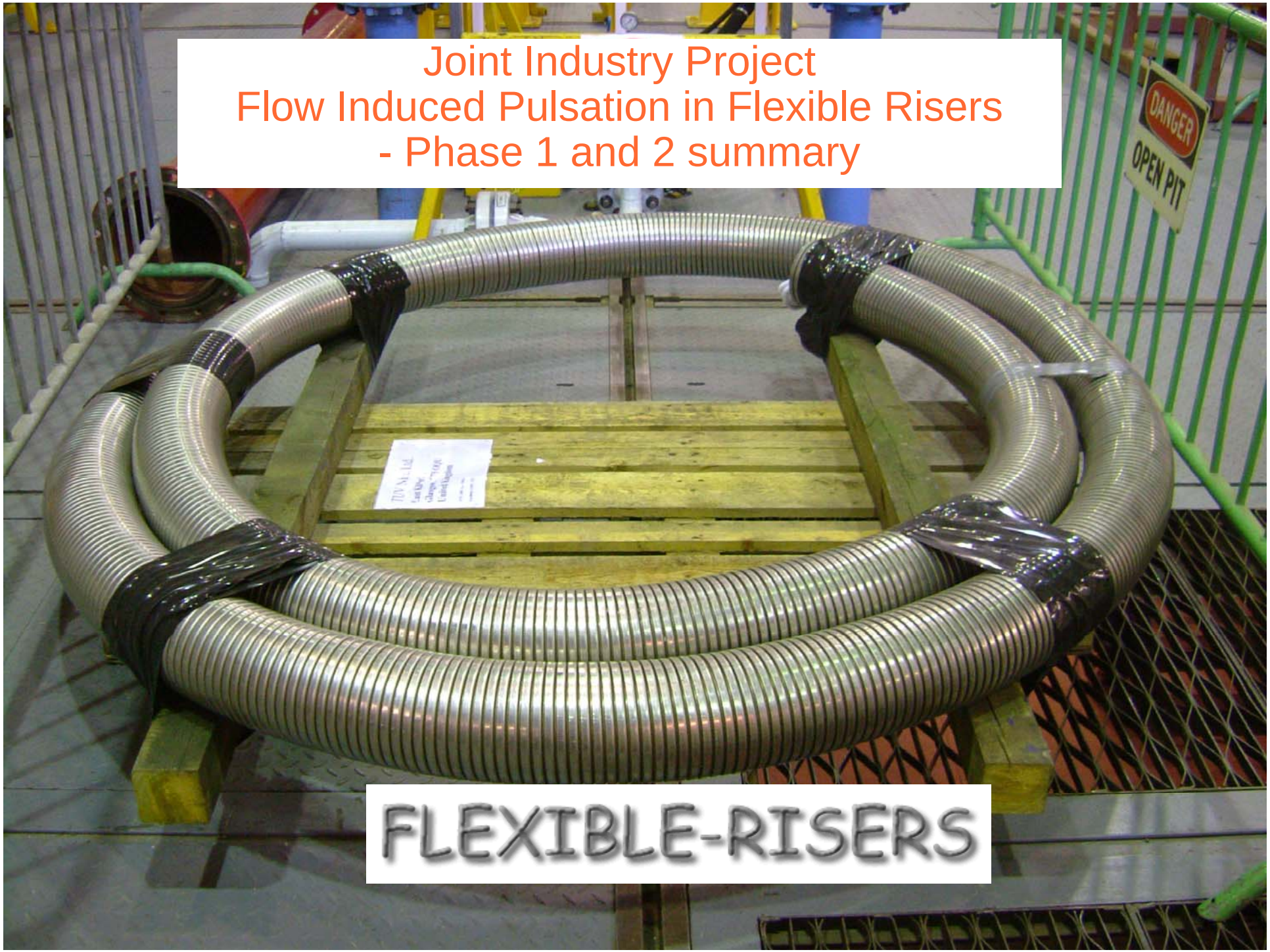


Joint Industry Project
Flow Induced Pulsation in Flexible Risers
- Phase 1 and 2 summary

Existing / Previous JIP Participants

Phase 1 and 2:

- ExxonMobil Upstream Research Company
- BP Exploration
- Bureau Veritas Energy & Process Group
- UK Health & Safety Executive

Phase 1 only:

- Statoil

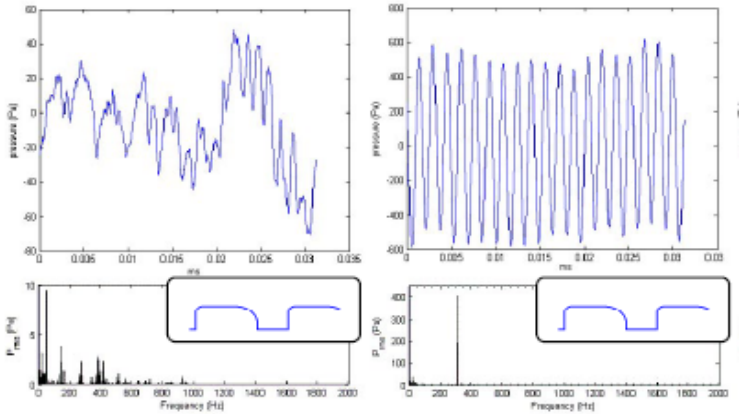
Principal Subcontractor

- TNO

Project Management

- OTM

Goal of JIP

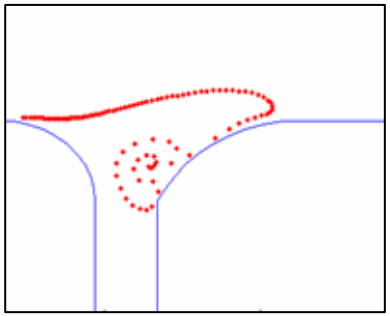


Flexible risers can “sing”:

- this provides an operational hazard

- The goal of the JIP Flexible risers project is:
  - To provide guidelines for assets with existing risers
  - To provide guidelines for operators looking to use flexible risers

- Method:
  - Inventory of existing installations with singing flexibles
  - Research in the singing phenomenon (process conditions, geometry, etc..)
    - Experiments on artificial corrugated, and real carcass, geometries
    - Numerical analysis on vortex shedding on corrugations



JIP Phase 1 & 2 Questions

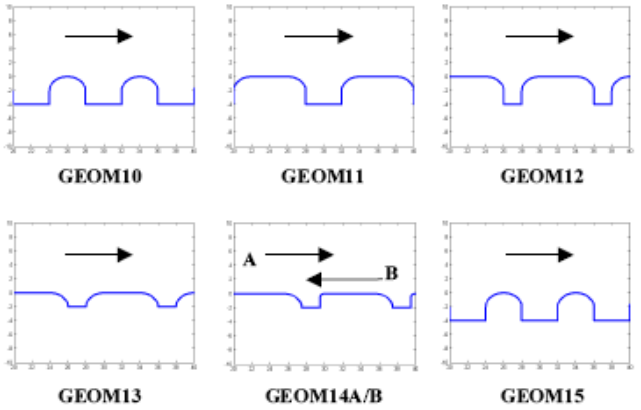
We want to be able to predict:

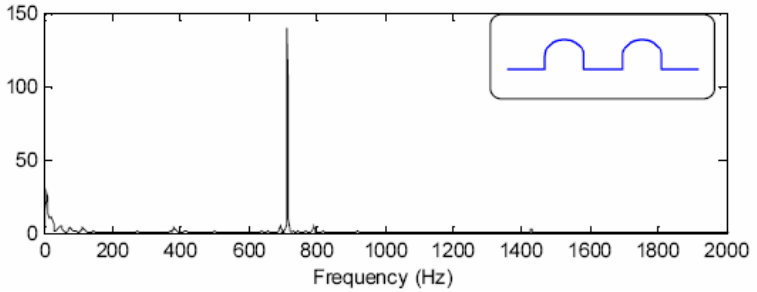
- The ‘Onset’ process flow velocity
- The pressure pulsation frequency
- The pressure pulsation amplitudes
- The pressure drop along the riser

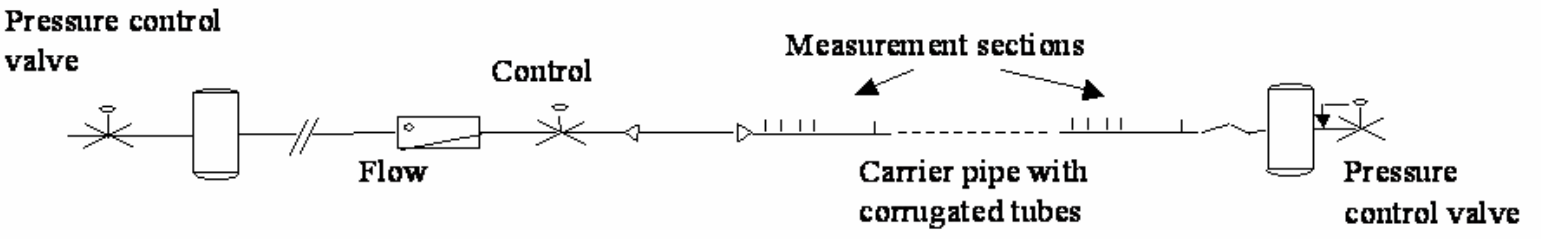
We want to be able to establish the influence of line pressure, riser carcass geometry (corrugations, length) and boundary condition is investigated

JIP Phase 1 & 2 experiments

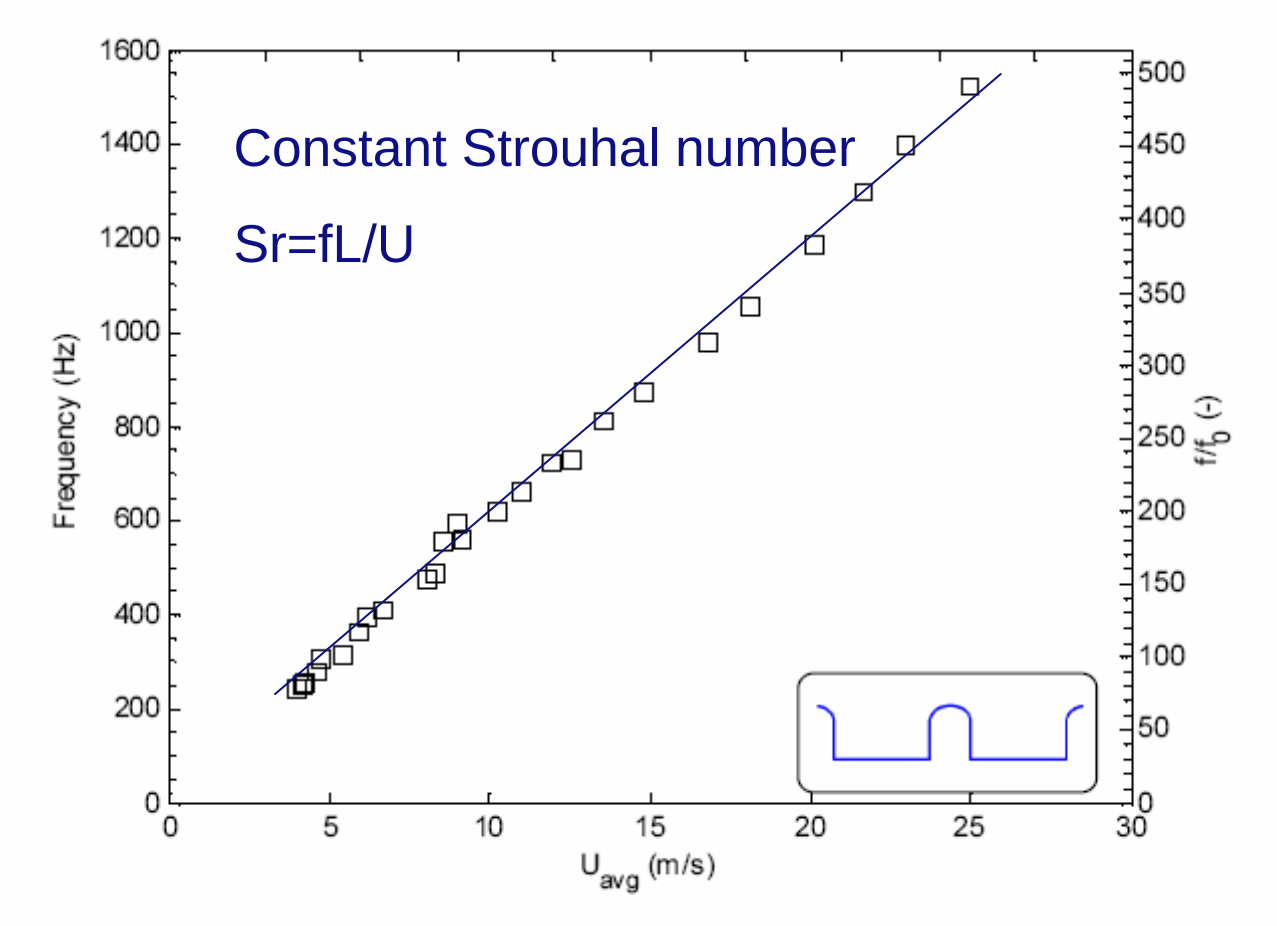
- High Pressure testing (40, 60 bar)
  - 6” Wellstream/Coflexip/NKT
- Low/medium pressure testing
  - 2” Wellstream/Coflexip
  - 2” artifical geometries
  - Over 20 geometries
- Measuring
  - P’ at 10 locations
  - Multi Microphone method



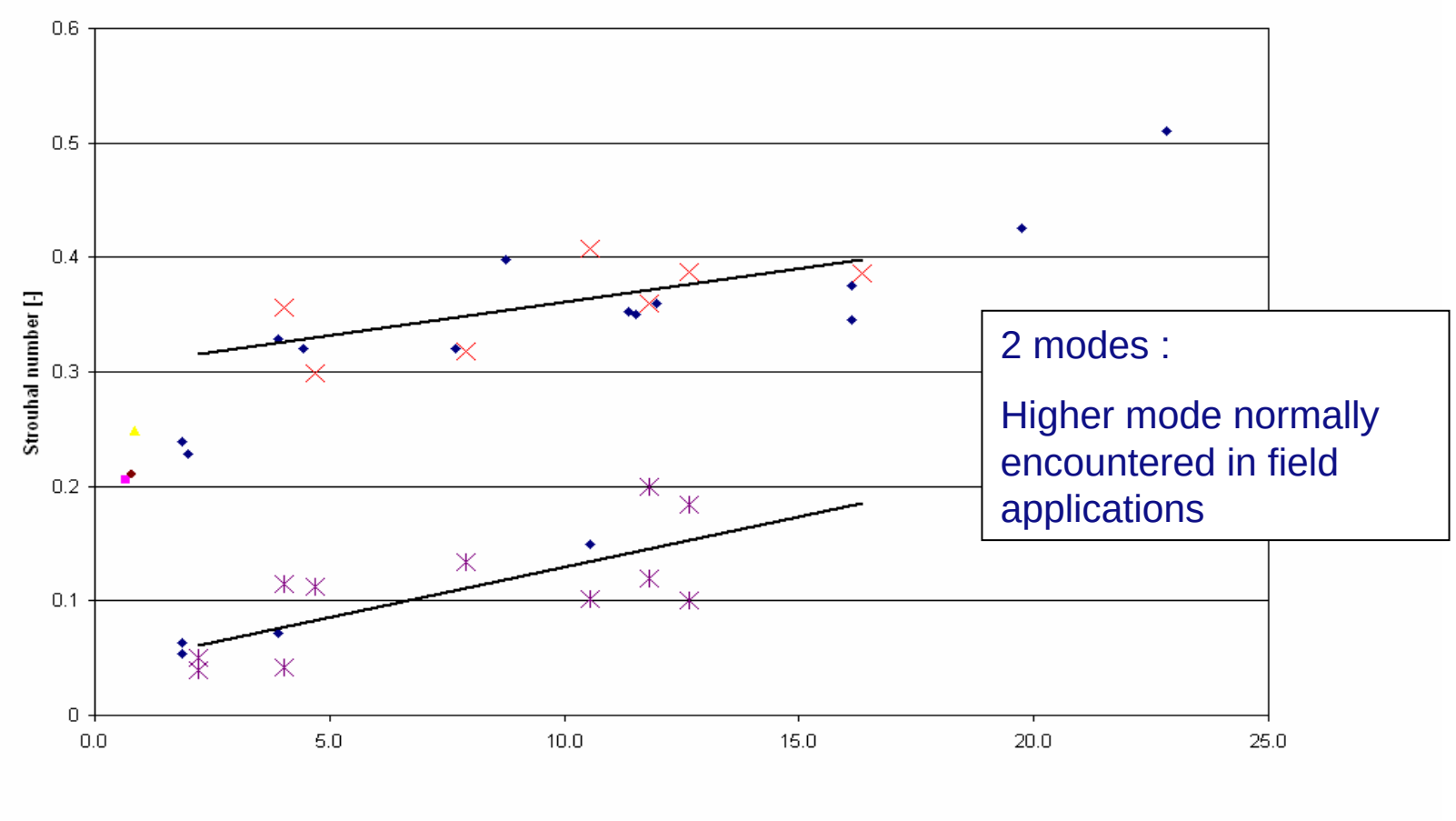




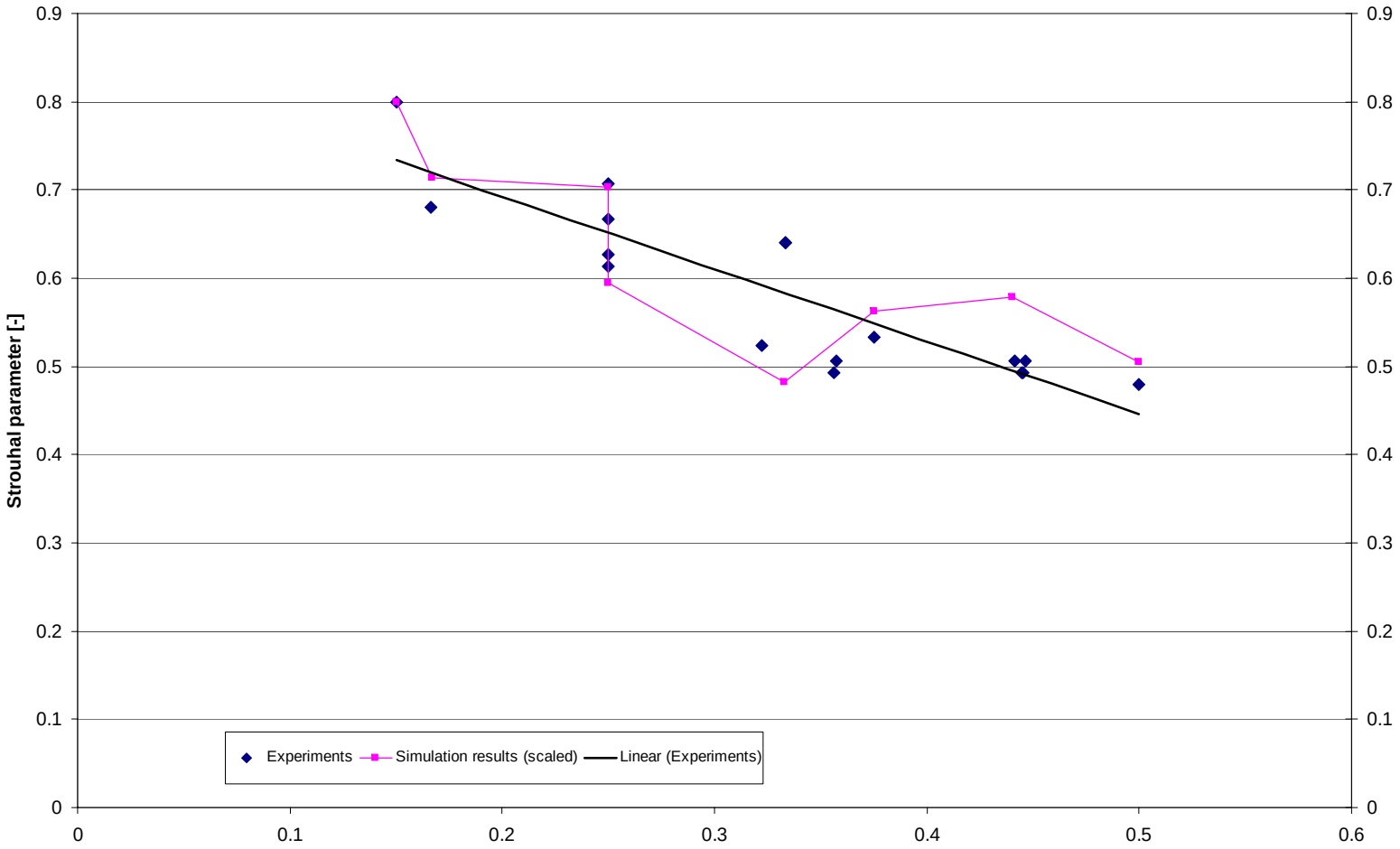
Frequency


Constant Strouhal number
Sr=fL/U
Frequency (Hz)
U_{avg} (m/s)
f/f_0 (-)
0
200
400
600
800
1000
1200
1400
1600
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400
450
500

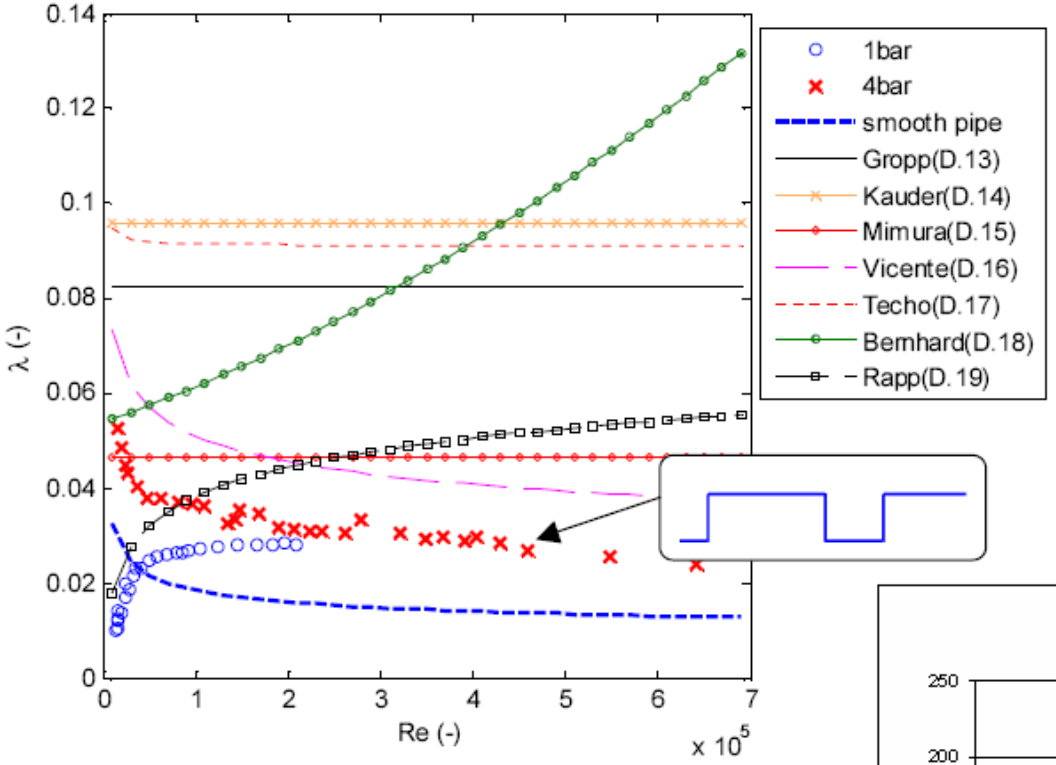
Frequency vs Geometry

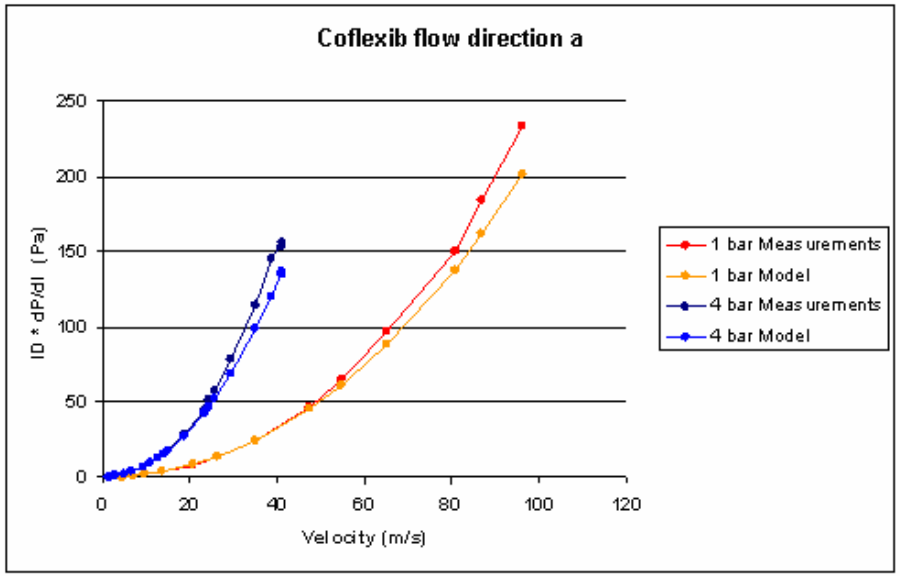


Frequency vs Geometry



Pressure drop





Amplitude

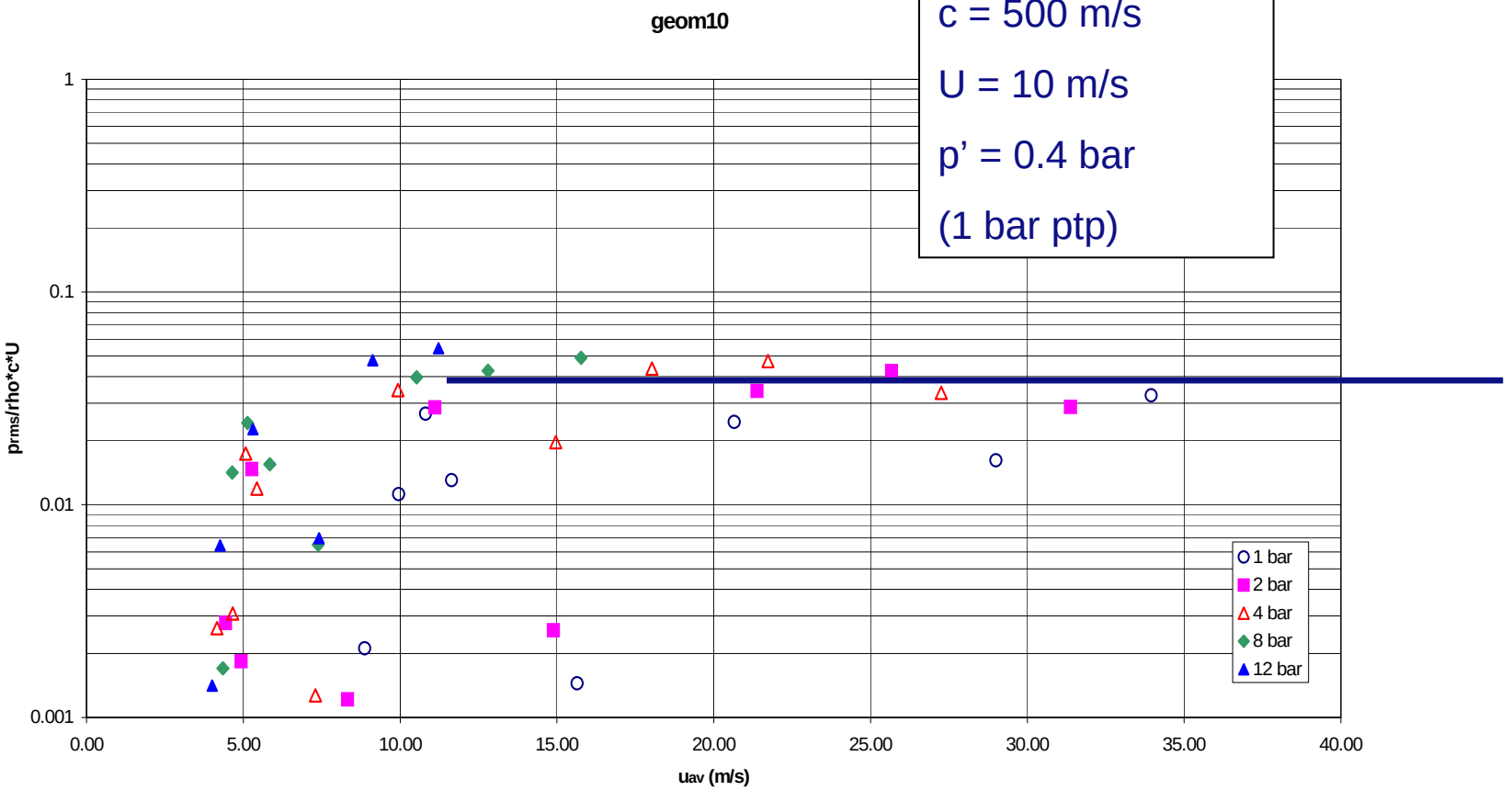
ρ = 200 kg/m^3

c = 500 m/s

U = 10 m/s

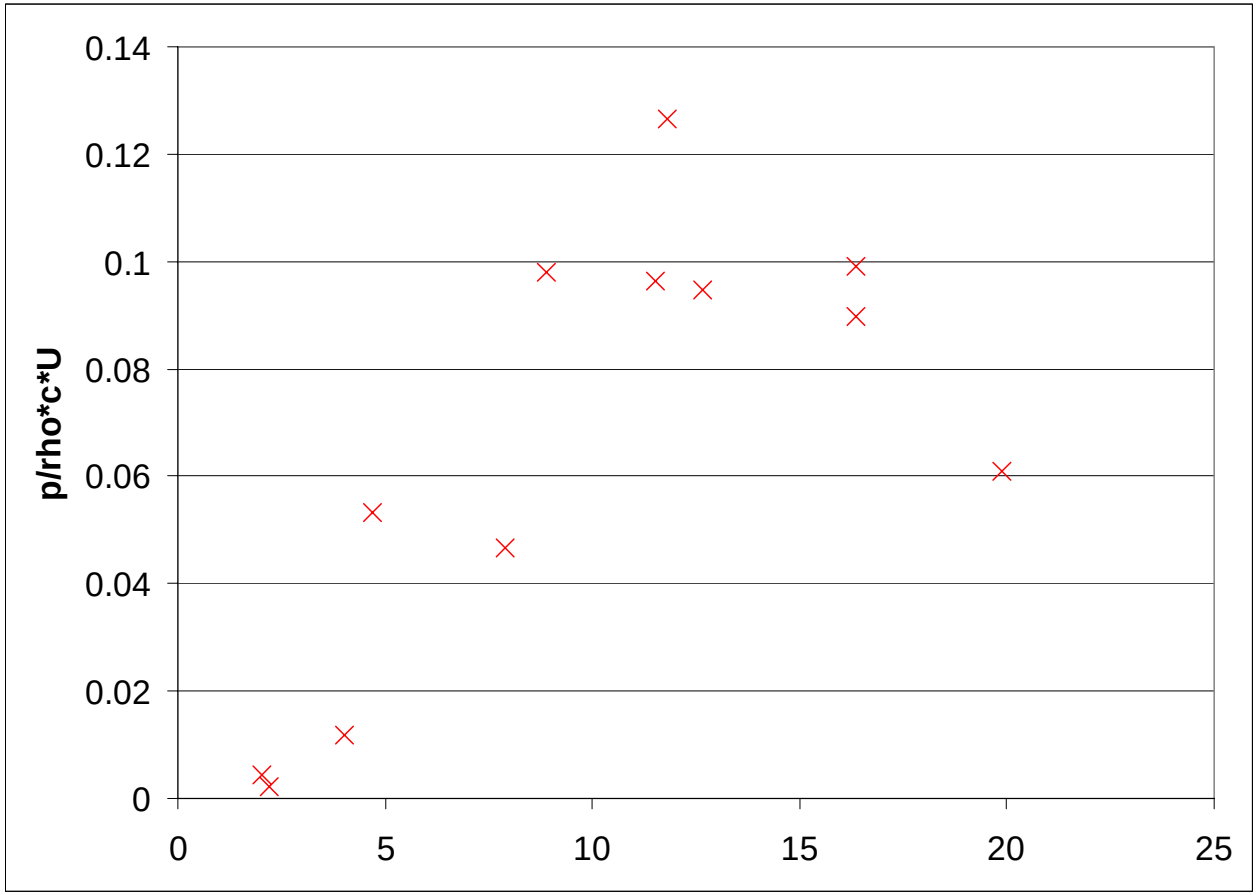
p' = 0.4 bar

(1 bar ptp)



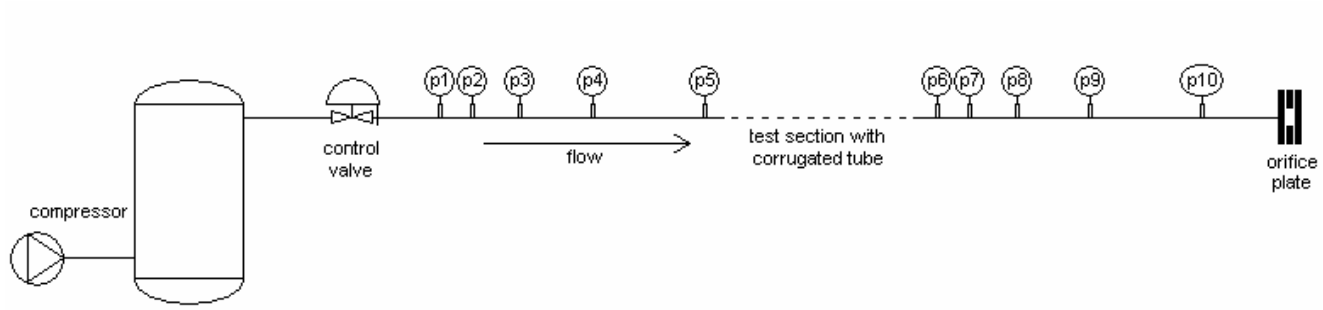
Amplitude

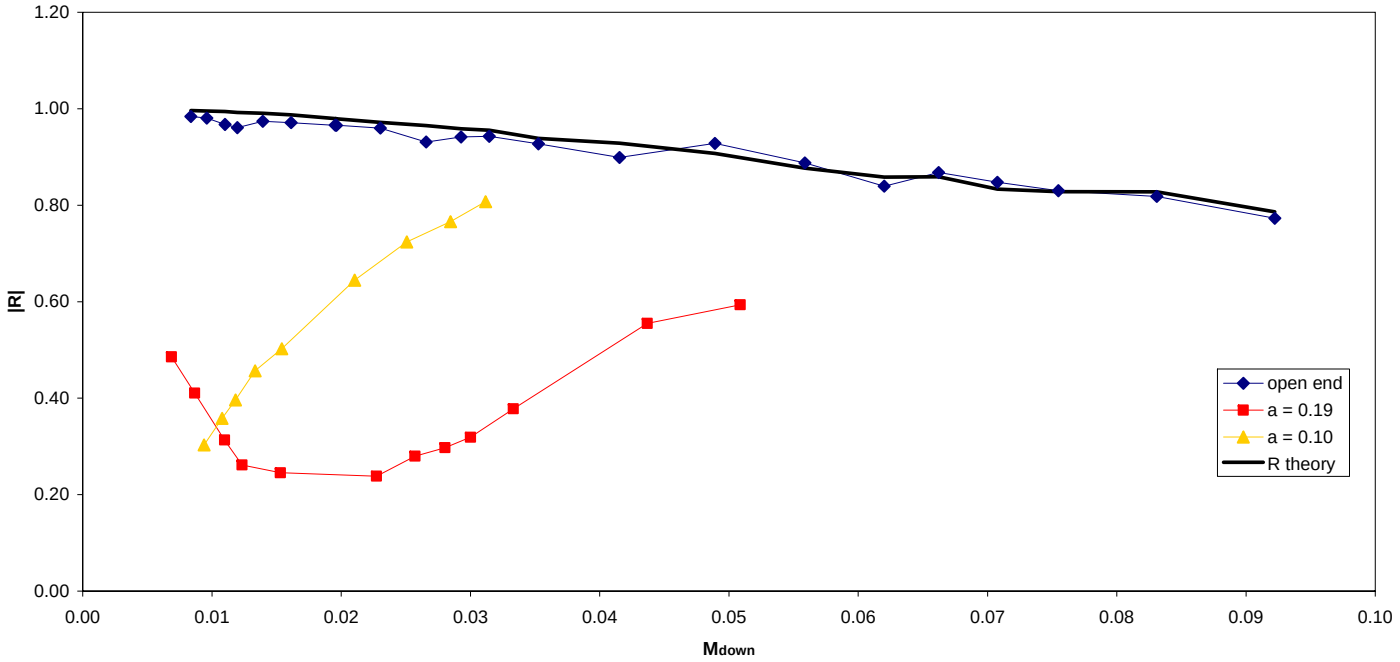
Some geometries will excite higher amplitudes than others

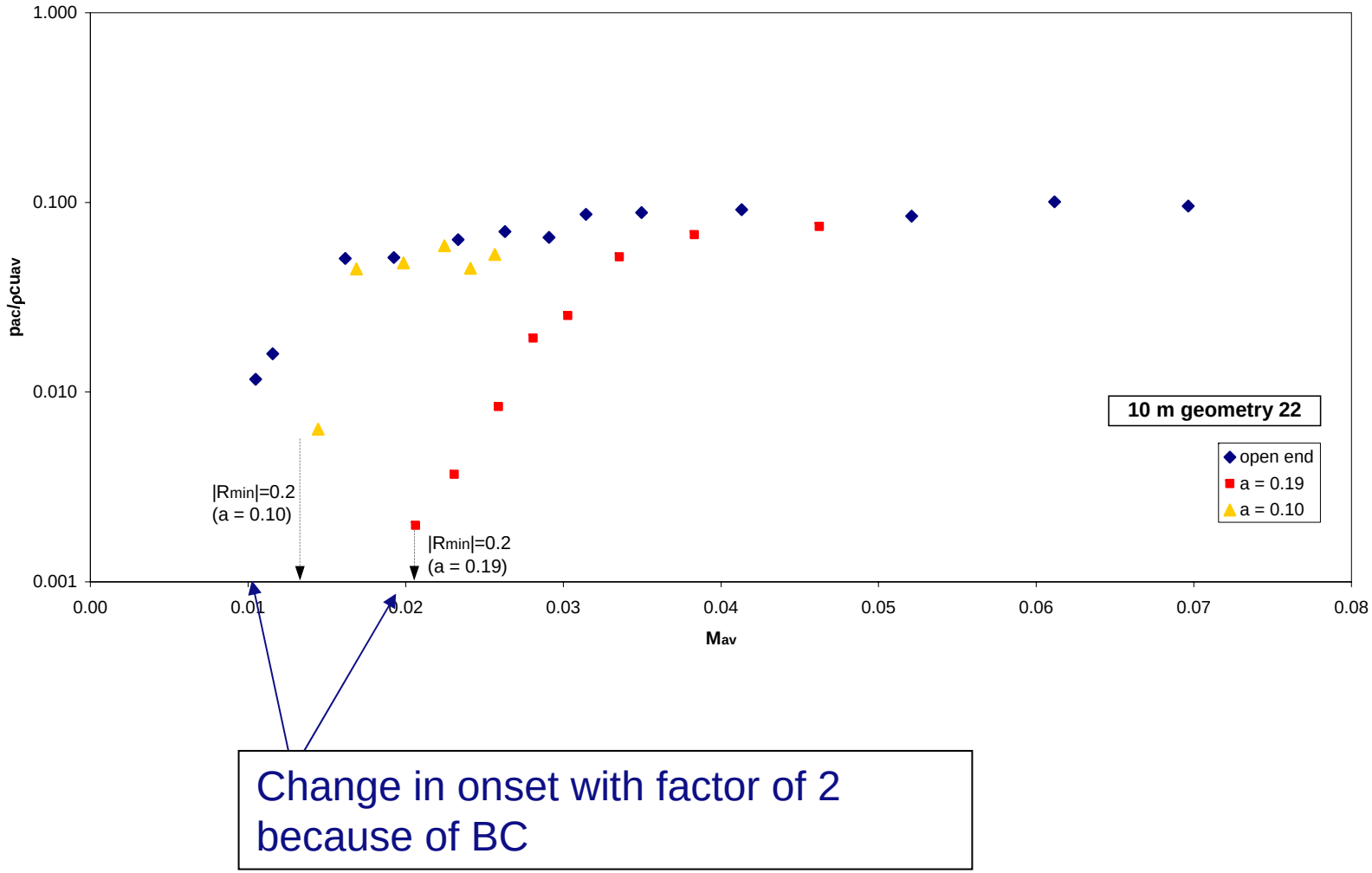


Onset velocity - Boundary conditions

- Boundary conditions are extremely important

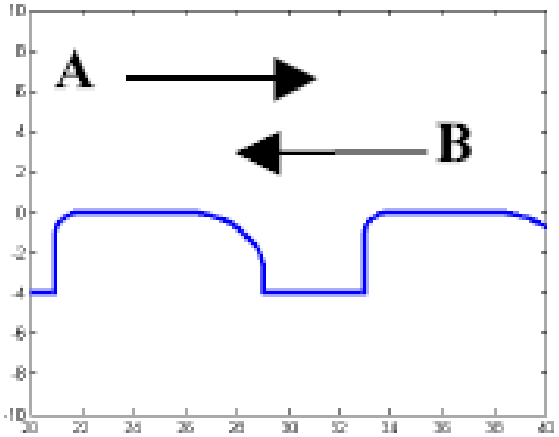






Change in onset with factor of 2 because of BC

Onset velocity - Installation direction



(At atmospheric pressure)

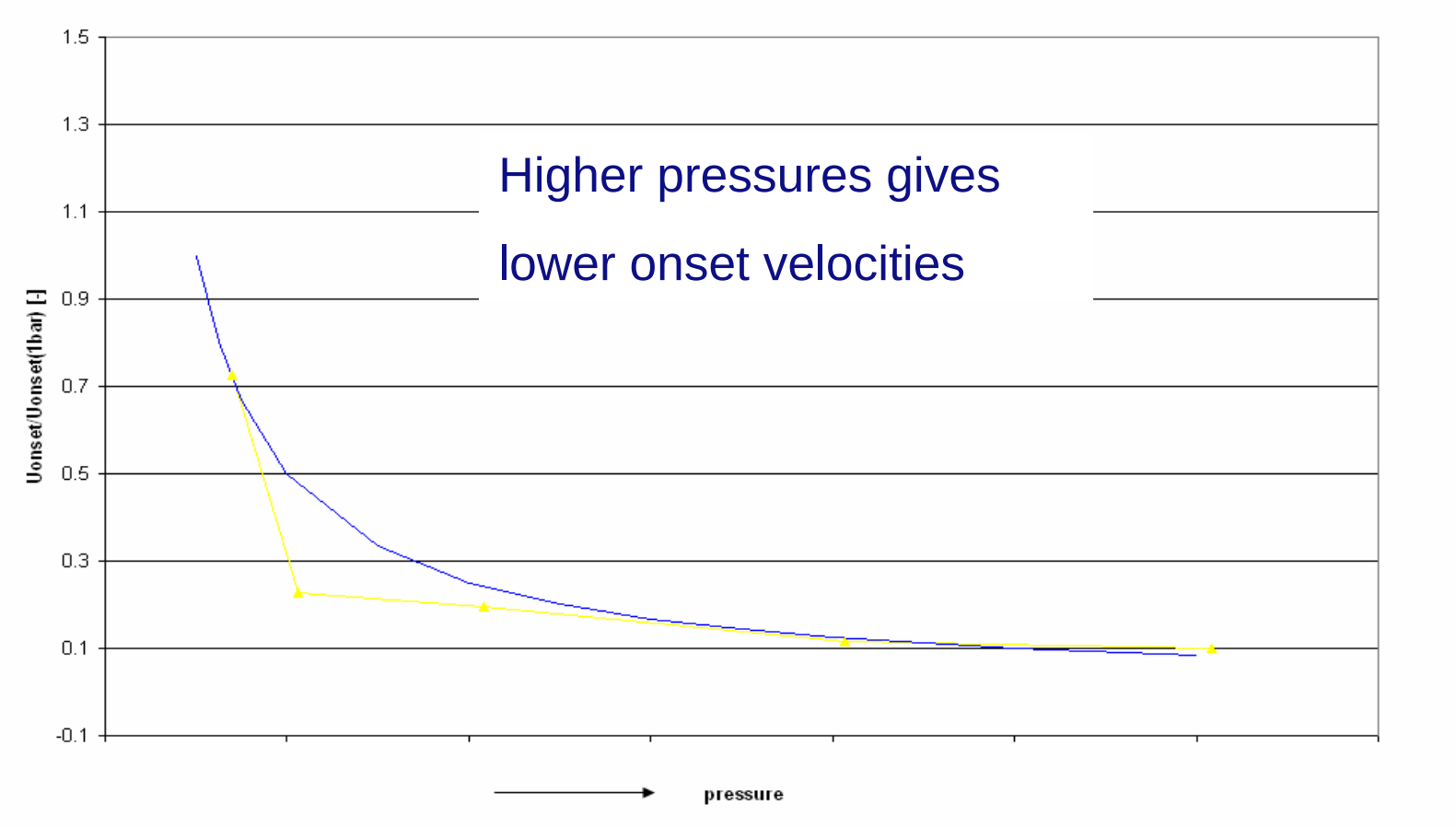
Onset velocity

- Uonset A direction : 13.1 m/s
- Uonset B direction : > 96 m/s

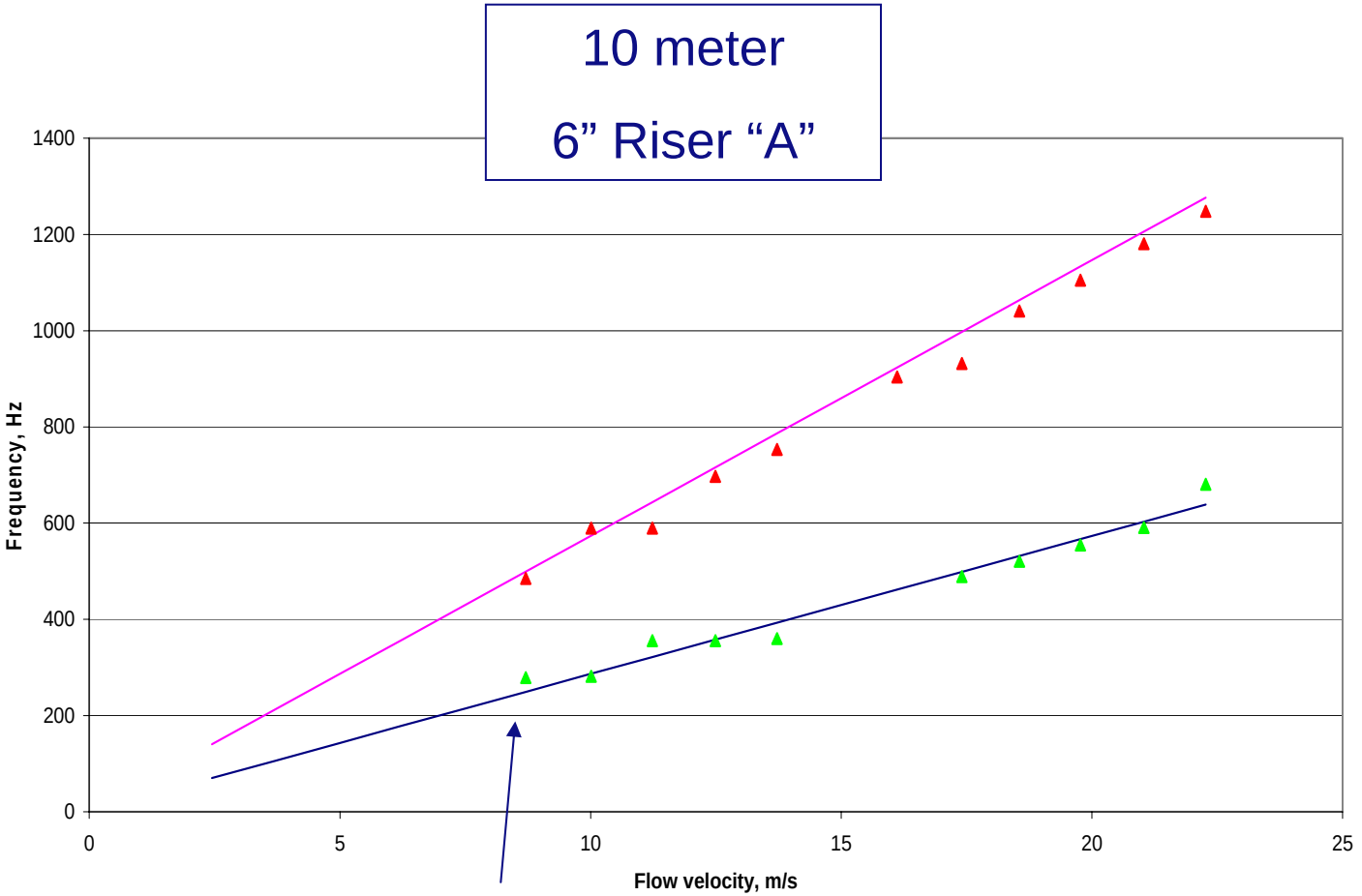
Pressure drop

- λ A direction : 0.07
- λ B direction : 0.045

Onset velocity - Pressure



High Pressure experiments (NEL)



Onset at 8 m/s!

JIP II Main conclusions

- Frequency :
  - Whistling frequency can be predicted (including effects edge rounding, gap width etc)
- Pressure drop :
  - Based on experiments a better pressure drop prediction can be made
- Amplitude :
  - Geometry dependence amplitude
  - Pressure dependence amplitude
- Onset velocity :
  - Geometry dependence onset
  - Minimal onset criterion is understood
  - We lack yet a comprehensive model to include all geometry, process and systems effects

FLEXIBLE-RISERS