Fluid transients and FSI

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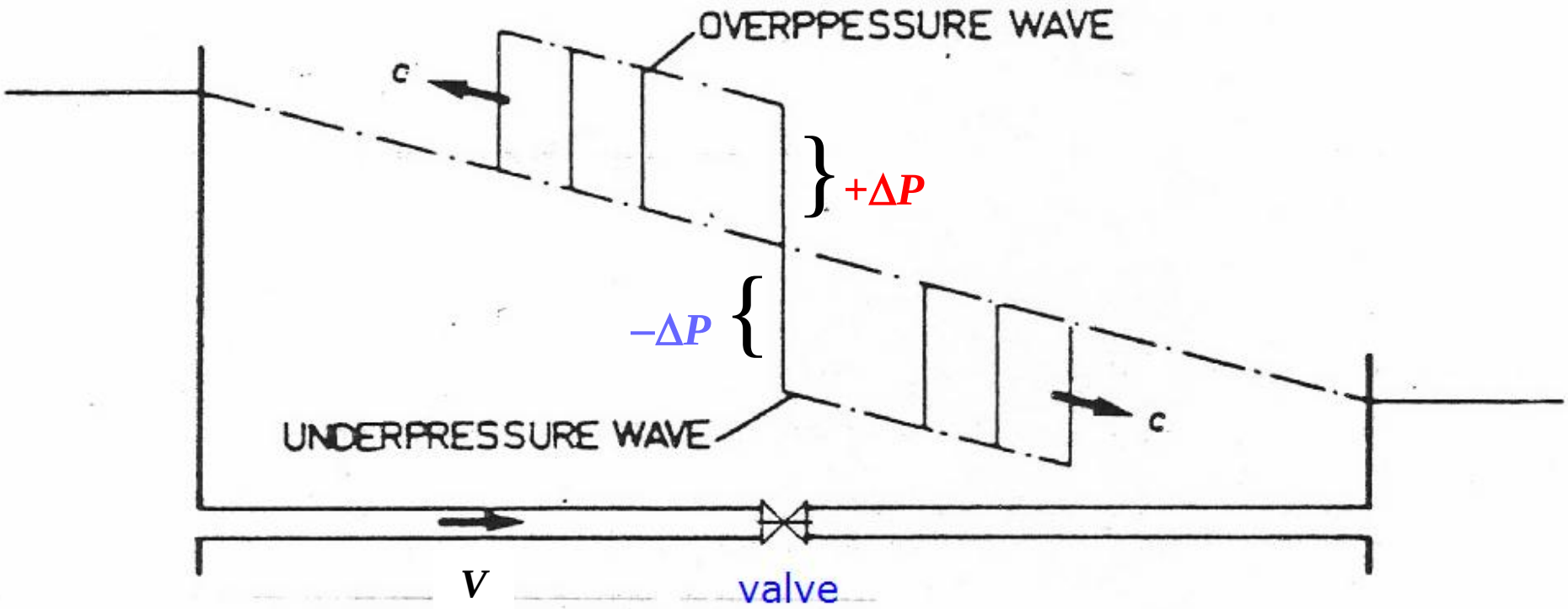
water hammer: $\Delta P = \rho c \, \Delta V$ Joukowsky

$c \approx 1000$ m/s



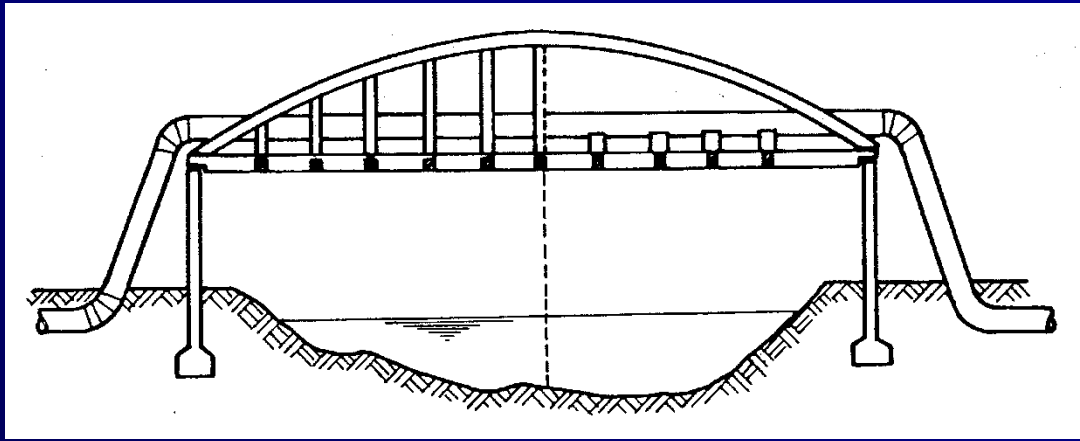
Manuel, 1968
Wijdieks, 1983

large force on valve: $2 \Delta P \, \pi R^2$

$V \approx 1$ m/s

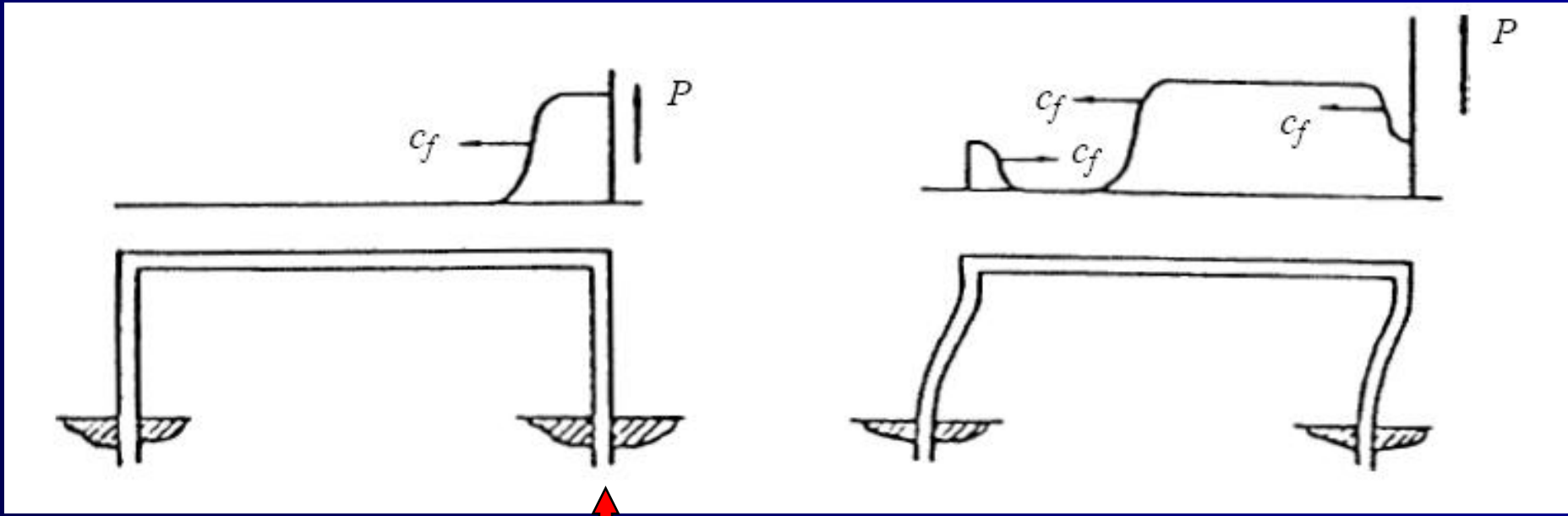
$2\Delta P \approx 20$ bar

pipe bridge



Almeida & Koelle, 1992

waterhammer forces on pipe bridge (FSI)



Tijsseling & Lavooij, JFS 1990

FSI

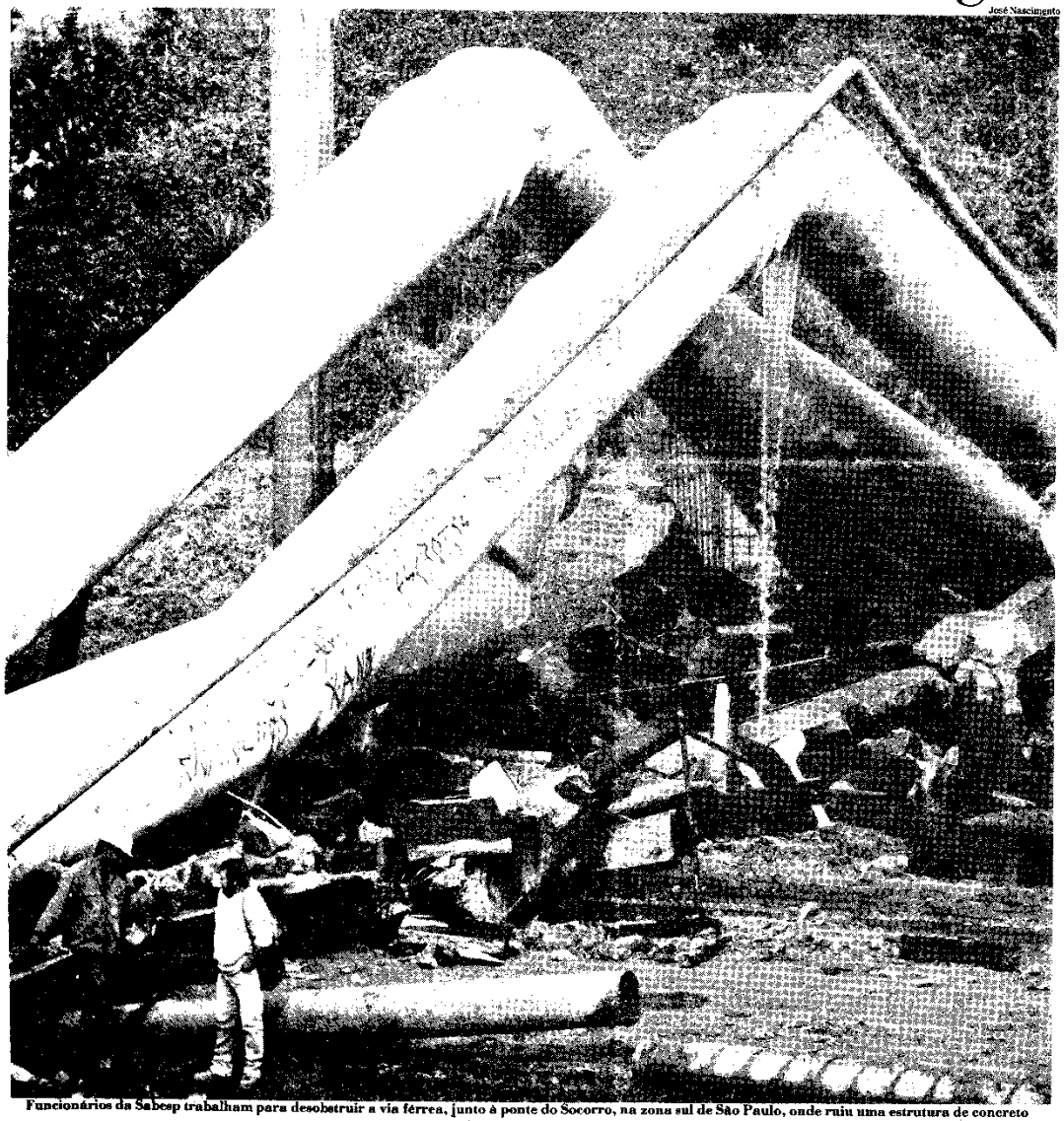
waterhammer
initiated 5 km downstream

news paper

FOLHA DE S. PAULO Quarta-feira, 22 de junho de 1988 — CIDADES — A - 13

adutora; 3 milhões ficarão sem água

José Nascimento

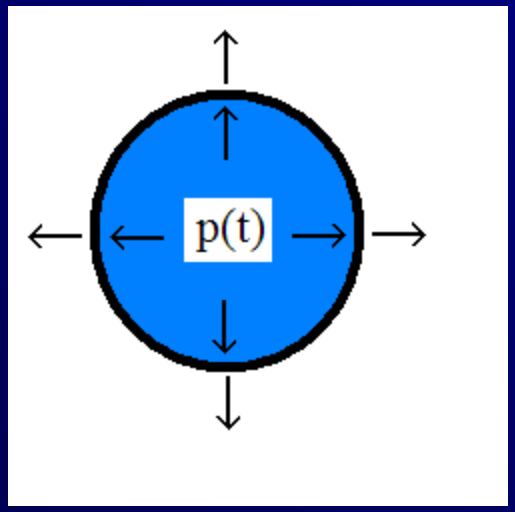


Funcionários da Sabesp trabalham para desobstruir a via férrea, junto à ponte do Socorro, na zona sul de São Paulo, onde ruiu uma estrutura de concreto

Almeida & Koelle, 1992

FSI
Poisson coupling

radial motion of the pipe wall



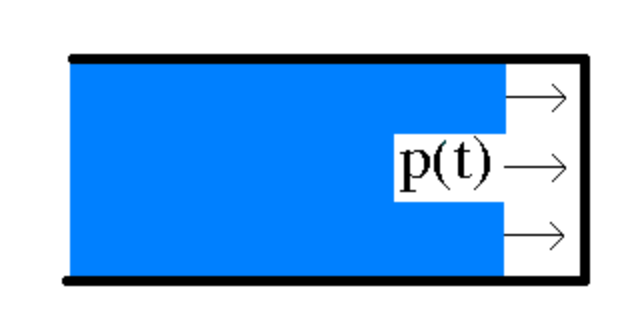
pipe cross section

$$\sigma_{\text{hoop}} = \frac{R}{e} P$$

$$\frac{R}{e} = \frac{\text{pipe radius}}{\text{wall thickness}}$$

FSI
junction coupling

axial motion of the pipe wall

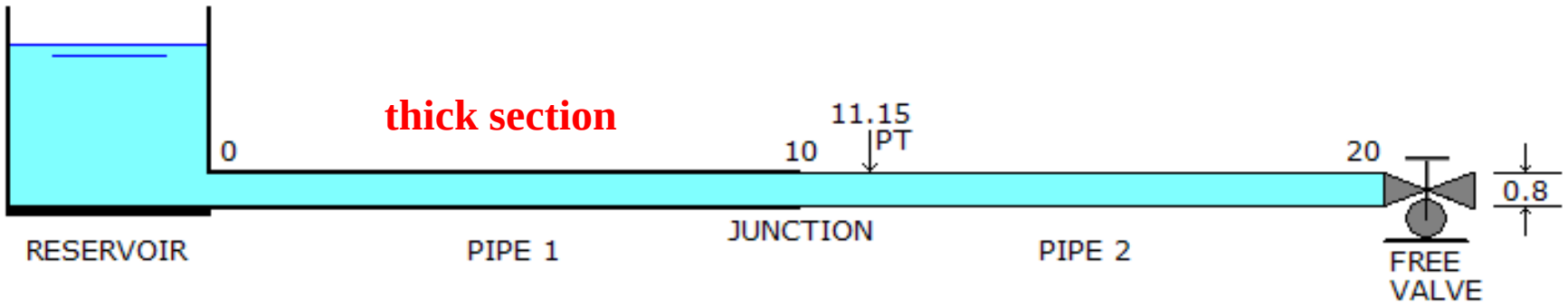


free closed pipe end

$$\sigma_{\text{axial}} = \frac{R}{2e} P_{\text{end}}$$

$$V = \dot{u}_z$$

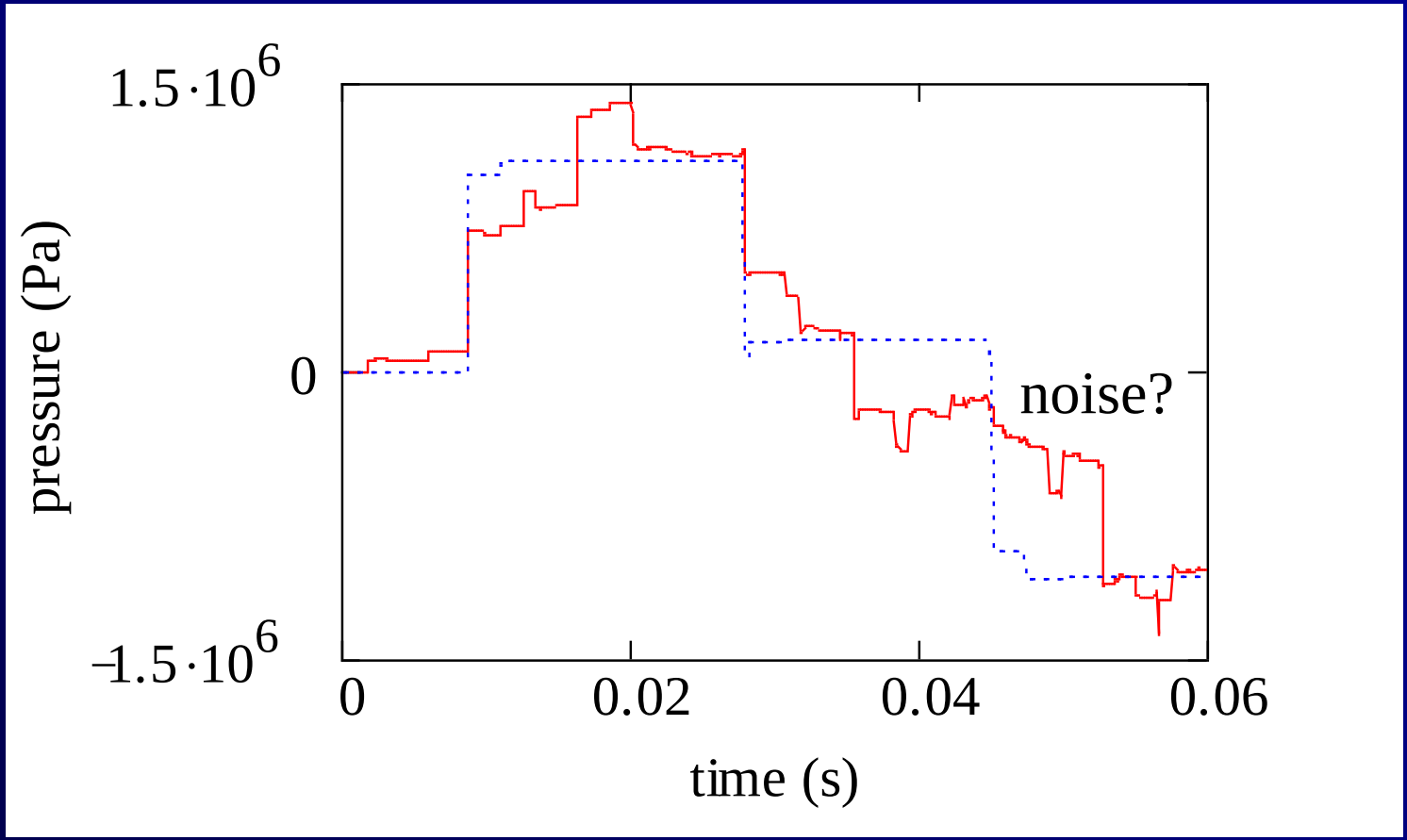
FSI test problem



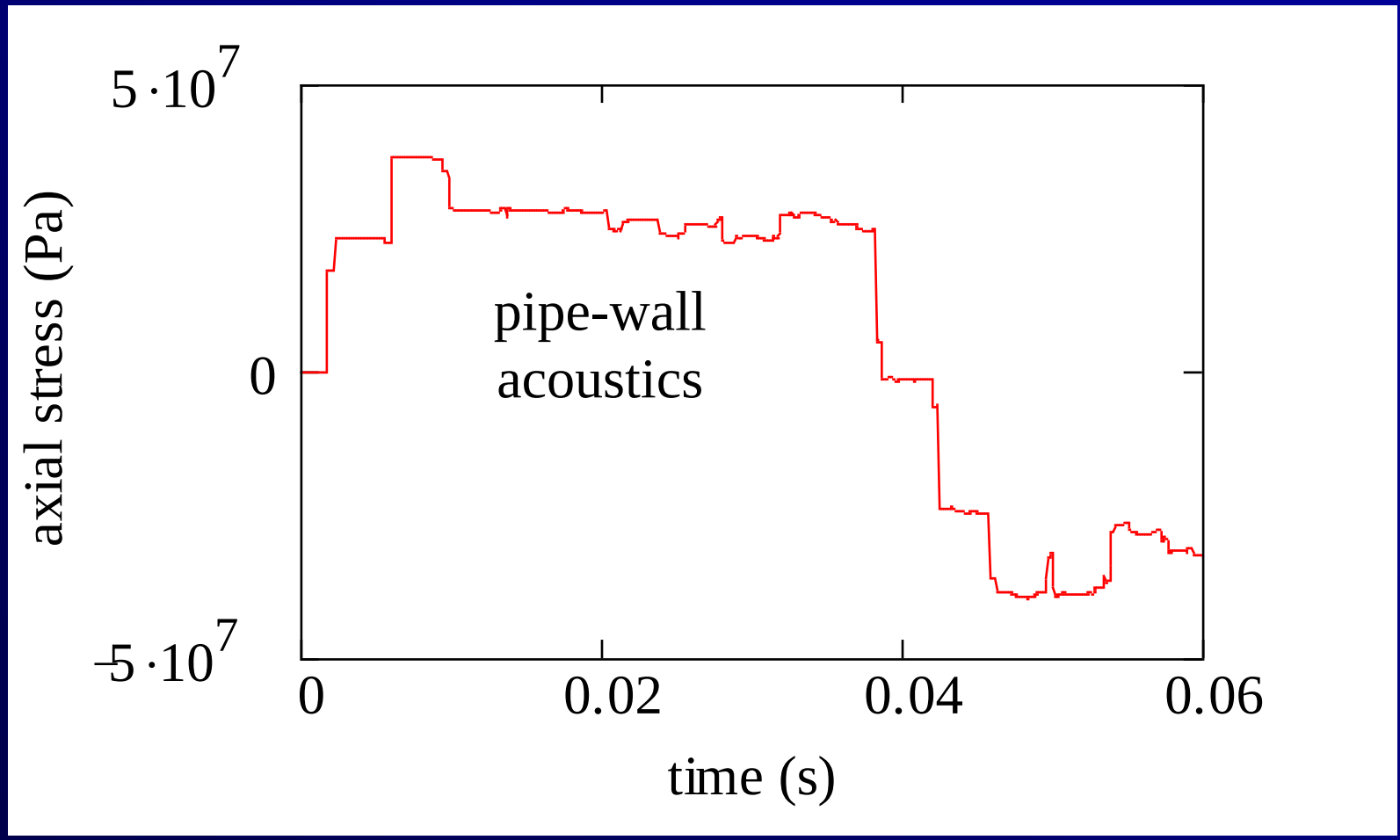
Tijsseling, PVP-2009

L = 20 m, R = 0.4 m, e_1/R = 0.04, e_2/R = 0.02

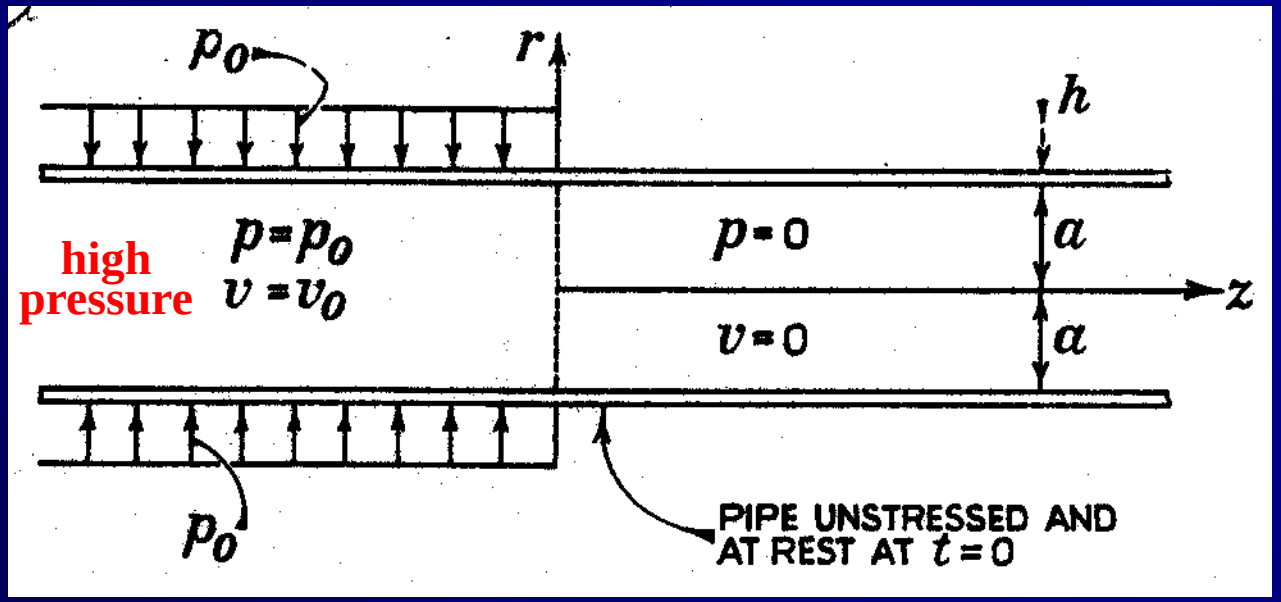
calculated pressure at PT for instantaneous valve closure



calculated axial pipe stress at PT for instantaneous valve closure

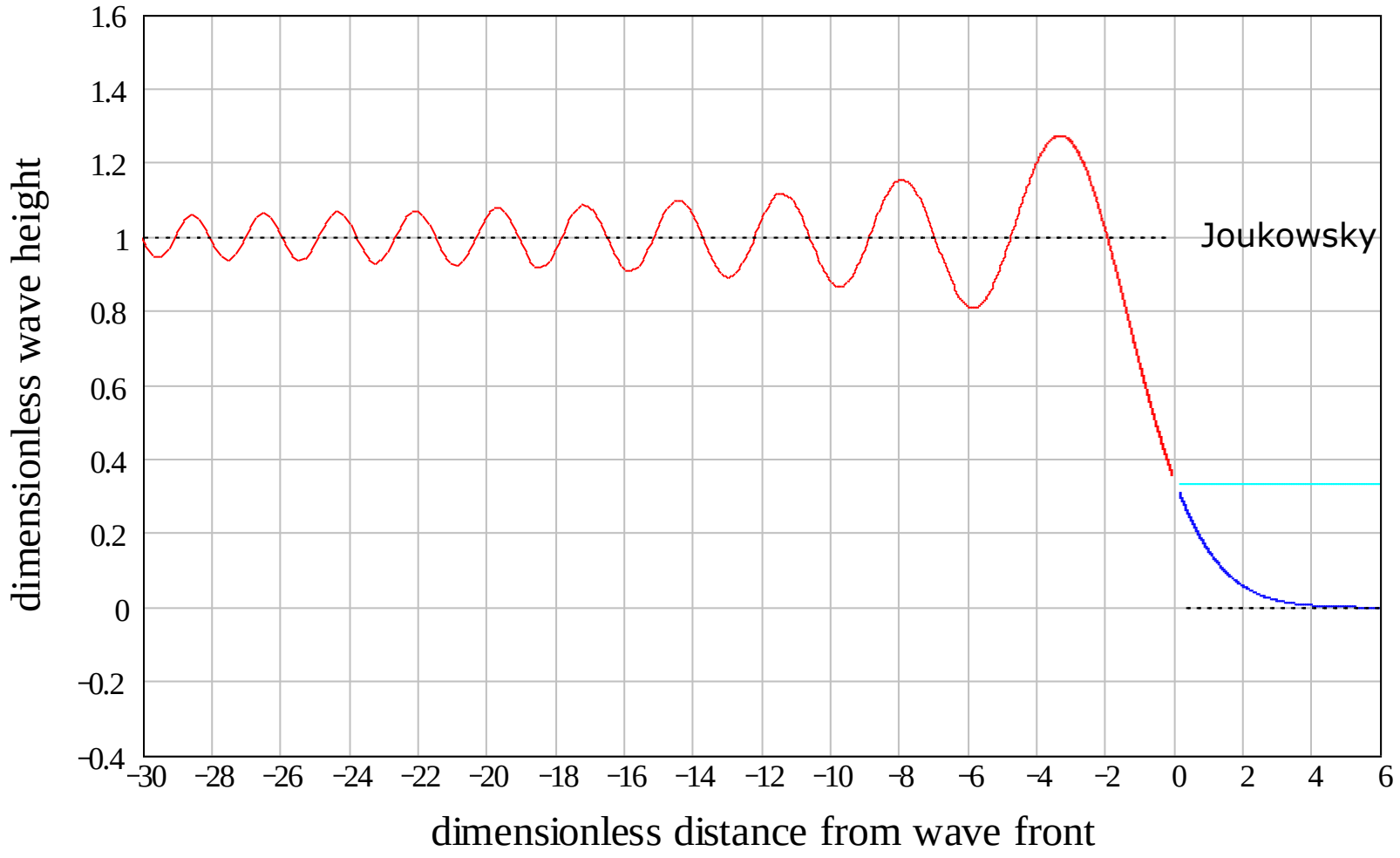


Skalak's wave-front problem



Skalak, 1956

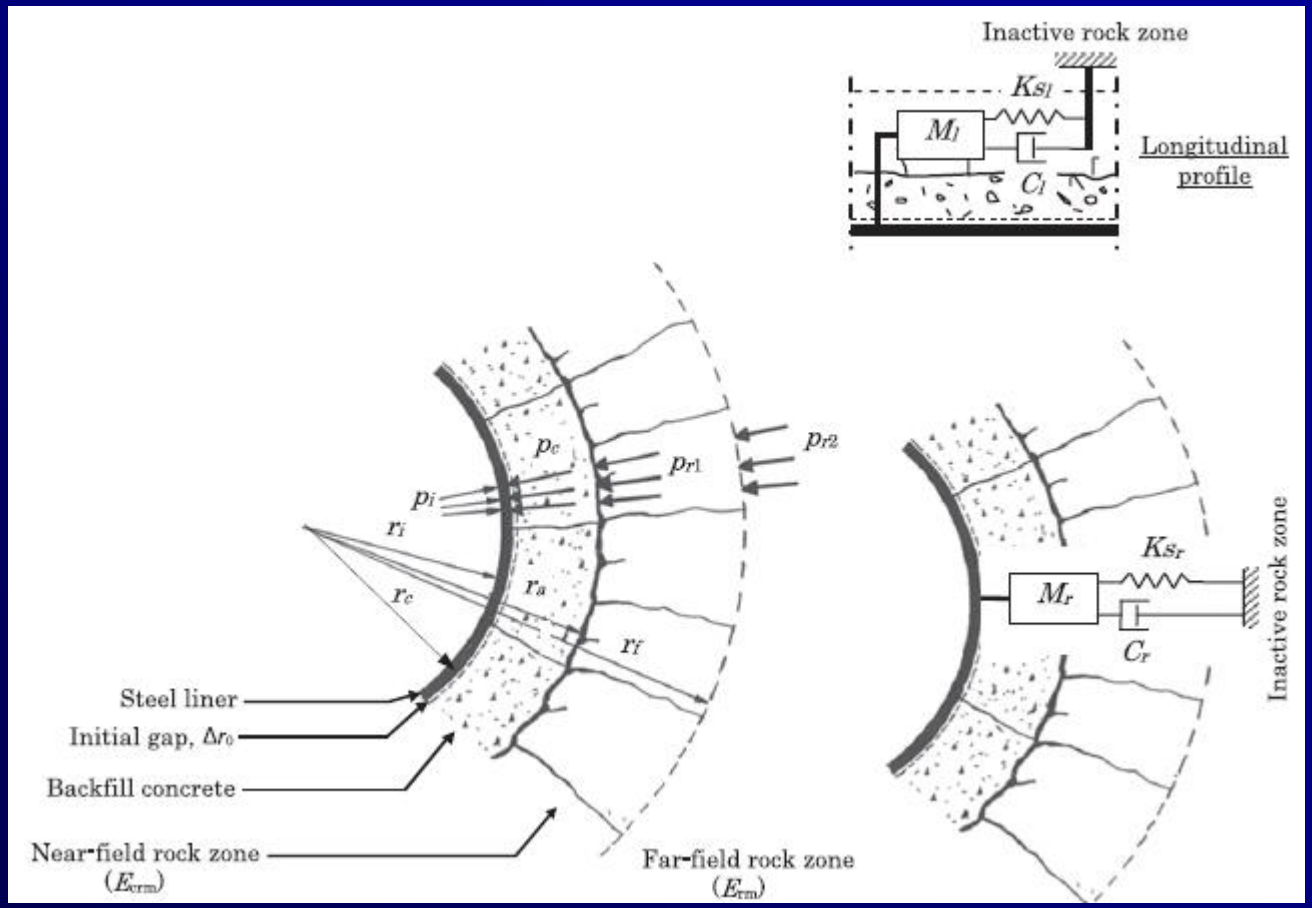
Skalak's solution (wave front)



Tijsseling et al, JSV 2008

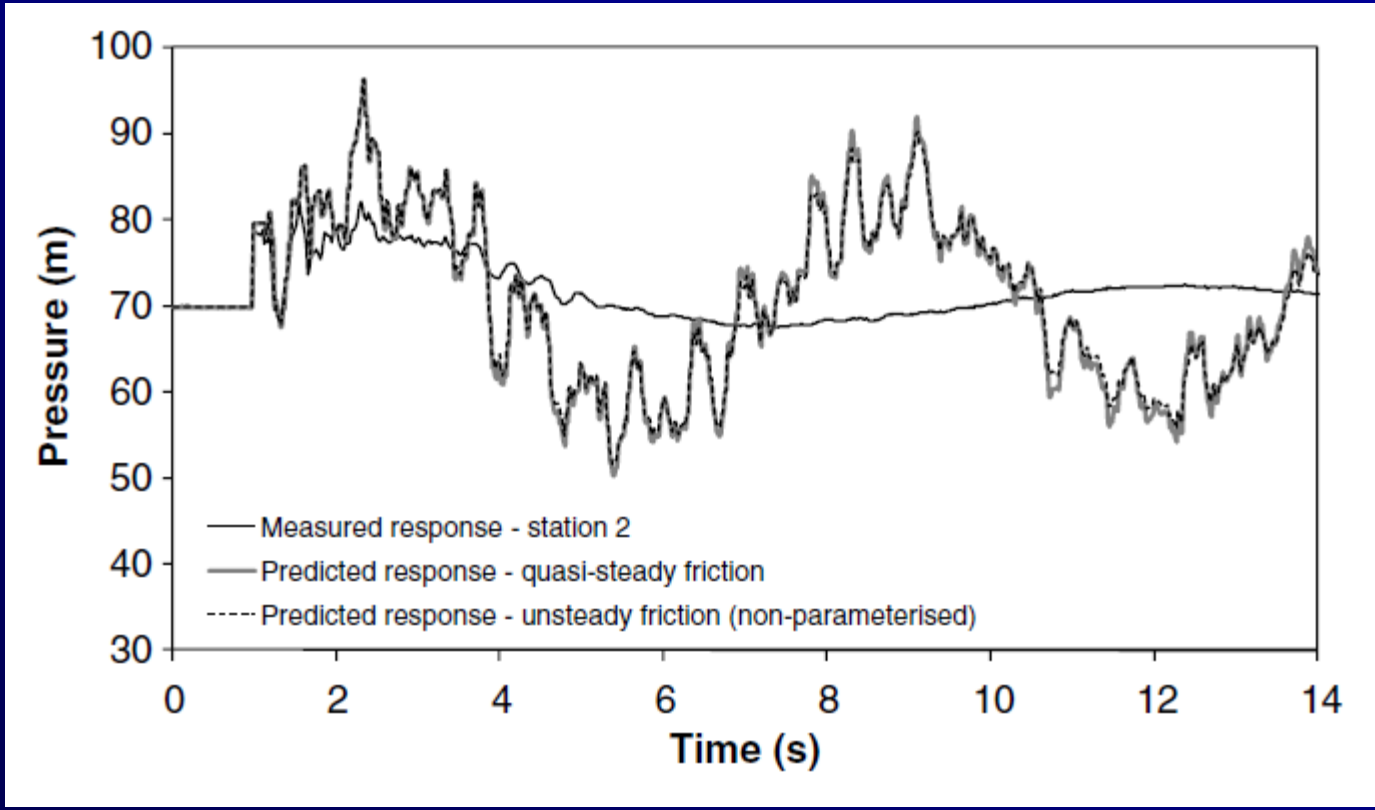
wave front dispersion (dimensionless)

Rock-bored tunnels



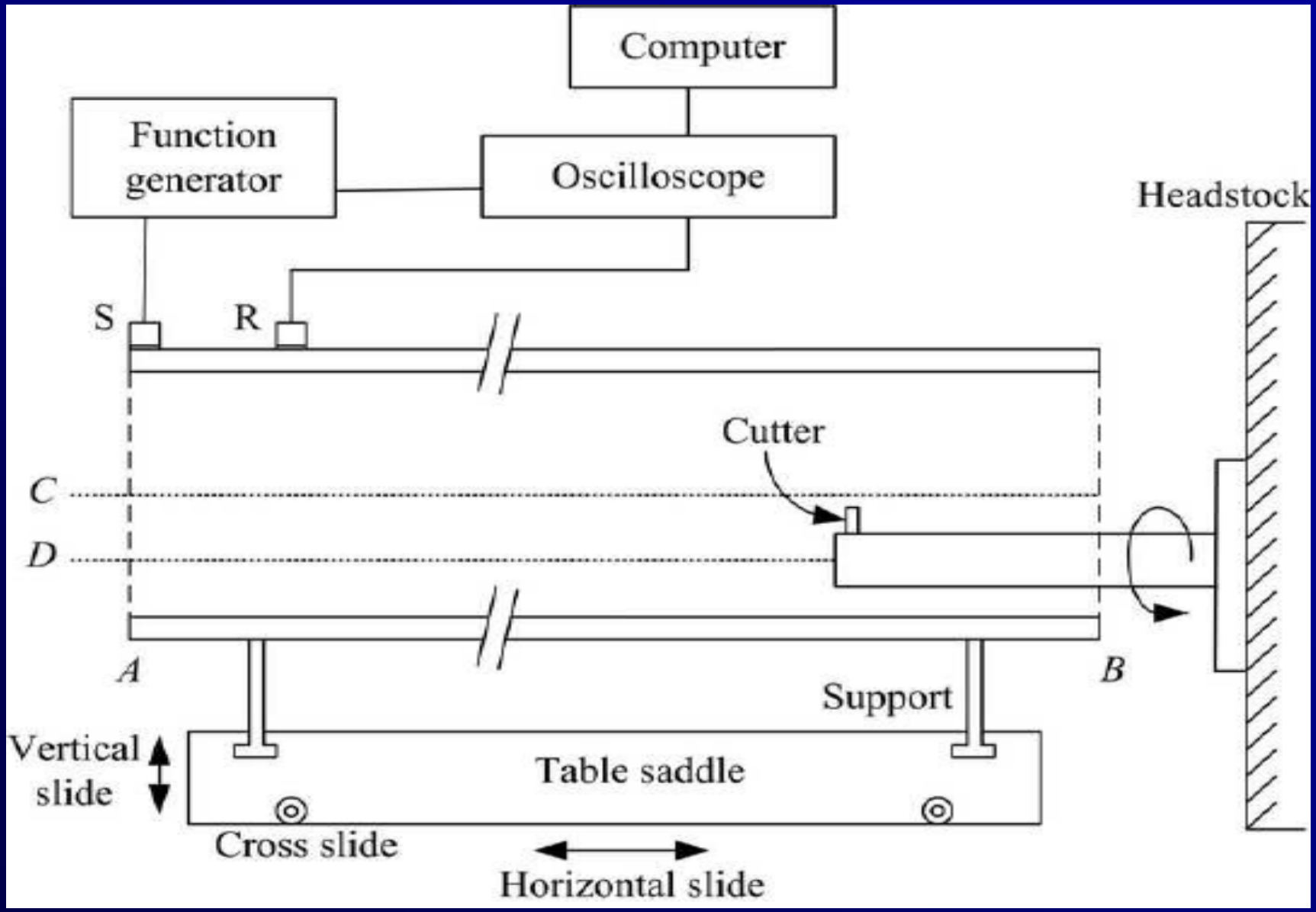
Hachem and Schleiss,
JFS 2011

Underground hydraulic networks



Stephens et al,
JHE 2011

Laboratory set-up (Vogelaar, TU Eindhoven)



Clerkenwell Tunnel flood - London
January 2015

Network Rail sends Thames Water 'multi-million pound bill'

- Network Rail has issued Thames Water with a "multi-million pound bill" after leaks and a **burst water main** led to more than 1,000 trains being cancelled.

- "We believe this problem was first identified as far back as 2007, and the problems with water on the track have been caused by a **lack of maintenance** on their part."

- Thames Water identified a burst water main on Friday evening and found a **further four leaks** that are yet to be fixed.

- **Specialist teams** are also carrying out assessments of the pipe and checking roads nearby for additional leaks.