MWWD CONFERENCES

COURSE B– Hydraulics of WWTP Outfall Dispersion System

SECTION NR. 4b

Unsteady Pipe and Diffuser Hydraulics

Transient Flow

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Professor, dr.techn.

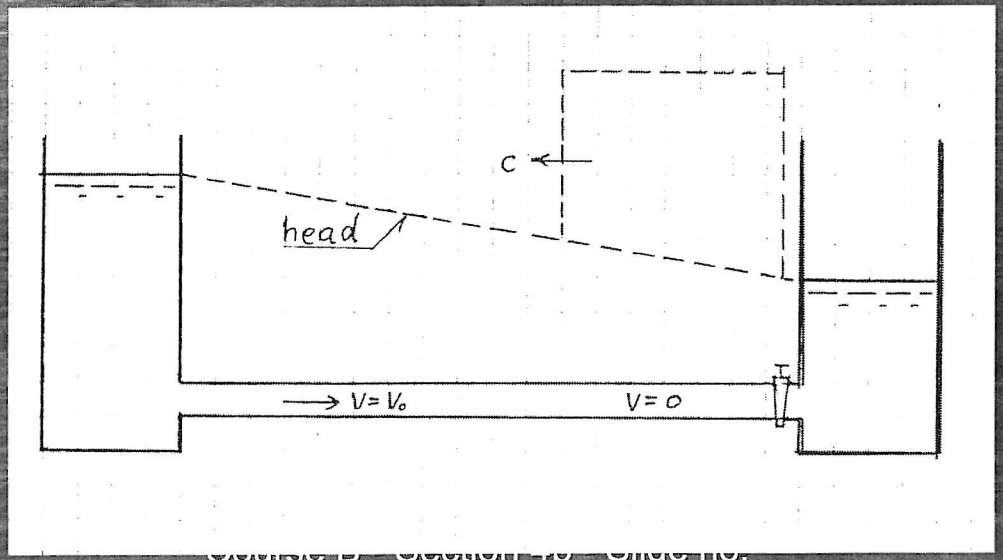
Types of transient flow in pipelines

Unsteady "rigid" flow

Same velocity and acceleration in all points

Full transient flow

Variations in velocity and pressure travel with the wave celerity



Theory of transient flow in pipelines

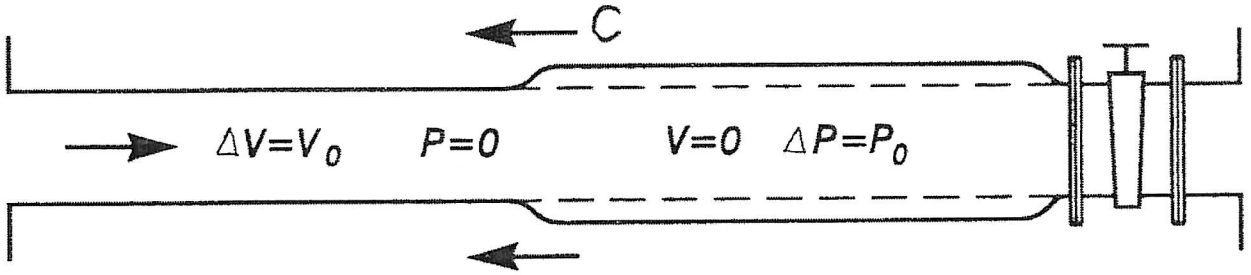
The very short version

Only the three most important elements shall be mentioned

1. The Joukowsky formula
2. Reflection of velocity and pressure changes
3. Cavitation

JOUKOWSKY FORMULA

Based on Newton's second law



$$\text{Pressure}: \Delta p = \pm c\,\rho\,\Delta v \quad \text{[Pascal]}$$

$$\text{Head}: \quad \Delta h = \pm \frac{c}{g} \Delta v \quad \text{[m water column]}$$

Wave celerity of transients

Depends on the elasticity of the fluid and the pipe

- Plastic pipelines
  c= 200 – 400 m/s
- Steel pipelines
  C=900 – 1200 m/s

General formula

$$c = \sqrt{\frac{1}{\rho\left(\frac{1}{K} + \frac{D}{eE}\Phi\right)}}$$

ρ fluid density

K fluid kompressibility

D pipe diameter

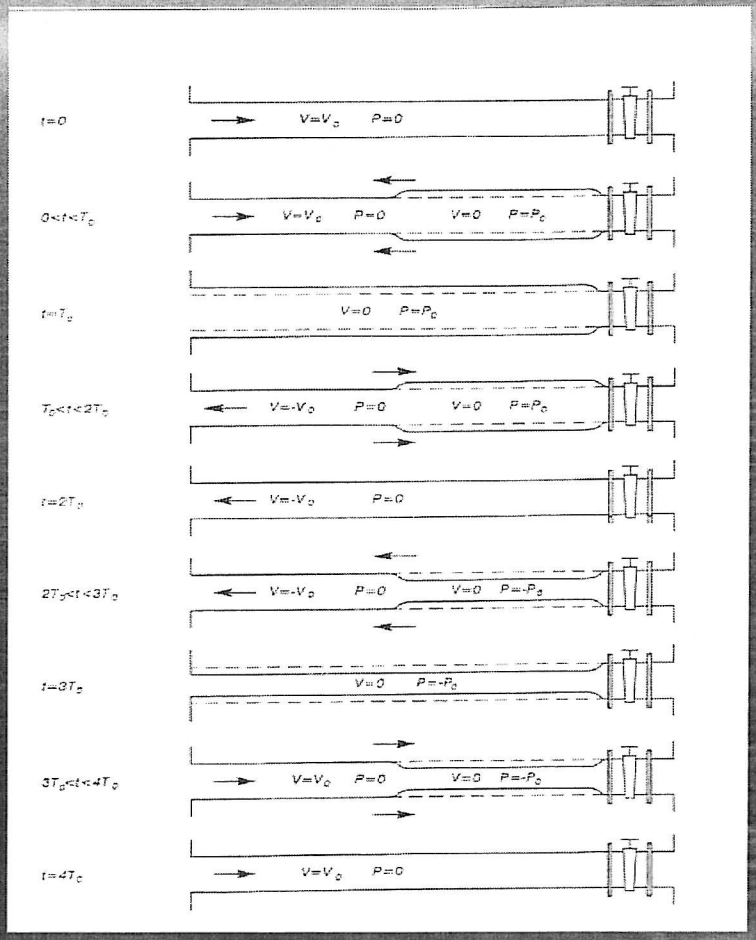
e pipe wall thickness

E Young modulus of pipe wall

Φ restraint factor (nomally = 1)

Reflection of waves

- Pressure and velocity changes are reflected both at open and closed ends in pipe
- Reflection time is T=2L/c



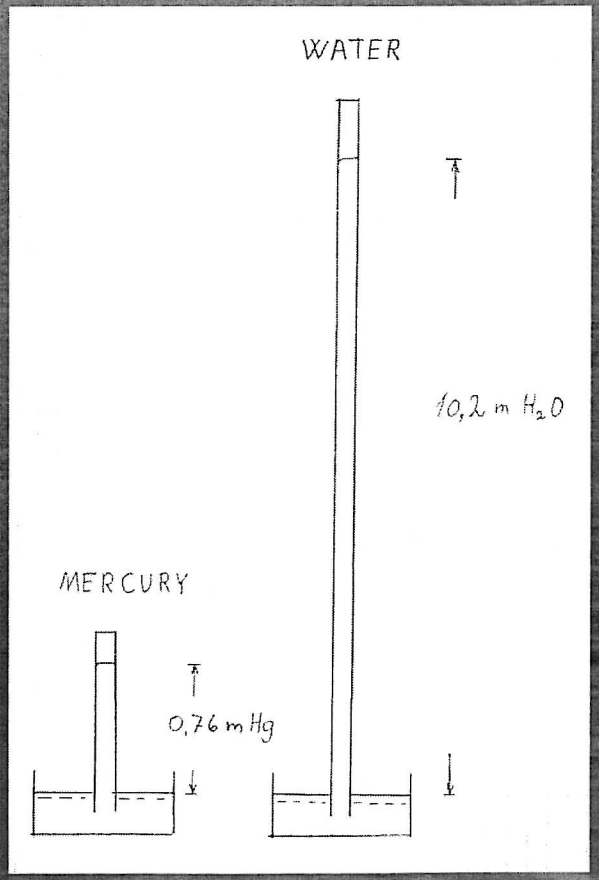
The progress after a sudden valve closure

Cavitation

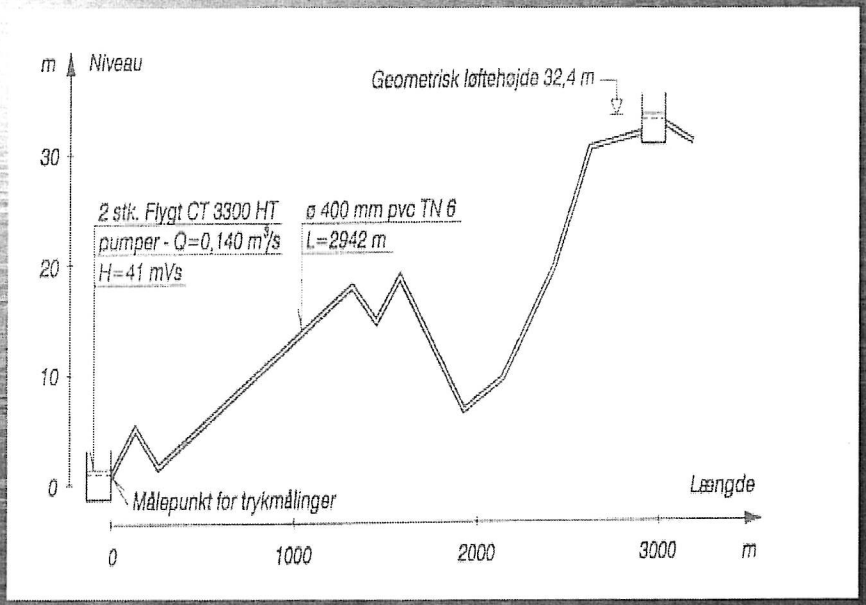
If the pressure in the fluid decreases down to the vapor pressure of the fluid a cavitation will occur

- In practice cavitation will occur if the pressure head reduces to – 10 m water column.
- Cavitation will often enhance the effect of transients
- Cavitation should be avoided

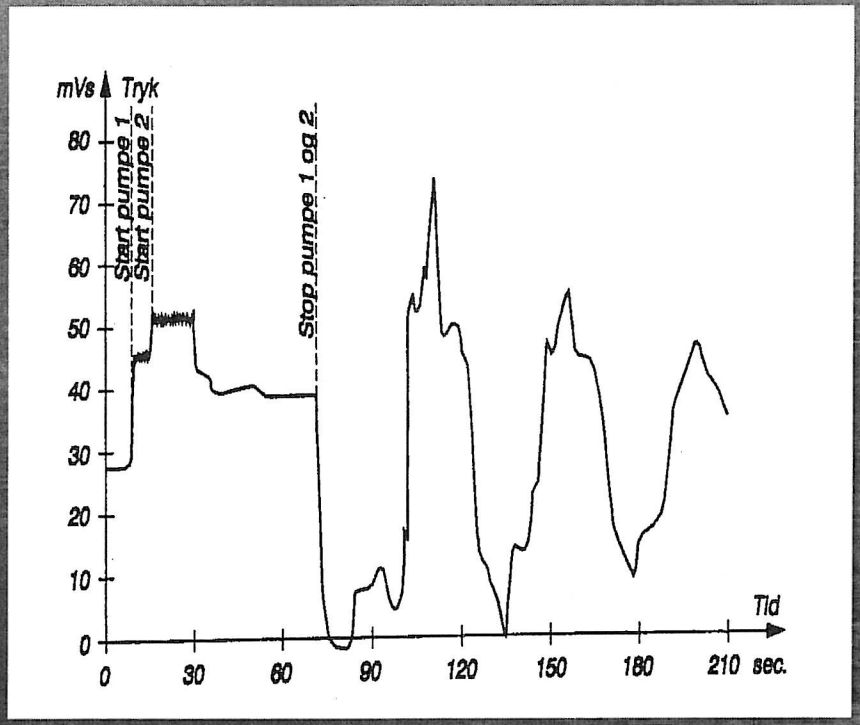
Water barometer



EXAMPLE –
Transient flow in sewer pressure main

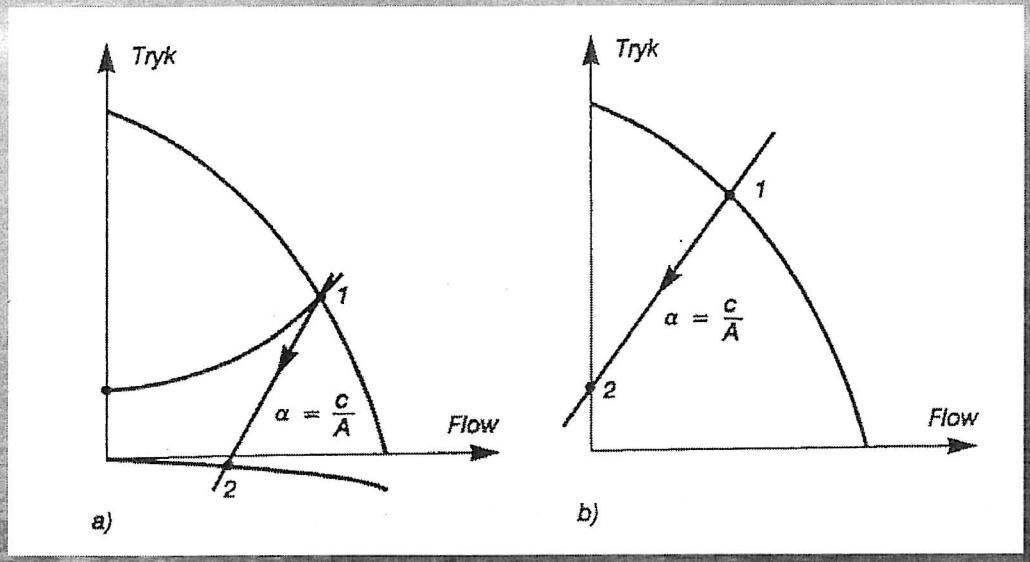


Length profile of pipeline



Time history of head in pipe near pump

Pump boundary condition



At pump shut-down two possibilities exist

1. The non return valve close immediately
2. The non return valve remains open until the pressure wave returns

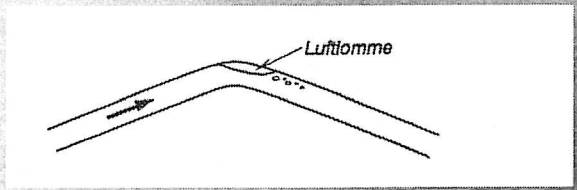
Reduction of water hammer

General principle: Reduce accelerations of the flow

- Speed control of pump (frequency converter)
- Air chambers
- Surge chambers

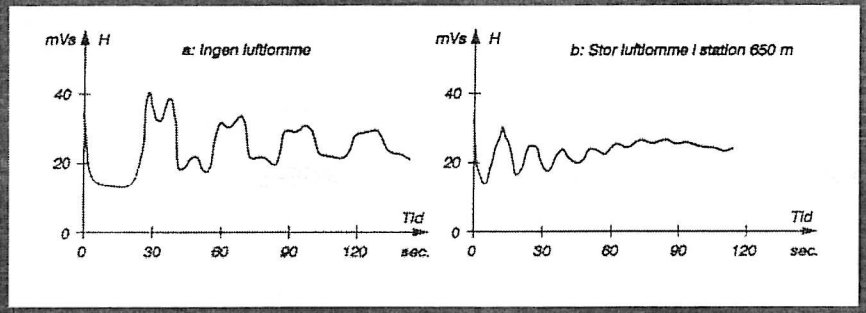
Air pockets and transients

Air pocket at high point



- Large air pockets will often reduce the transients
- Small air pockets can under certain circumstances enhance the transients
- Air pockets should always be avoided

No air pocket Large air pocket

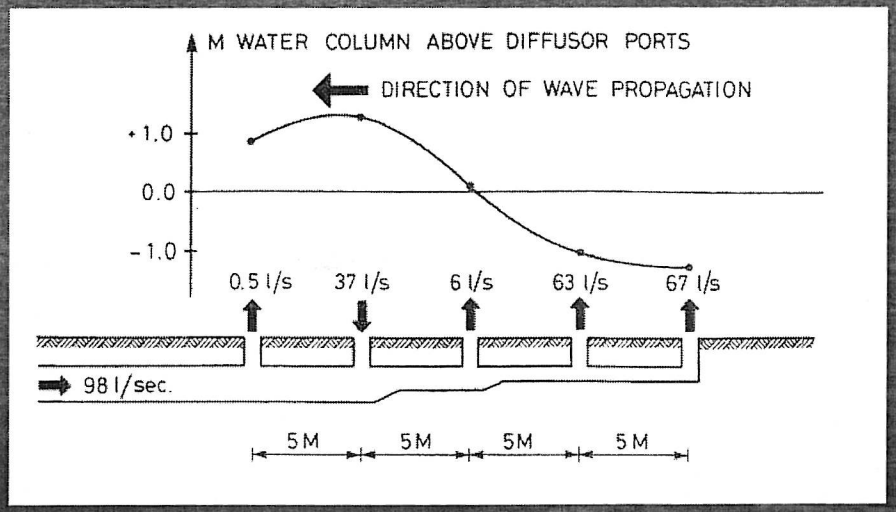


Time history of head in the same pipe after pump shut-down

Transient flow in diffusers
Effect of sea surface waves 1

- Pressure variations because of sea surface waves induce saline intrusion in diffusers

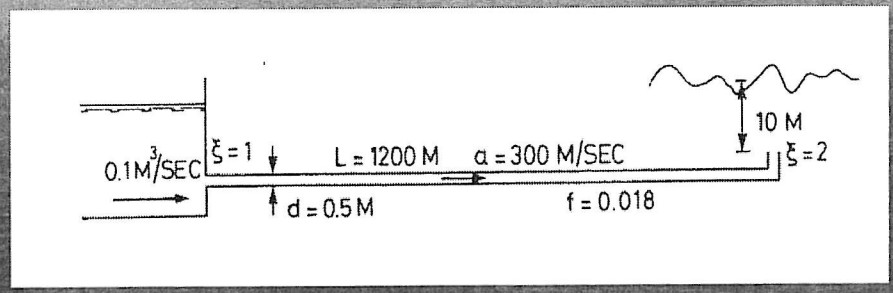
Unsteady flow in diffuser induced by waves

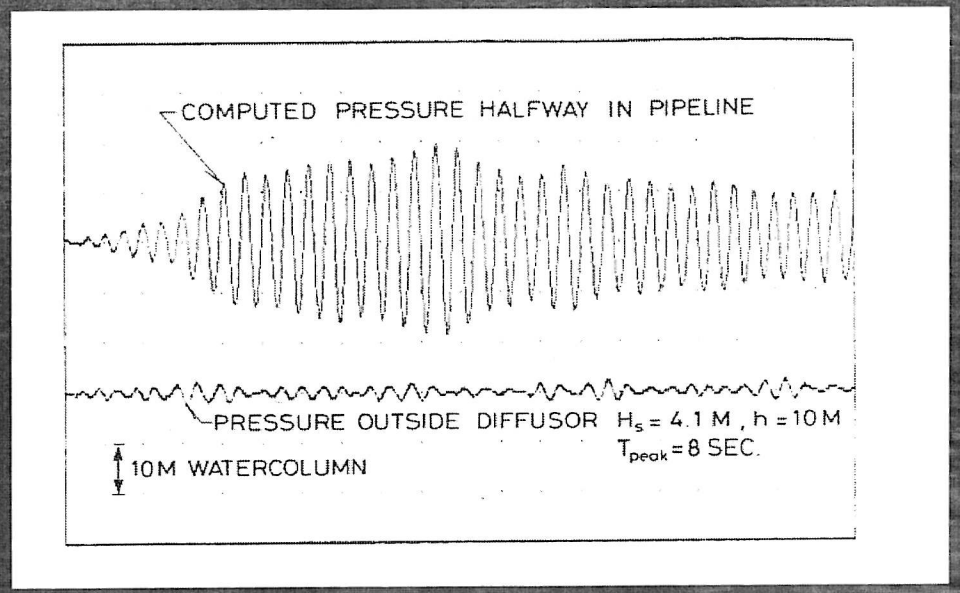


Transient flow in diffusers

Effect of sea surface waves 2

- Sea surface waves can in theory cause resonance in main pipe in long sea outfalls
- This effect has not yet been reported in practice





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Thorley, A.D.R. (1993) Fluid transients in pipeline systems. D&L George Ltd. UK.

Wylie, E.B. and Streeter, V.L. (1993). Fluid transients. FEB Press, Ann Arbour, Michigan, USA.

Larsen, T. (2003). User guide for WHPS (Water Hammer at Pump Shut-down). Torben Larsen, Aalborg.

Examples of computer simulation of transients in sea outfalls and pressure mains

The simulations showed hereafter are performed with the

WHPS (Water hammer at Pump Shut-down) software
which was developed by

Torben Larsen
E-mail: torben.larsen@civil.auc.dk

The simulations are not part of this PowerPoint presentation but a copy can be required by sending an e-mail to Torben Larsen

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- Marine and Environmental hydraulics
- Soil mechanics
- Structural mechanics and dynamics
- Physical geography