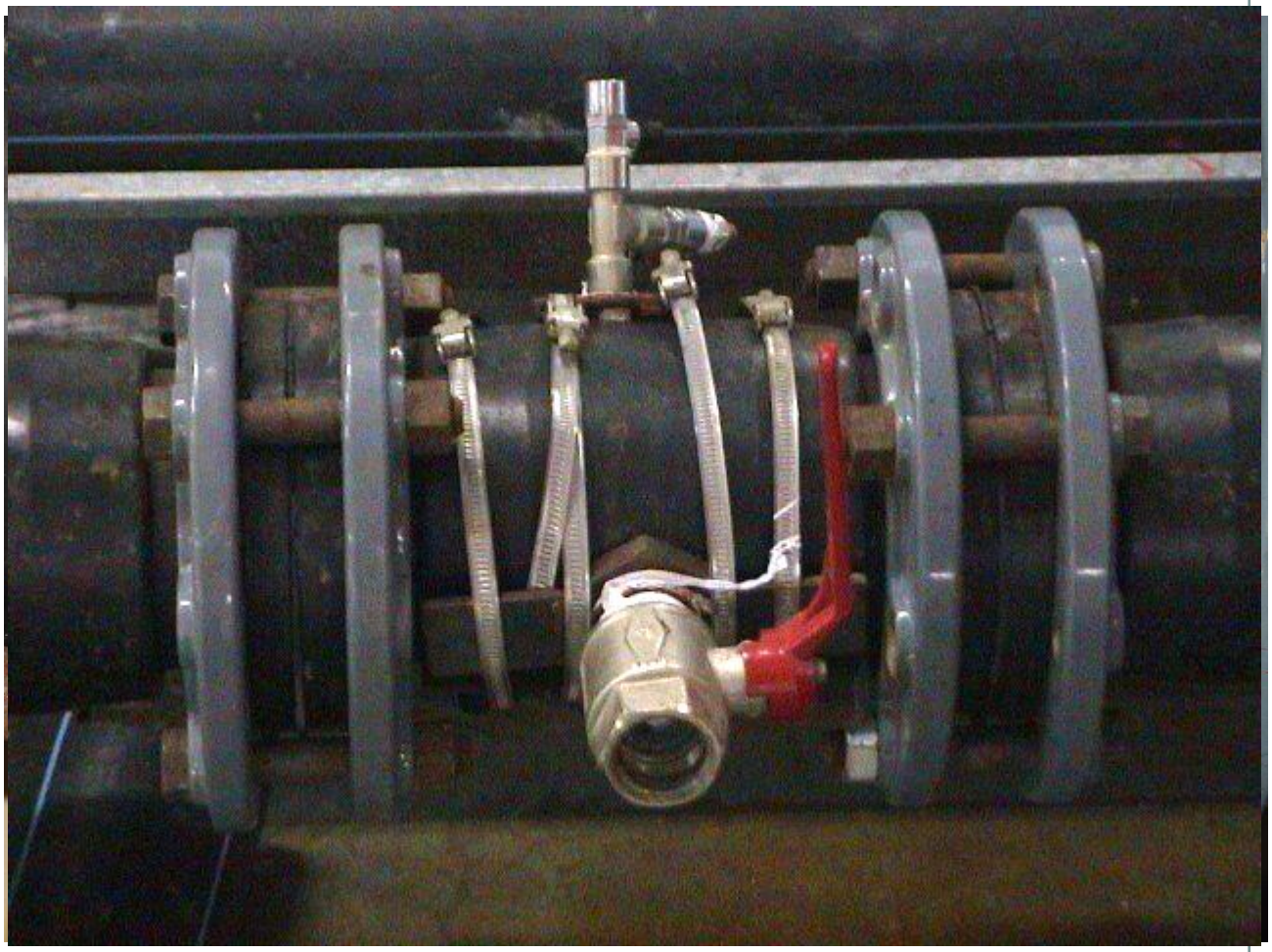
Small leak in the aqueduct of Perugia

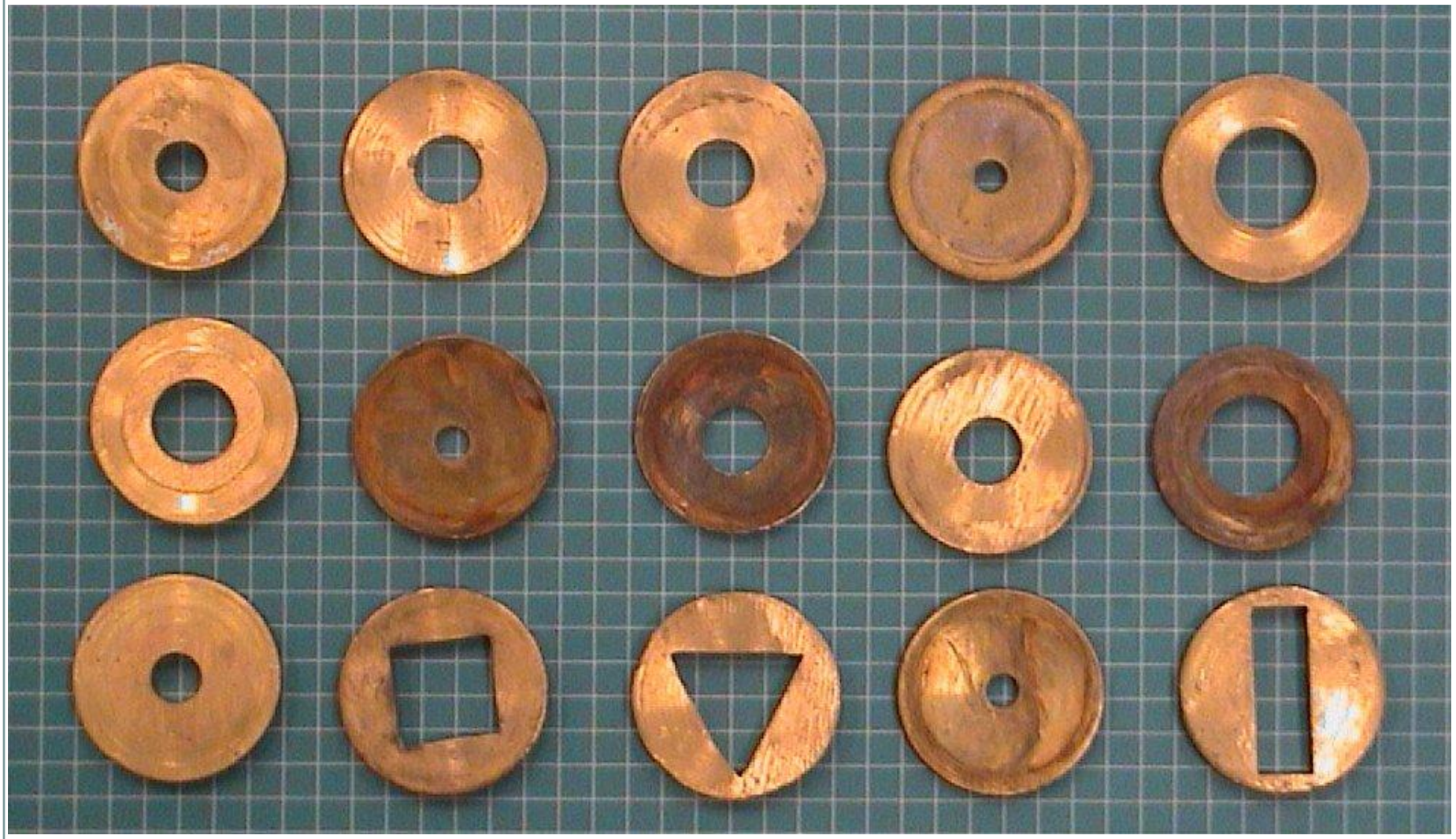


Draft inletin Zambia (Chulu, 2007)

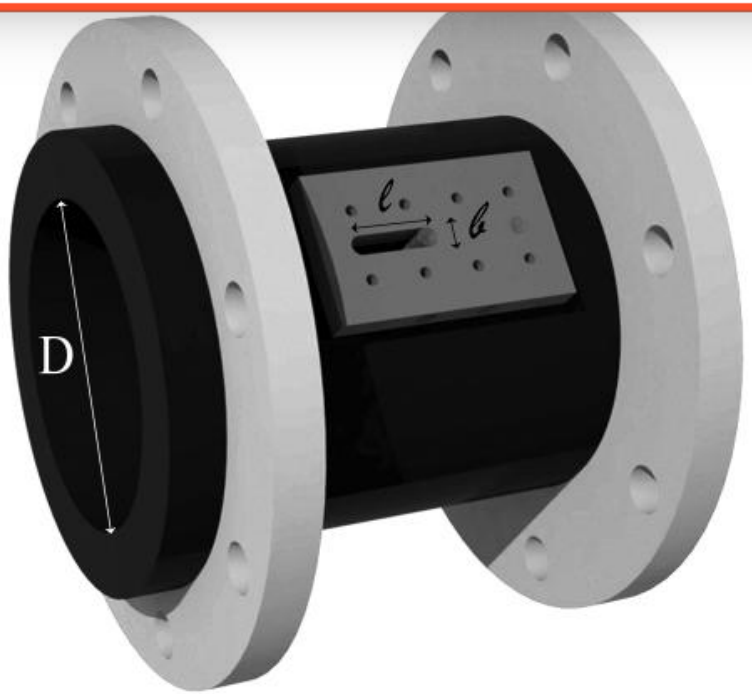
Simulation of a leak in the lab

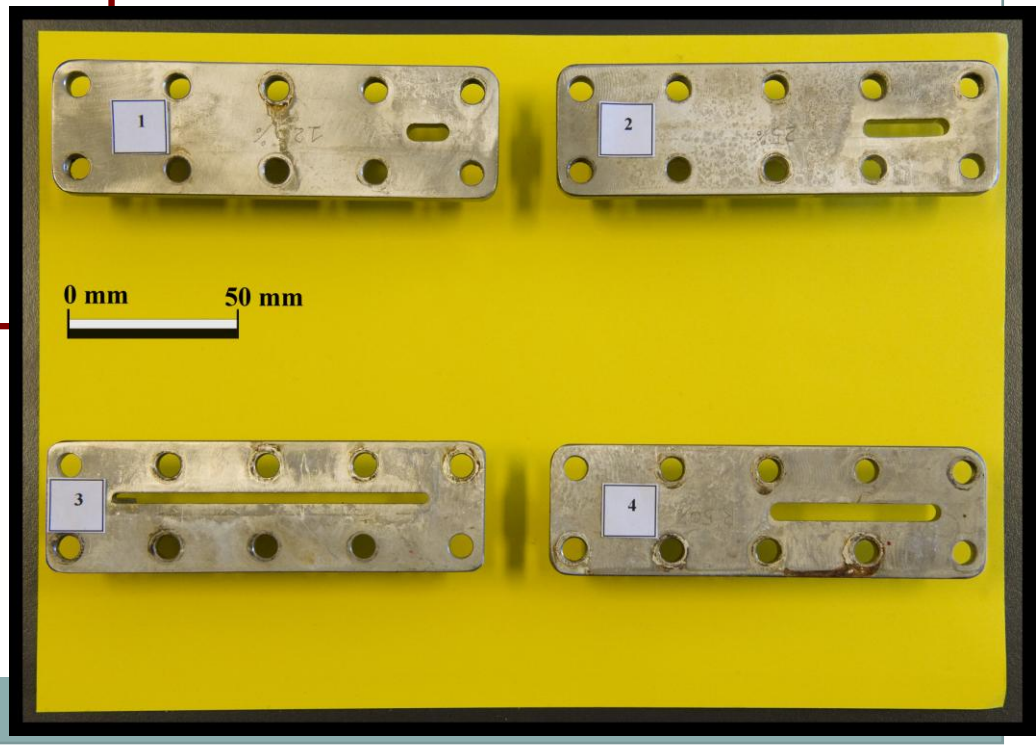


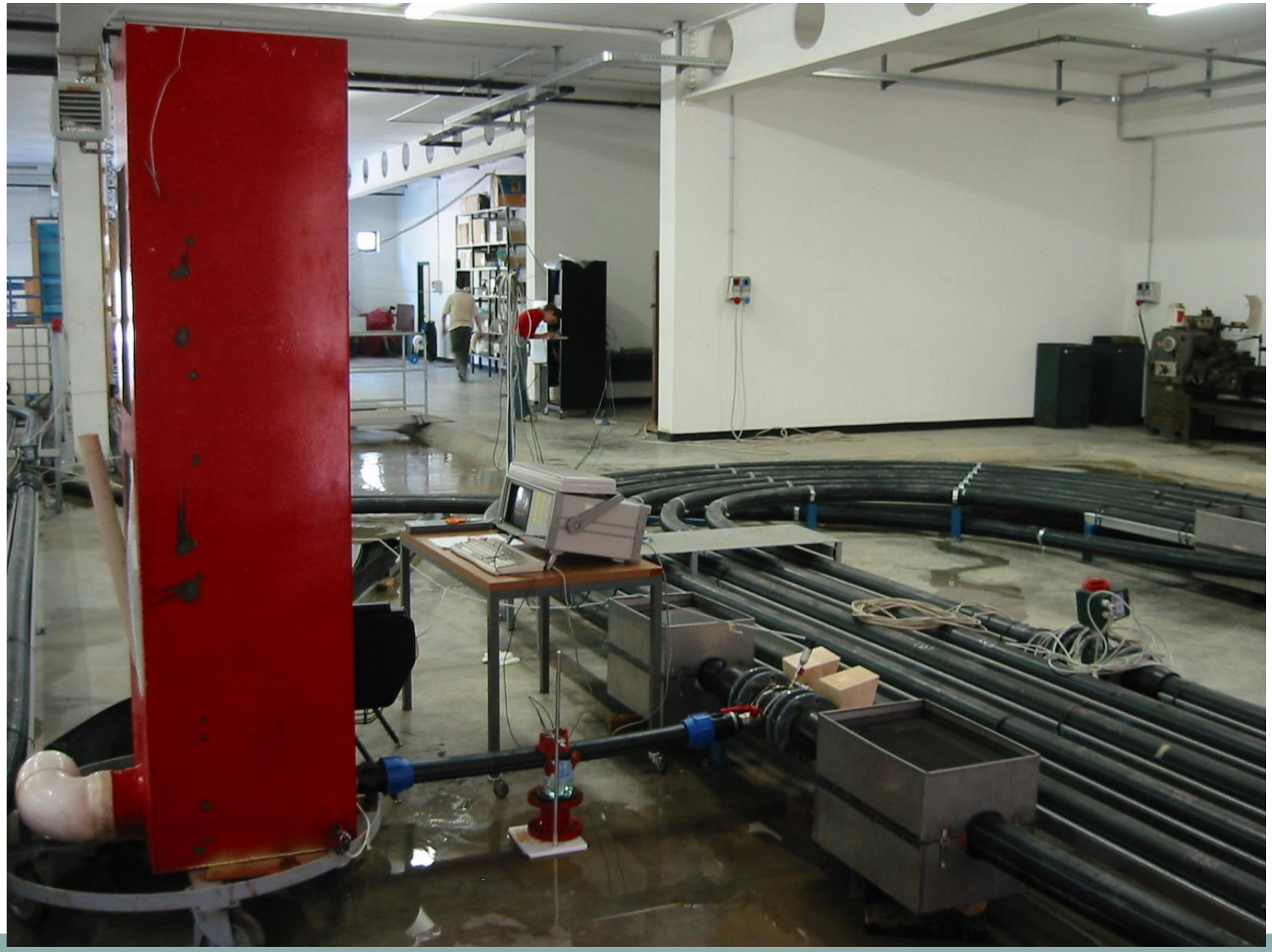




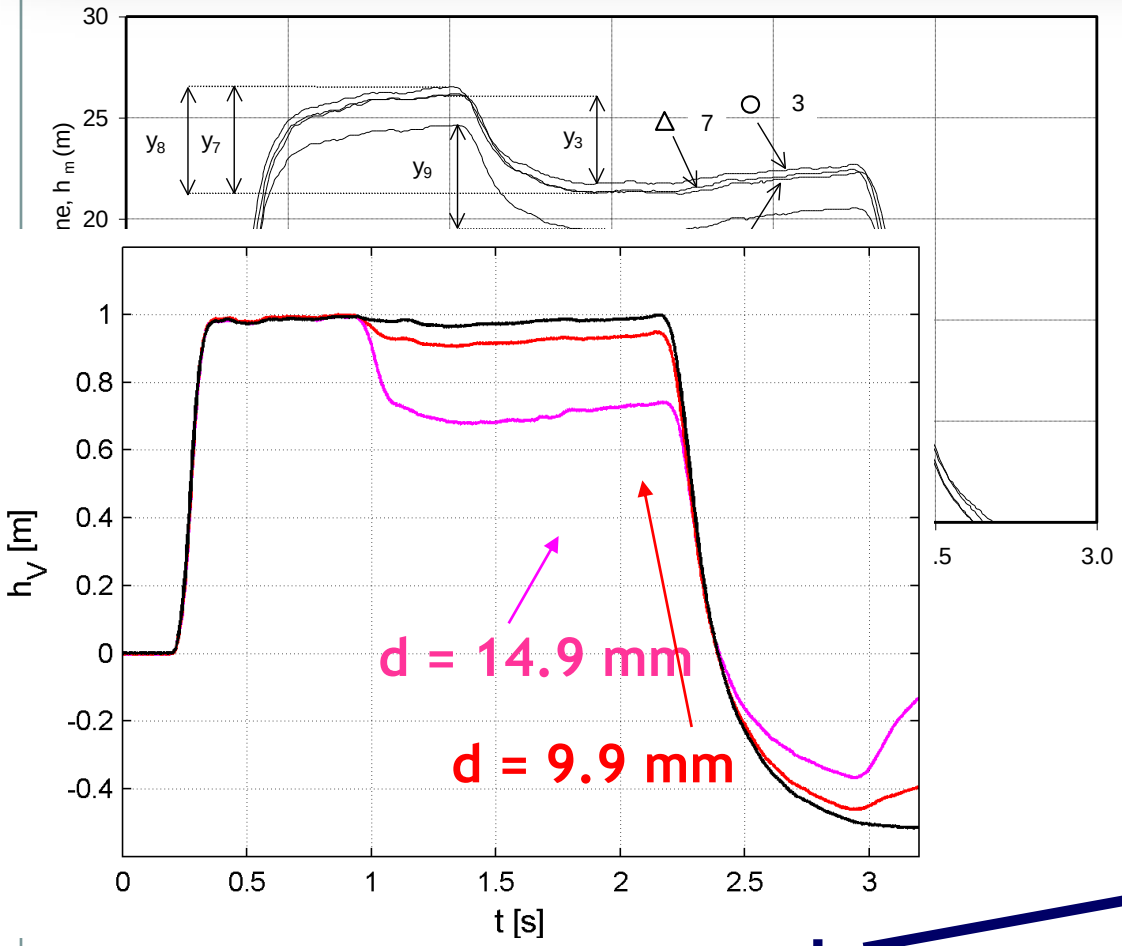
Simulation of a leak in the lab

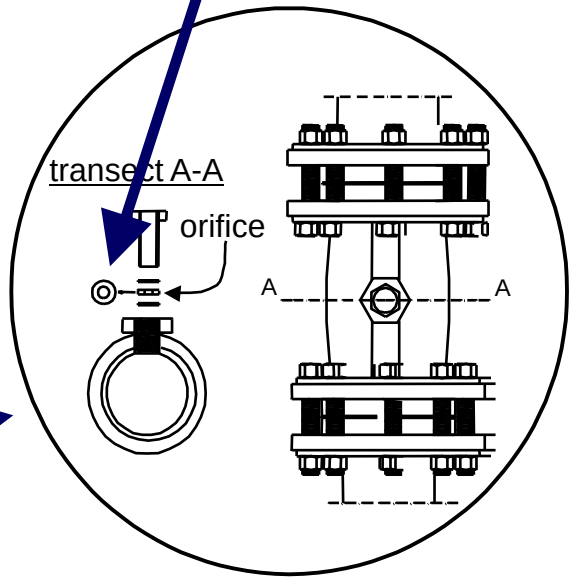


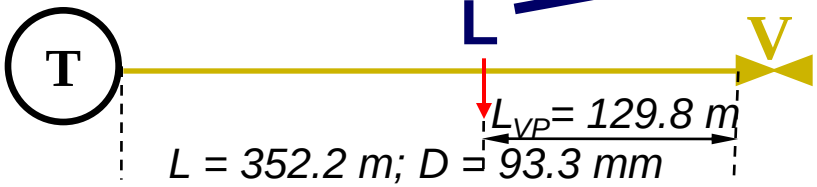




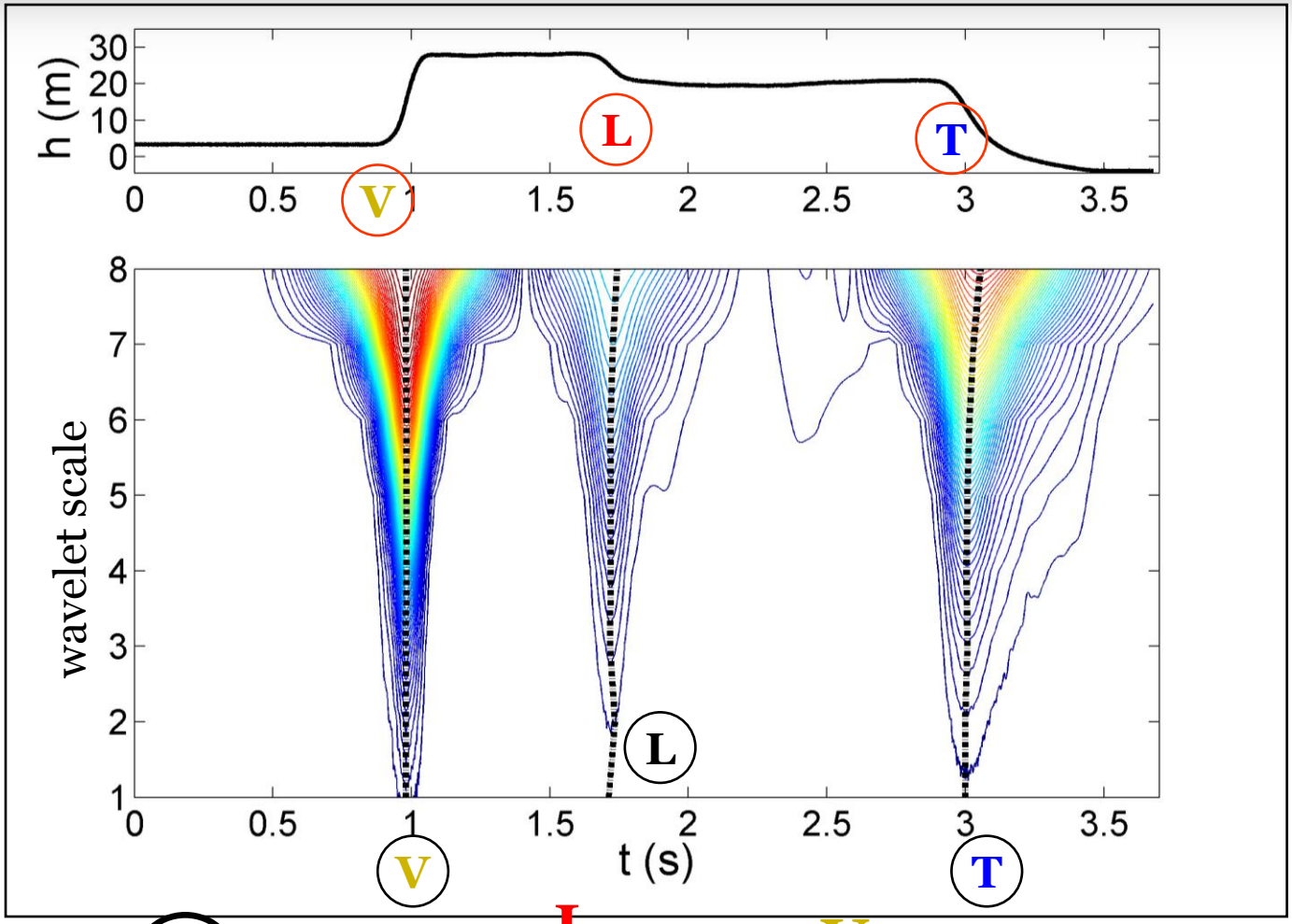
Experimental tests on damaged pipes

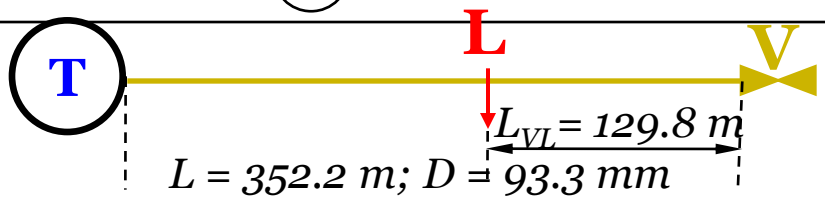






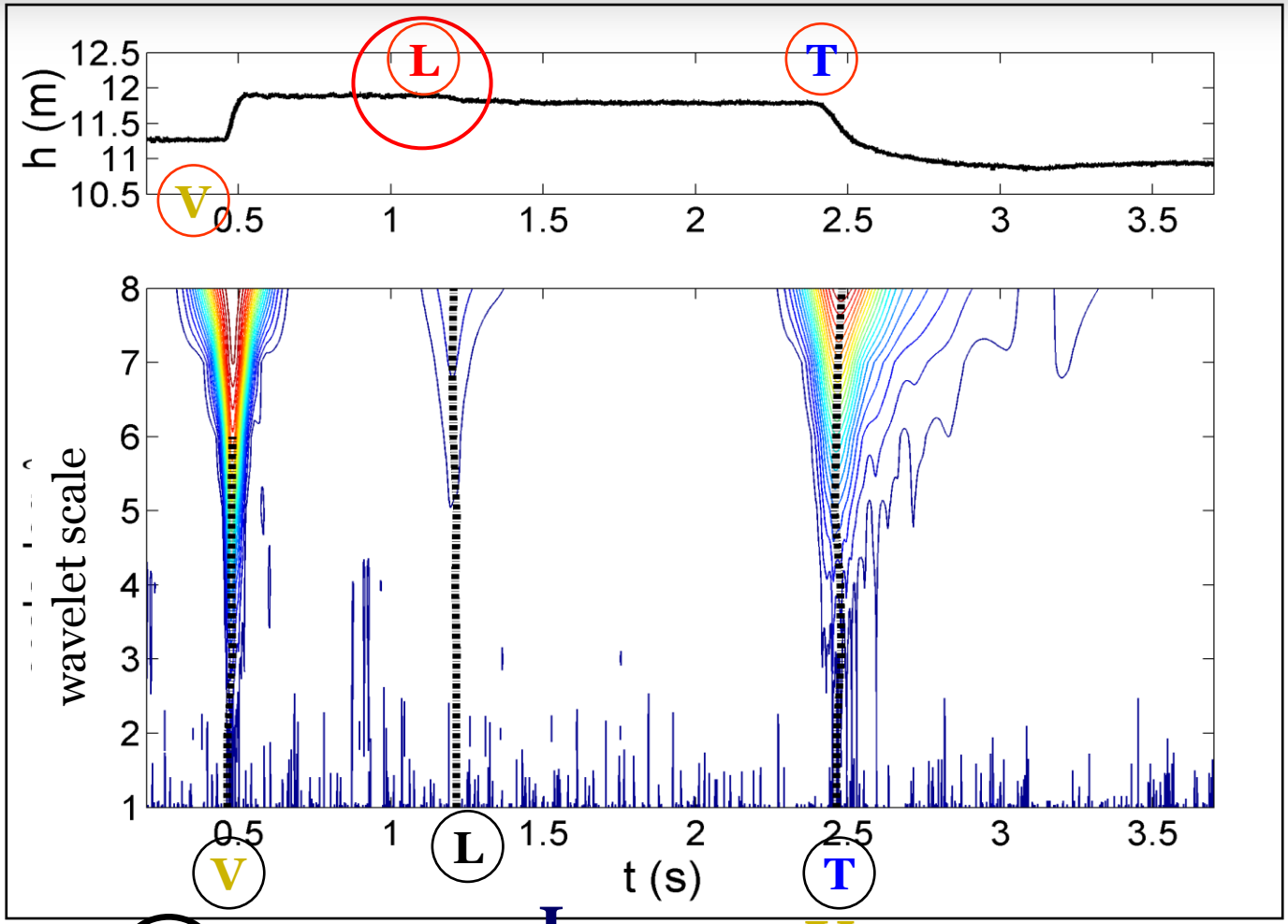
Localization of the leak

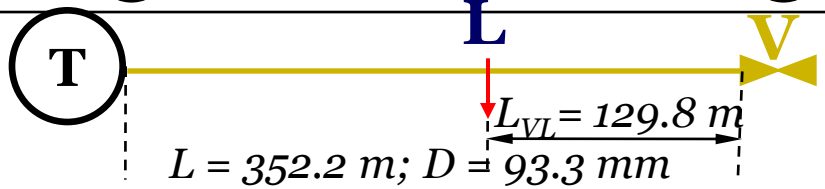




L_{VLen} = 129.5 m
error = 0.21%

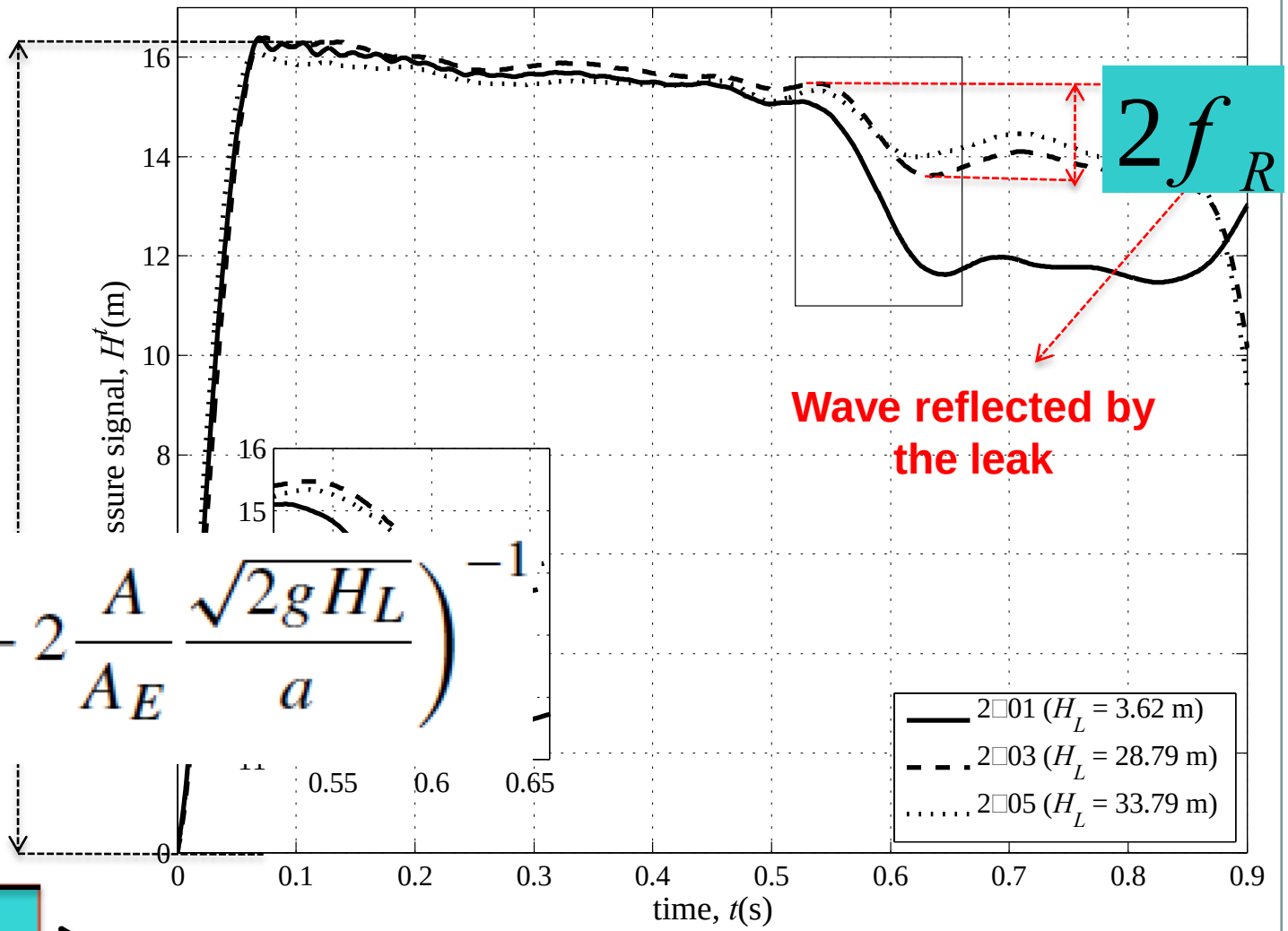
Localization of the leak

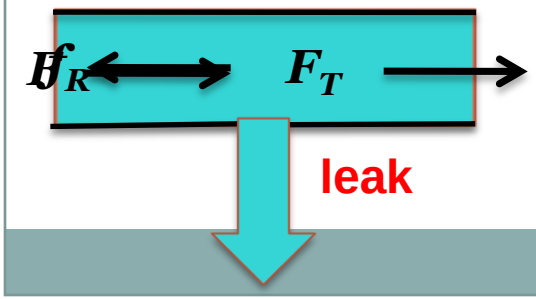




L_{VLen}= 129.12 m
error = 0.52%

$$C_R = -\left(1 + 2\frac{A}{A_E}\frac{\sqrt{2gH_L}}{a}\right)^{-1}$$





Simulation of an illegal branch in the lab

HDPE pipe
L = 164.93 m
D = 93.3 mm (*DN110*)

Distance between the end valve V and the connection J of the branch
L_{VB}= 102.70 m

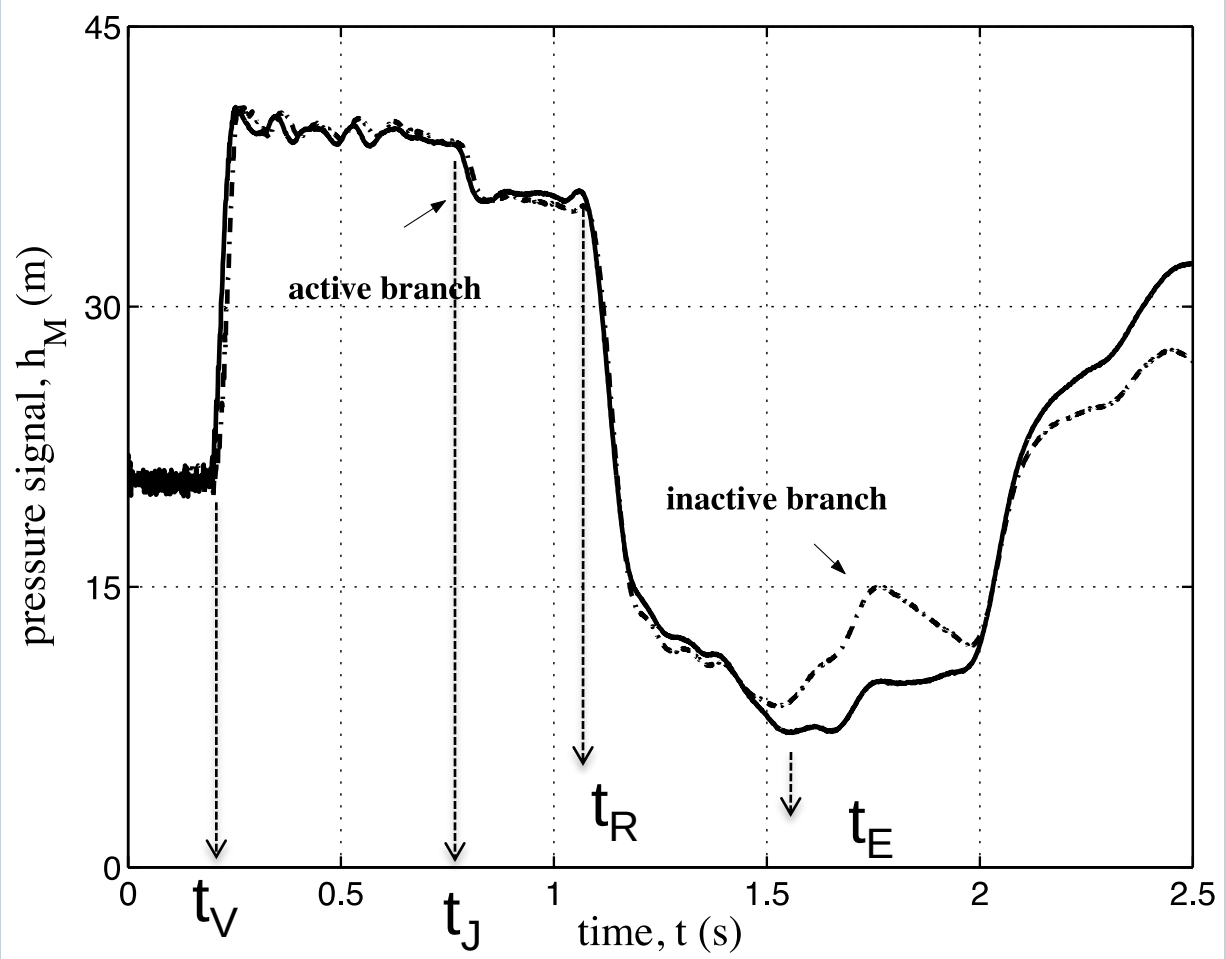
BRANCH CHARACTERISTICS:

length: L_b = 36.30 m
diameter: D_b = 22.3 m

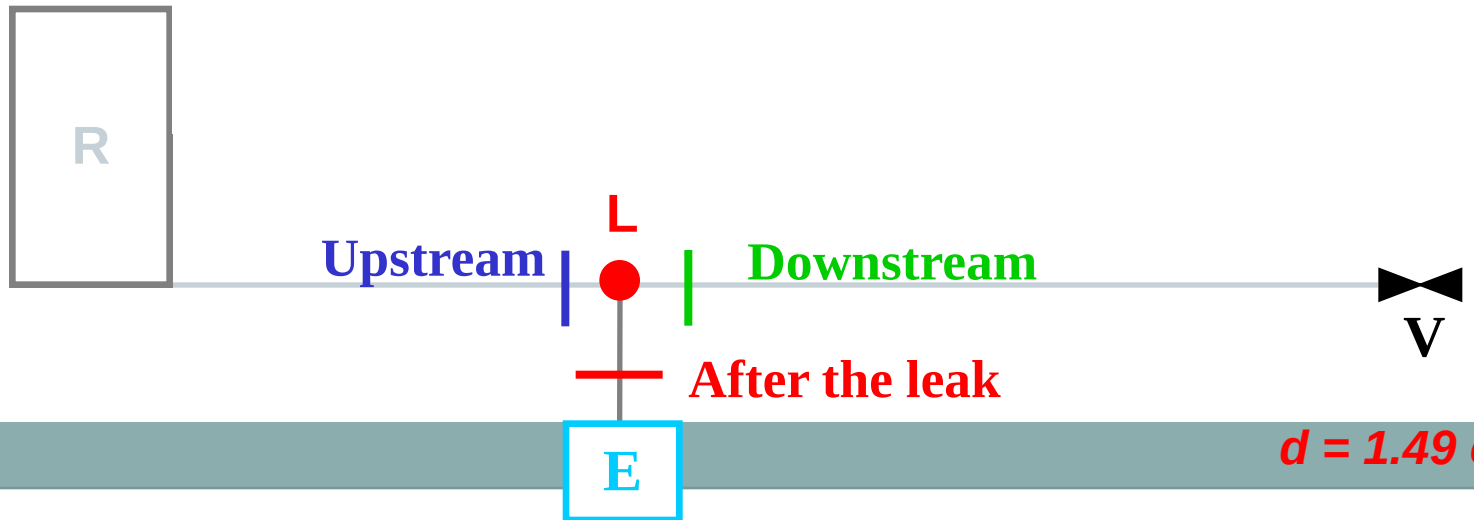
Experimental transient tests

Q_0 = 2.95 l/s

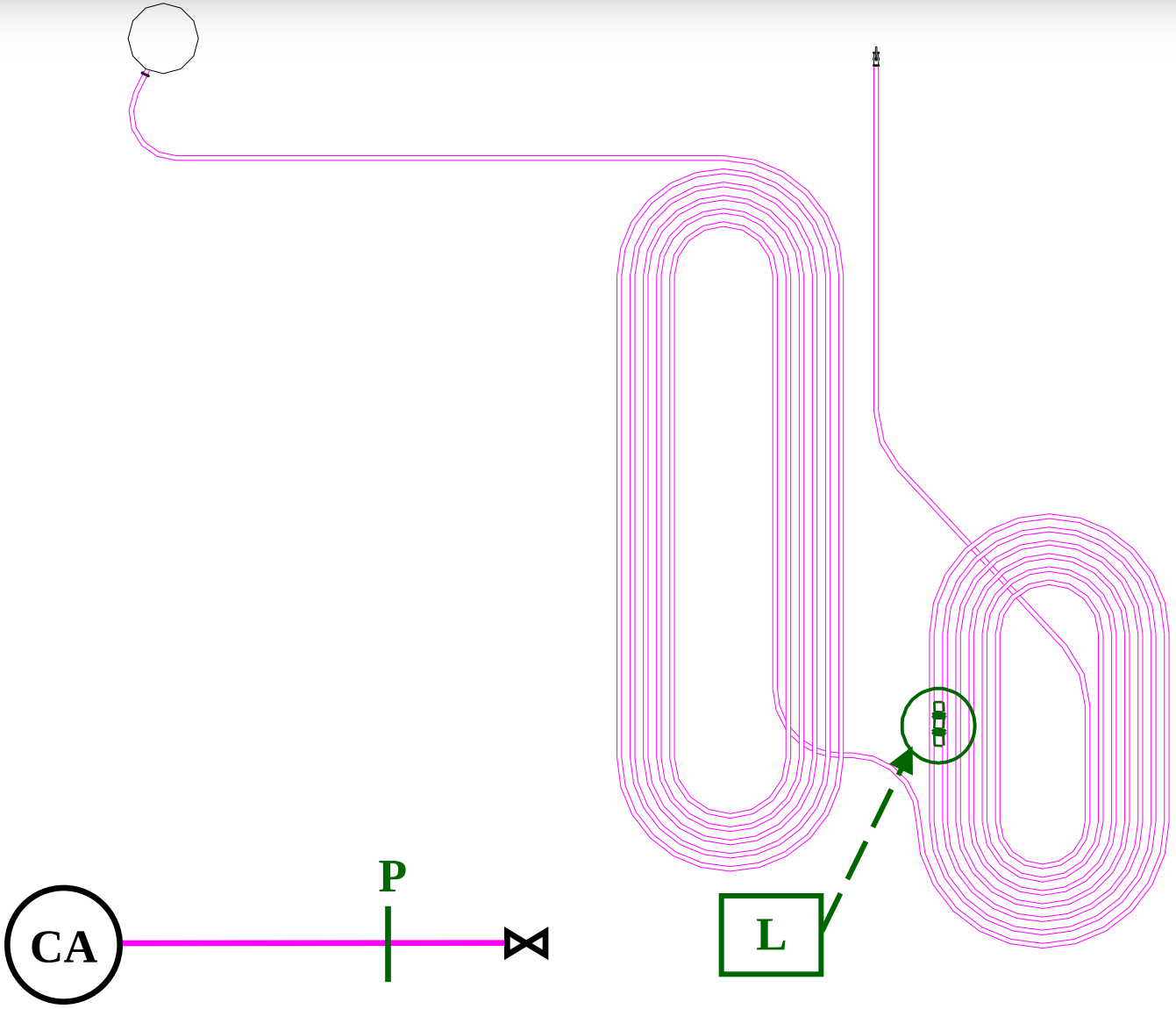
$$L' = \frac{t_J - t_V}{t_R - t_V} L$$



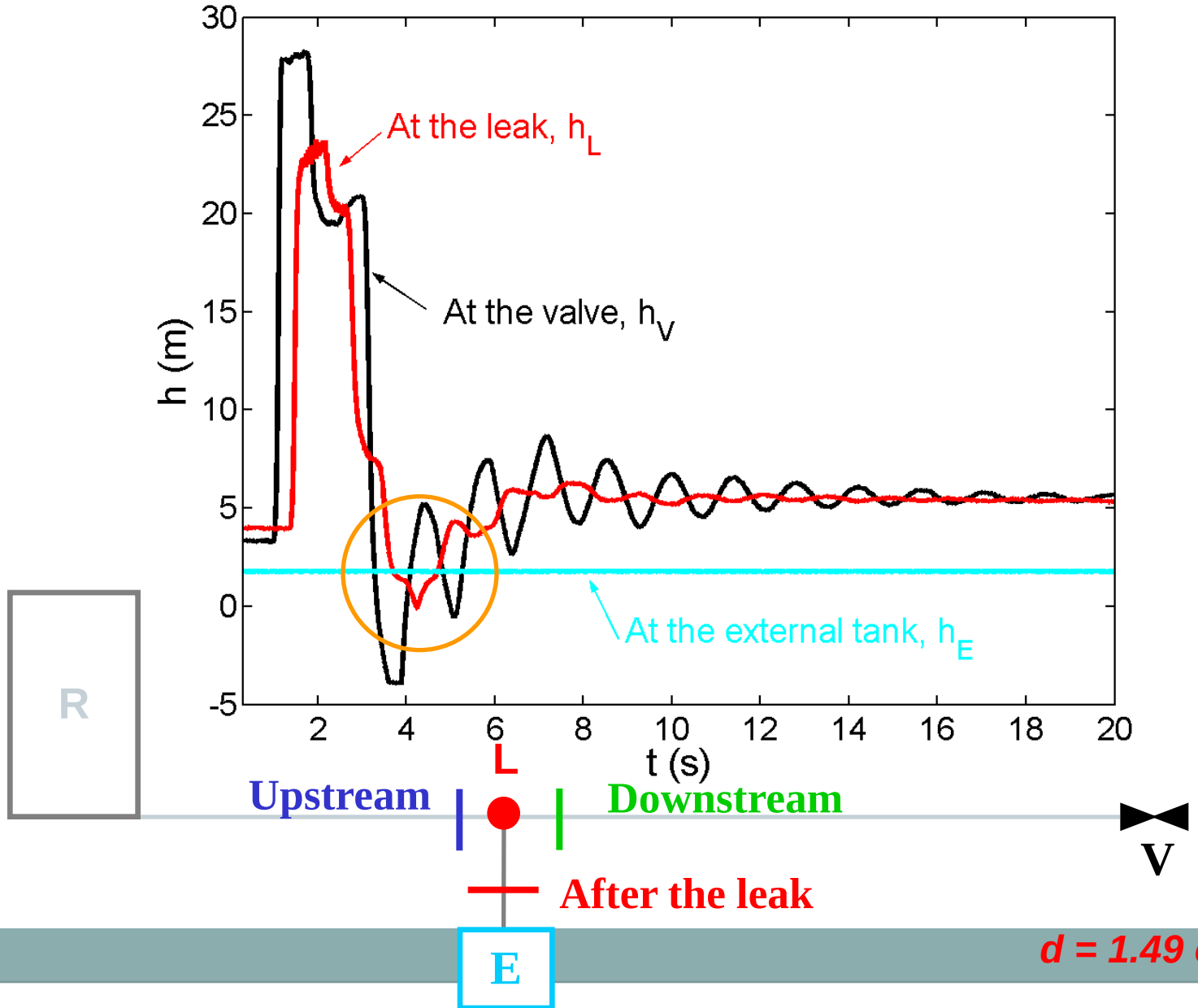
INTRUSION: experimental test

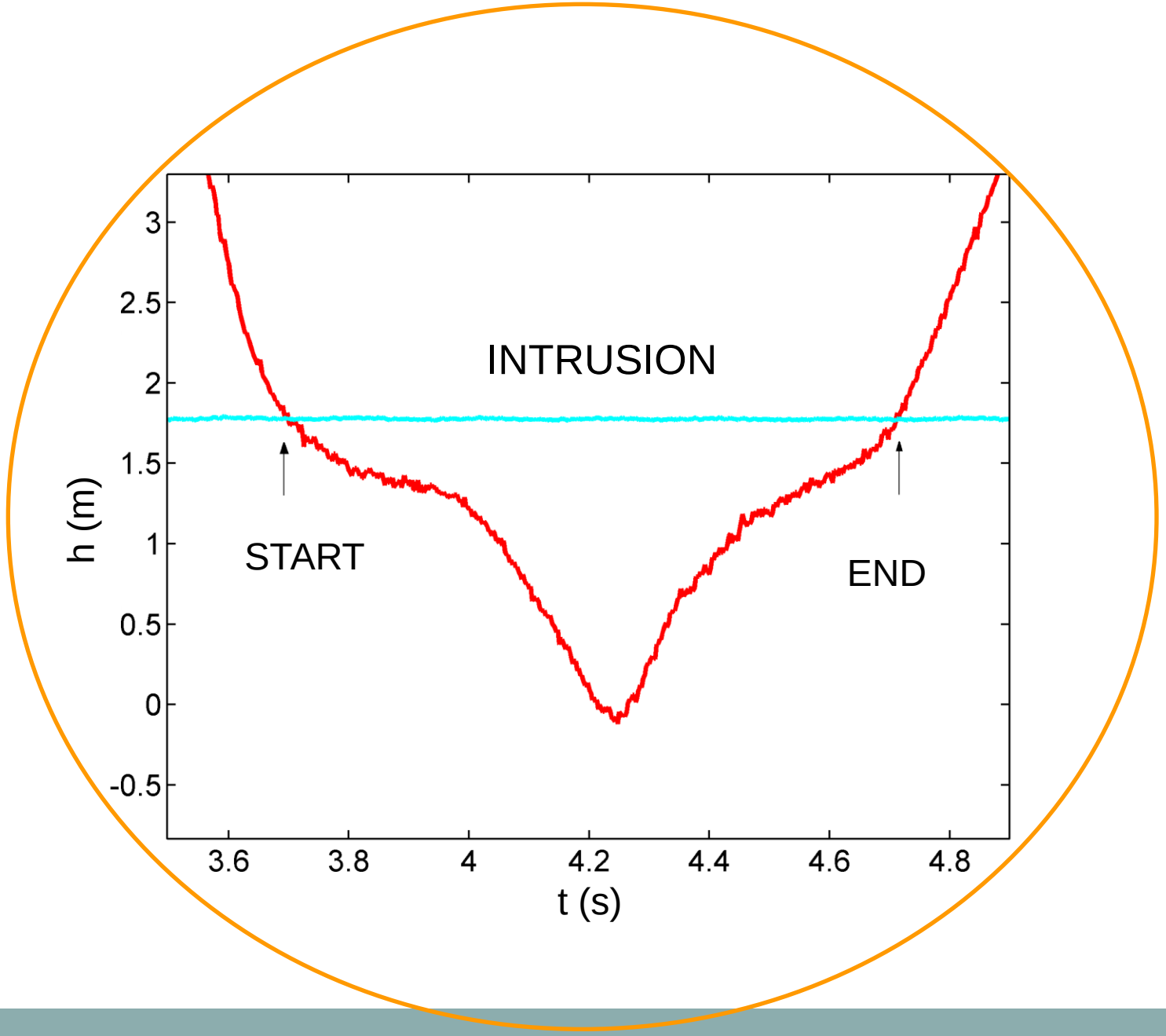


Intrusion: experimental test

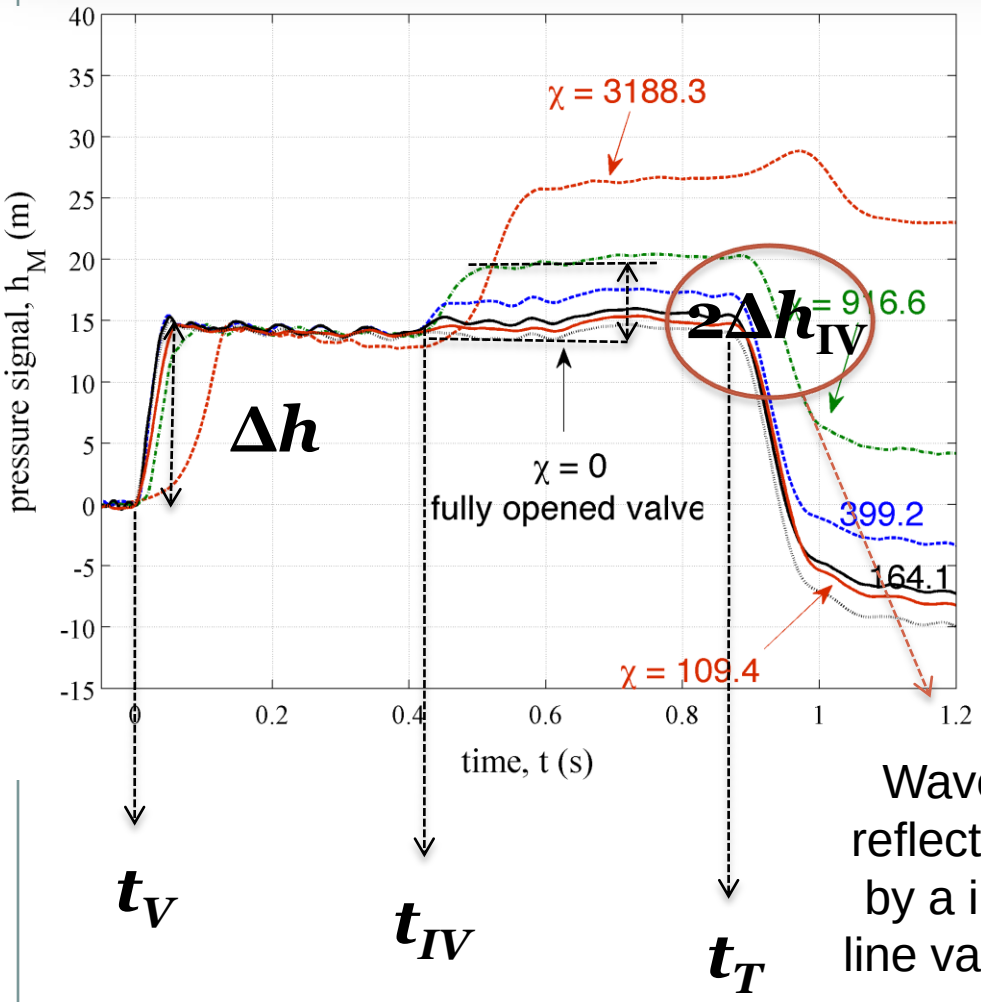


INTRUSION: EXPERIMENTAL TEST

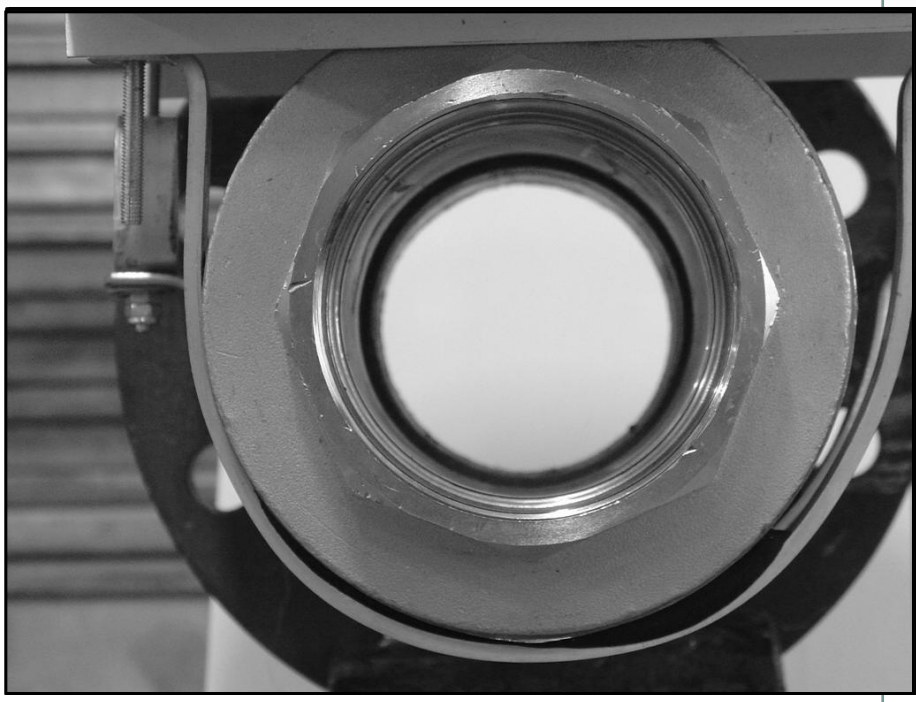



INTRUSION
START
END
h (m)
t (s)
3
2.5
2
1.5
1
0.5
0
-0.5
3.6
3.8
4
4.2
4.4
4.6
4.8

Transient test in a pipe with an in-line valve



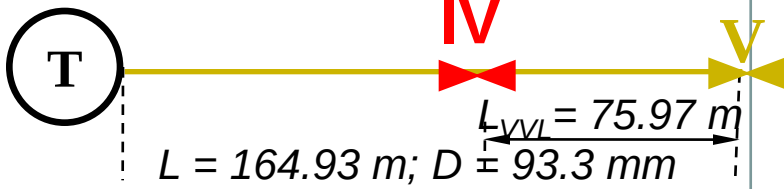
Wave reflected by a in-line valve



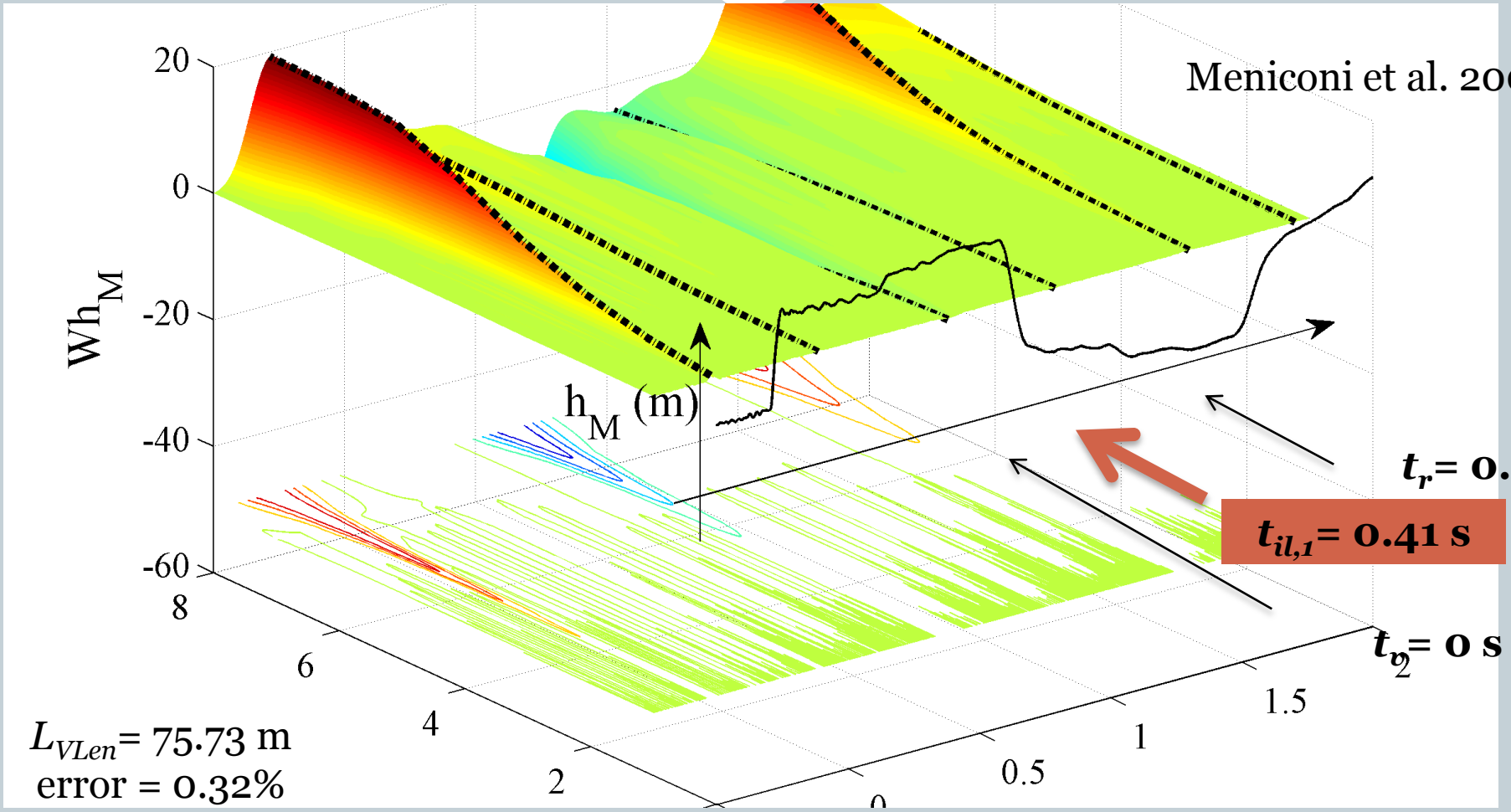
δ = [redacted]°

Q_0 = 2.57 l/s

(da Meniconi et al. 2010)

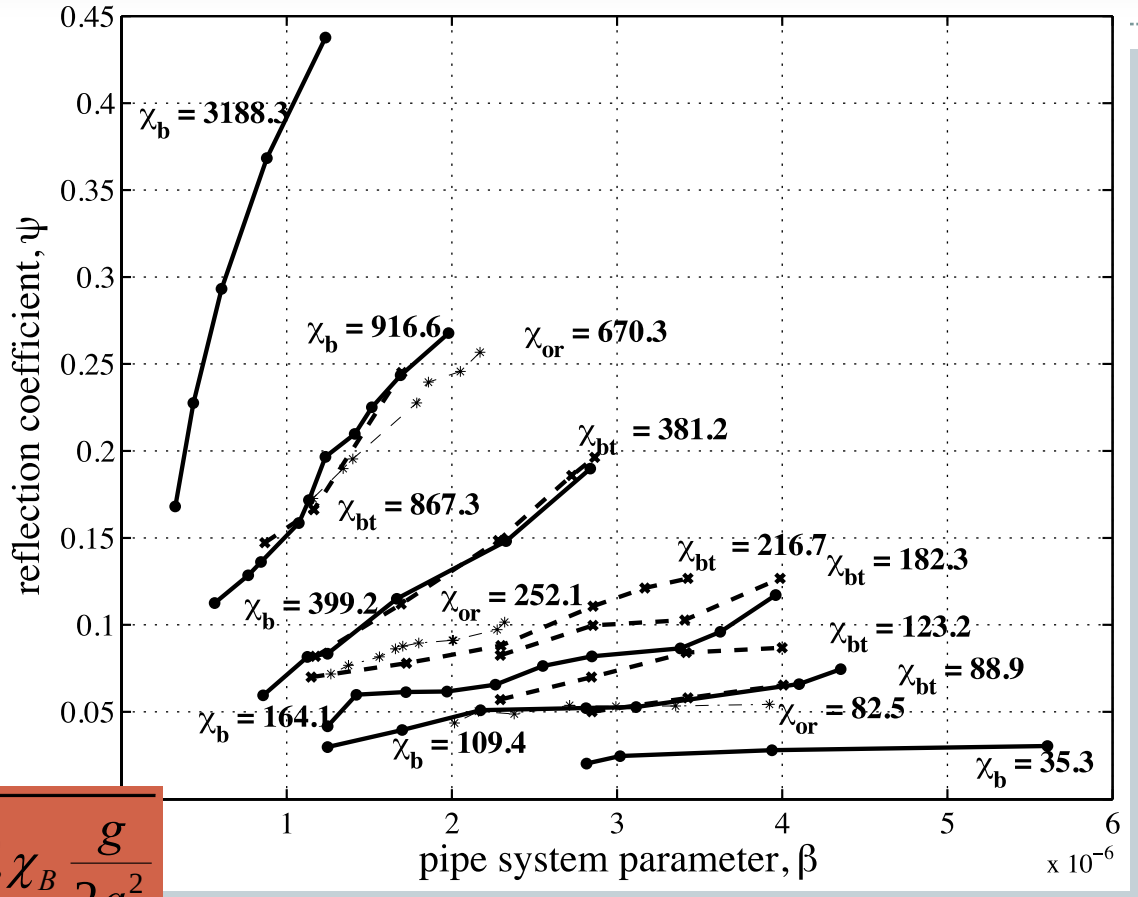


Localization of the in-line valve



Sizing of the in-line valve

$$\psi = \frac{\Delta h_B}{\Delta h}$$



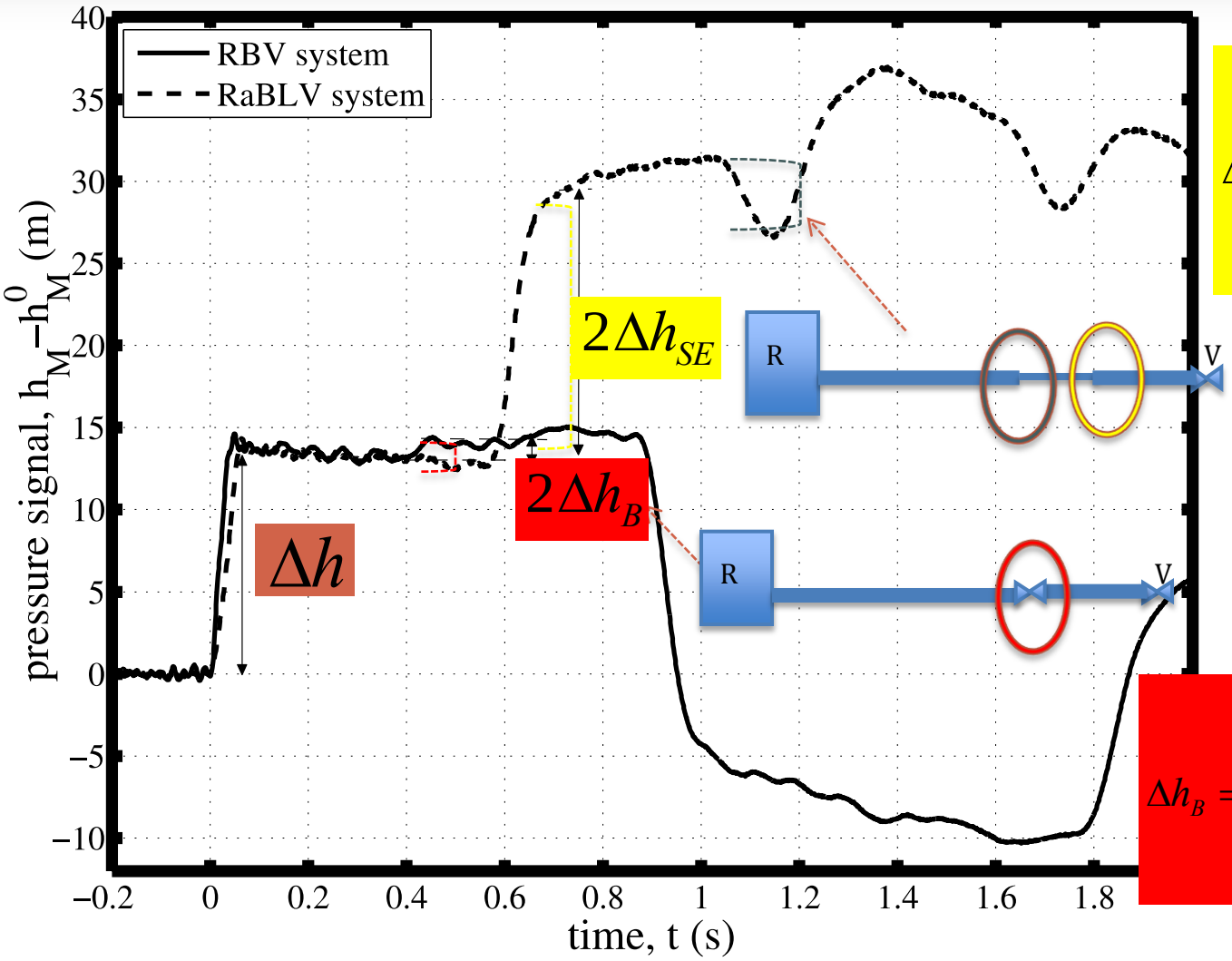
$$\Delta h_B = \frac{-1 + \sqrt{1 + \zeta_B^0 \chi_B \frac{g}{2a_1^2}}}{\chi_B \frac{g}{2a_1^2}}$$

$$\beta = \frac{V_0 D}{L' a}$$

(da Meniconi et al. 2010)

Partial Blockages

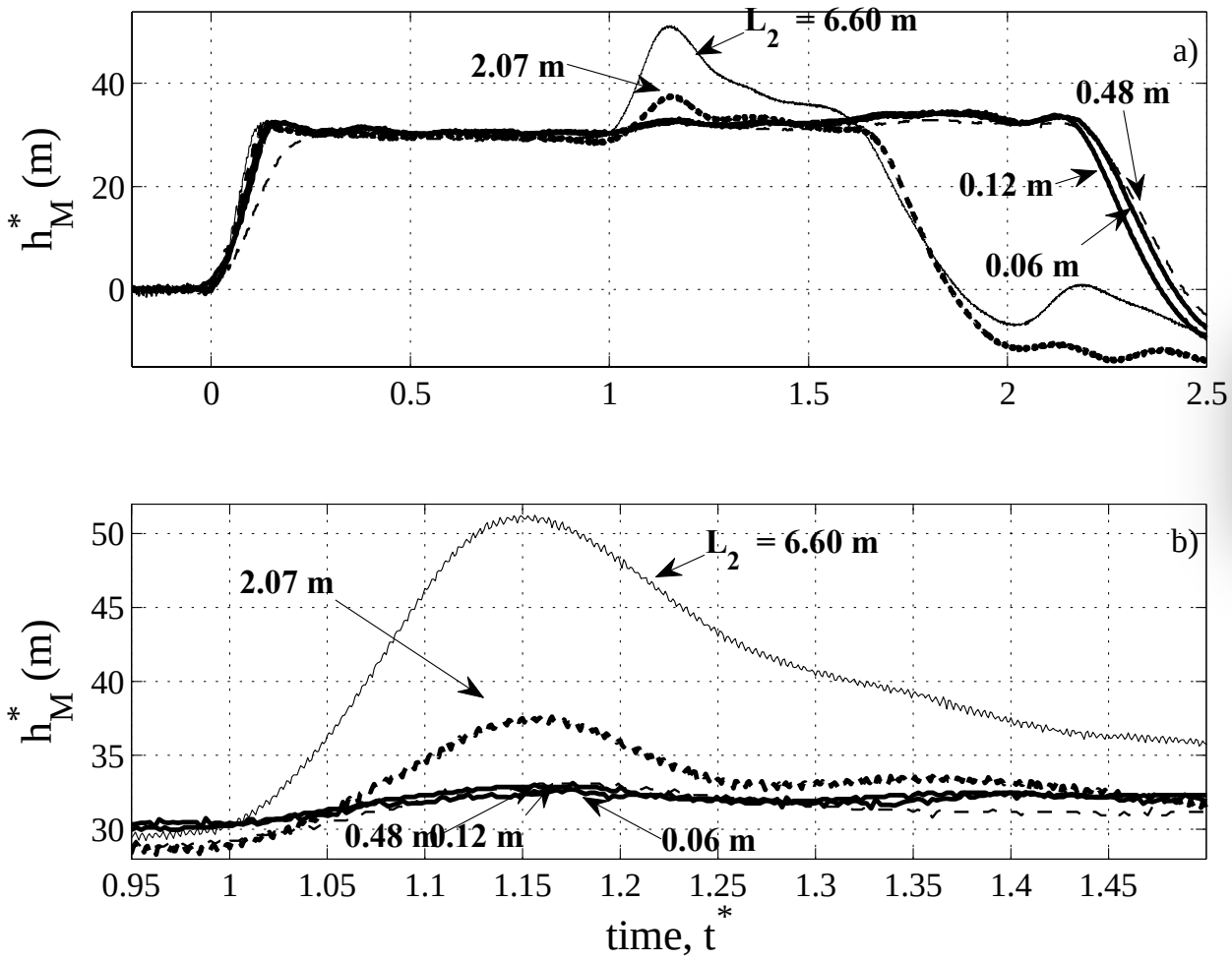
Interaction between pressure wave and a blockage (diameter reduction)



$$\Delta h_{SE} = \frac{\frac{a_2}{A_2} - \frac{a_1}{A_1}}{\frac{a_2}{A_2} + \frac{a_1}{A_1}} \Delta h$$

$$\Delta h_B = \frac{-1 + \sqrt{1 + \zeta_B^0 \chi_B \frac{g}{2a_1^2}}}{\chi_B \frac{g}{2a_1^2}}$$

Effect of the length of the blockage



Q_o= 3.02 l/s

A taste of more complex systems…

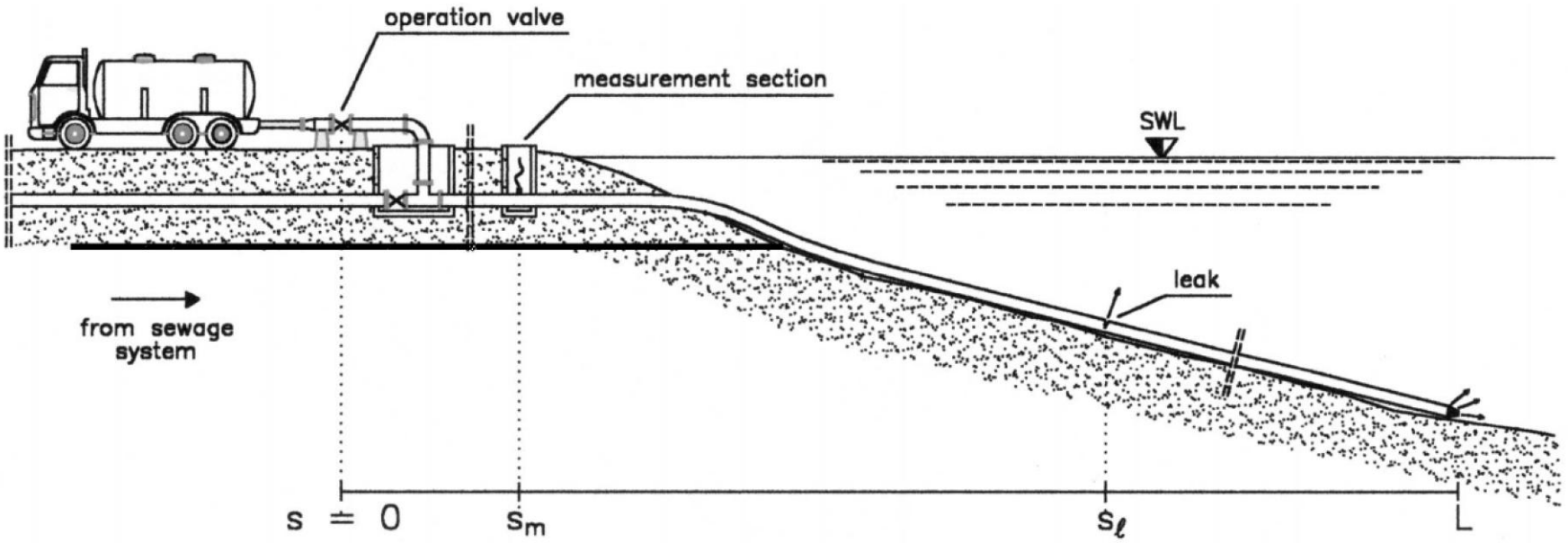


FIG. 2. Layout of Outfall Pipe and Possible Field Experimental Setup

A taste of more complex systems…

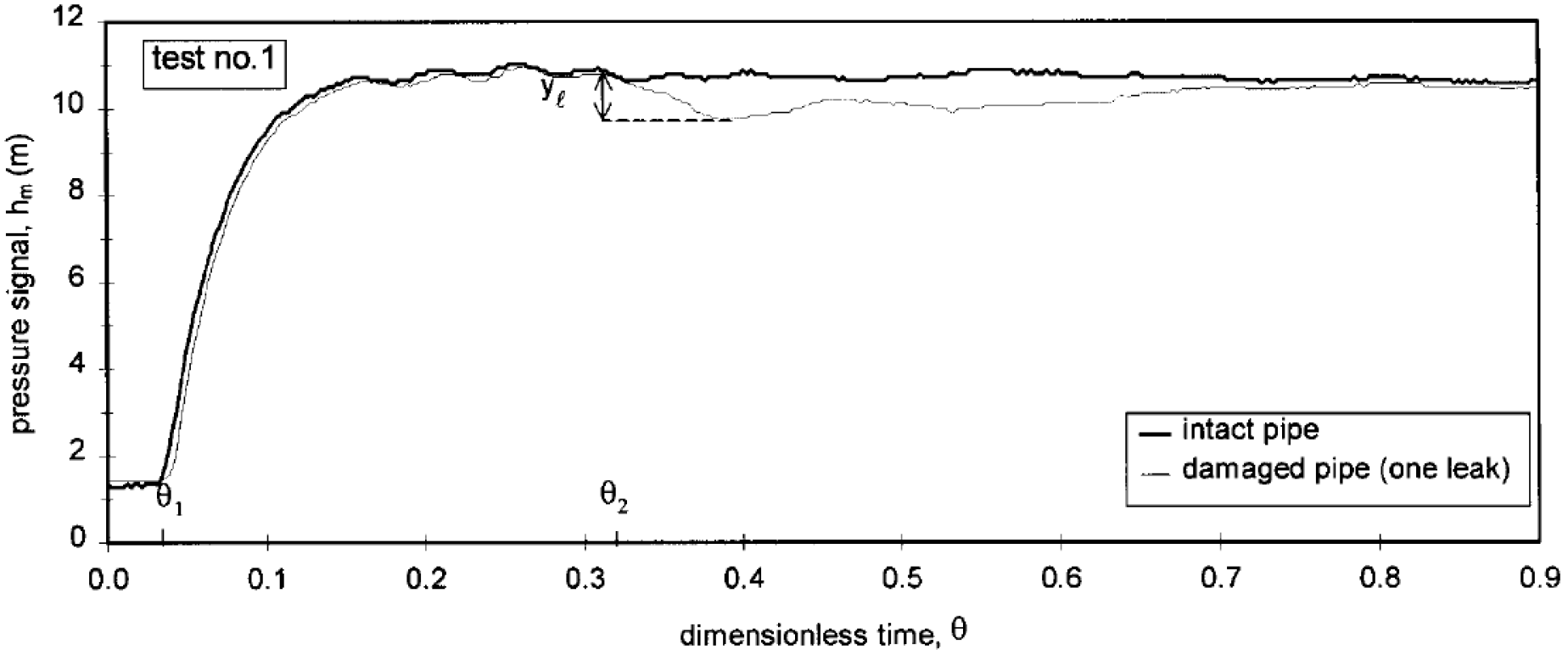


FIG. 5. Experimental Pressure Signal for Both Intact and Damaged Pipe (Test No. 1)

A taste of more complex systems…

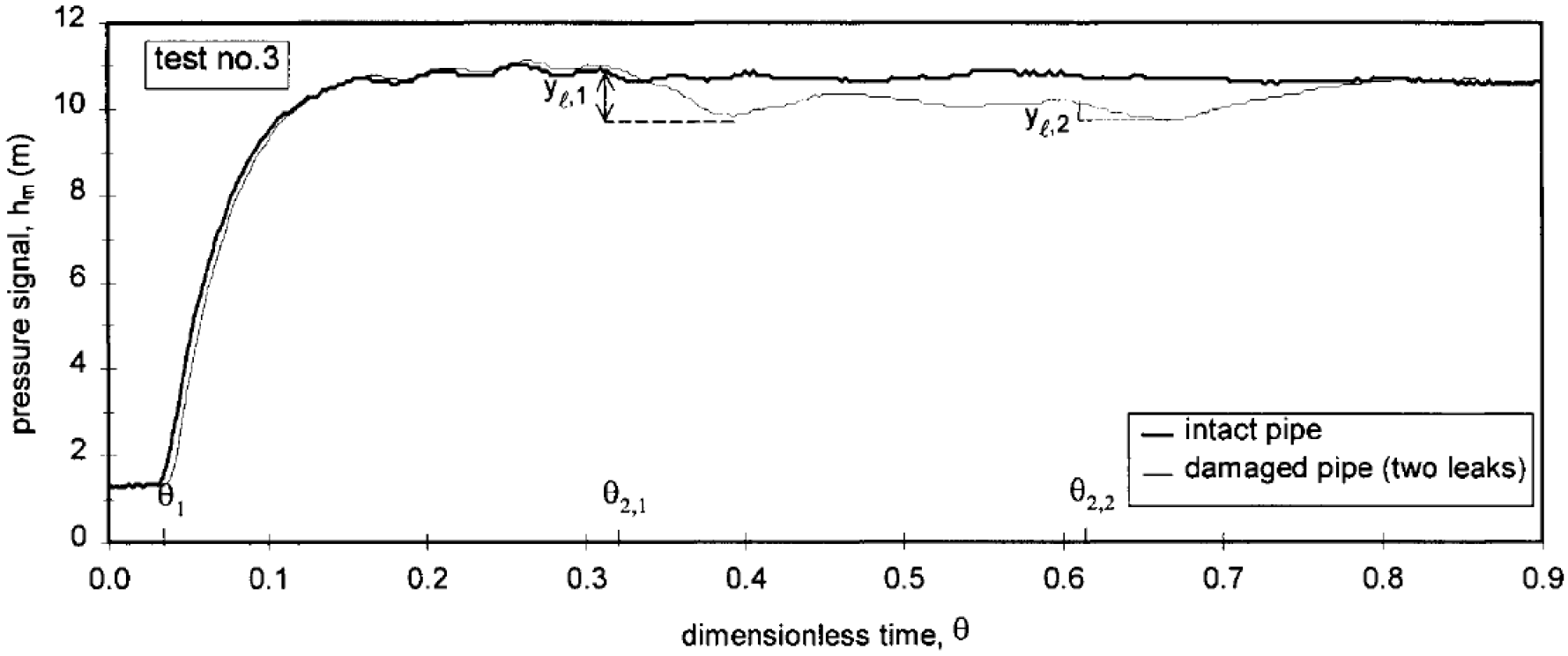
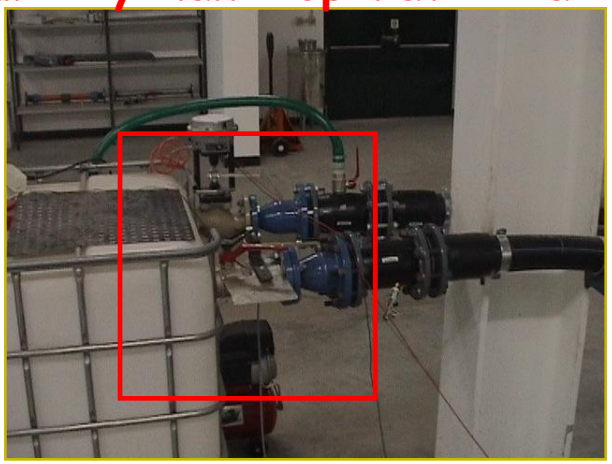


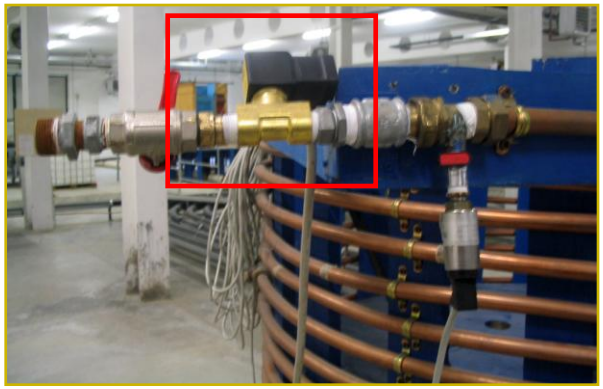
FIG. 6. Experimental Pressure Signal for Both Intact and Damaged Pipe (Test No. 3)

How to generate a transient?

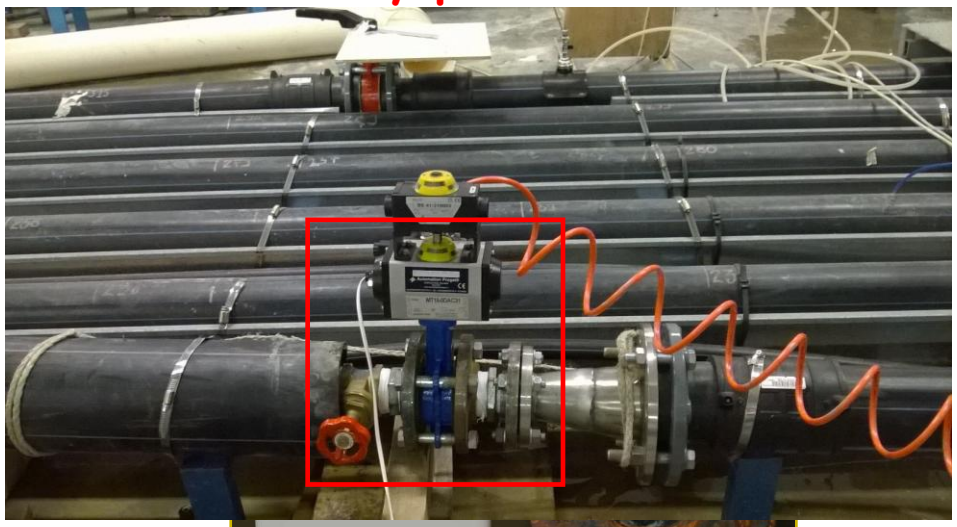
Closure by hand-operated valve



Closure by solenoid valve



Closure by electomechanical valve
Closure by pneumatic valve



Portable pressure wave maker (*PPWM*)

The Experimental Facility for Wave-based Defect Detection at University of Perugia, Italy

Execution of a proper maneuver

Spatial resolution

Preliminary survey

Selection of accessible and reliable measurement sections

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