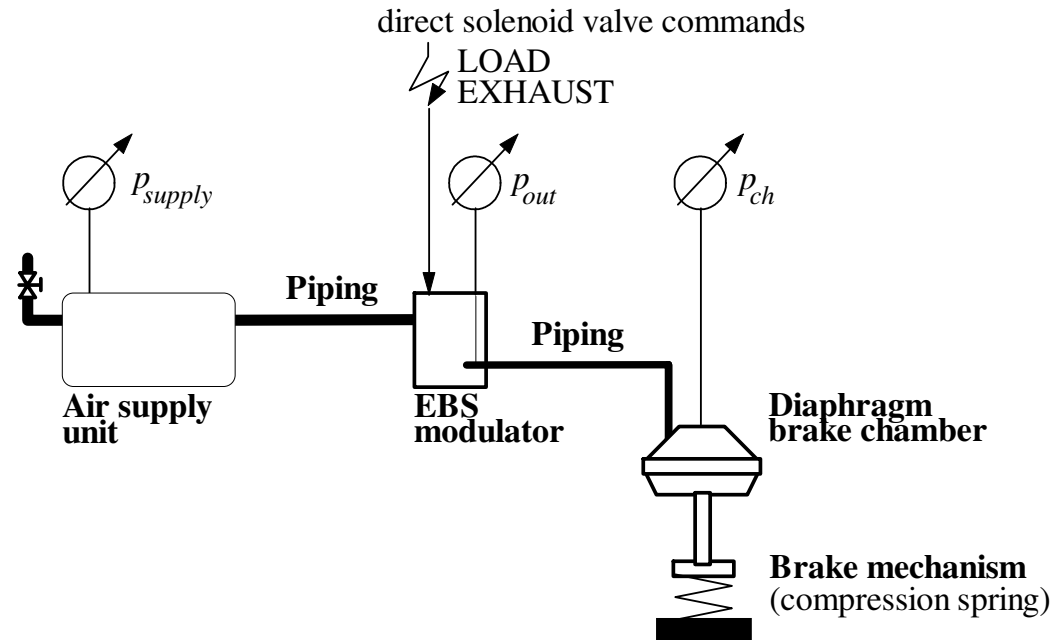# 5. MEASUREMENT OF UNSTEADY PRESSURE
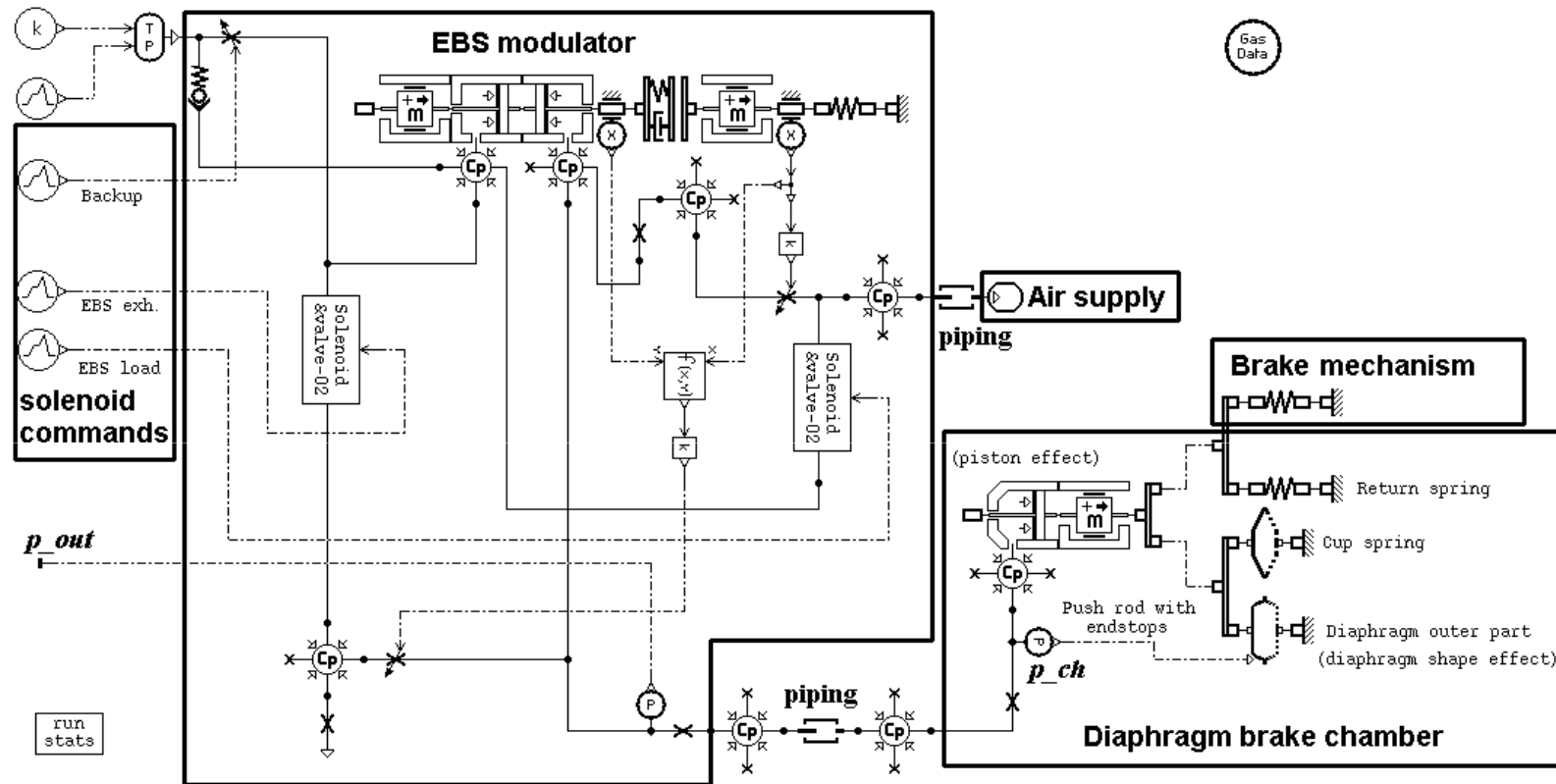
5.1.   Examples for practical use
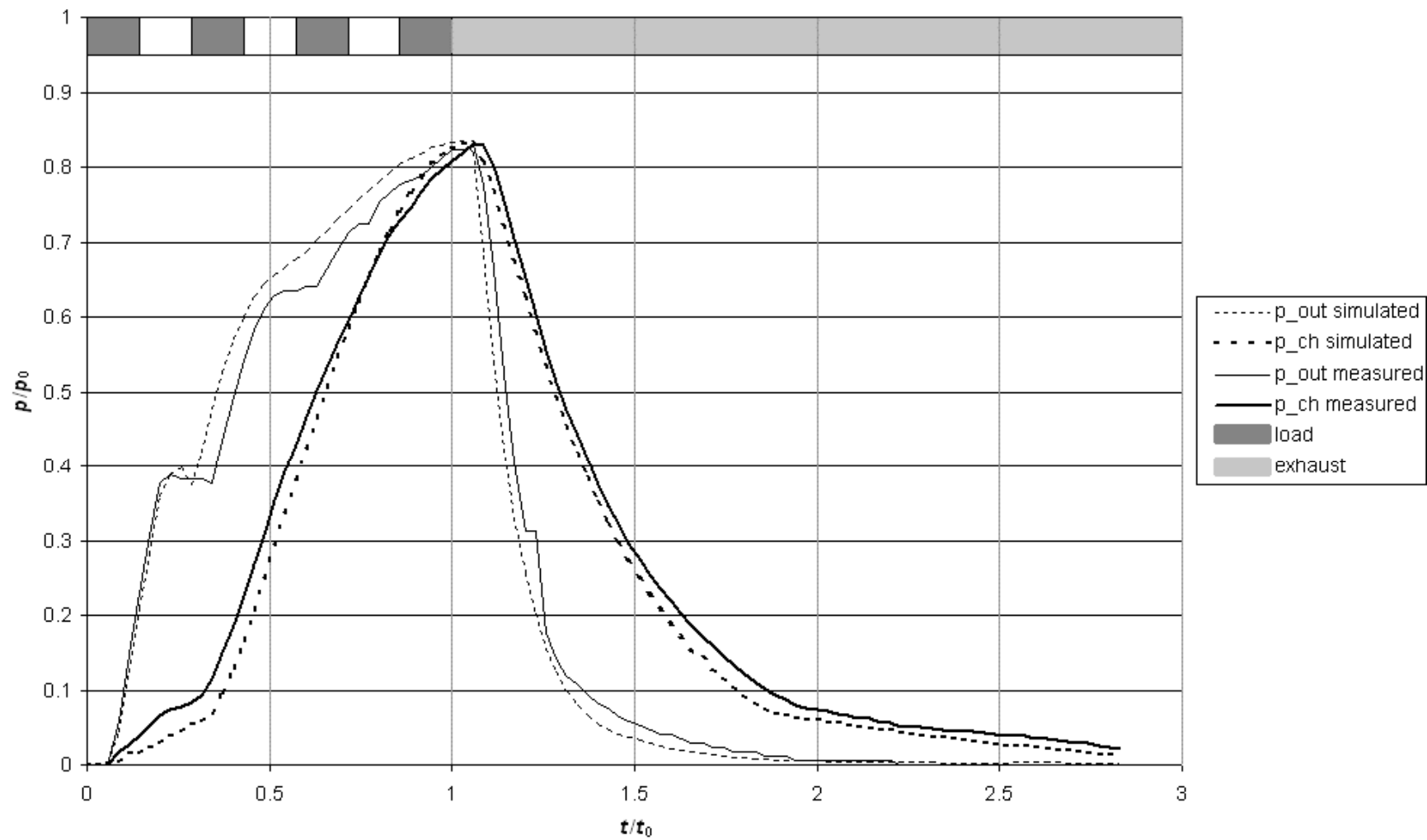
•In controlled technological and other industrial flow processes which are highly unsteady by nature

Electro-pneumatic braking systems of commercial vehicles

Dr. János VAD: Flow measurements

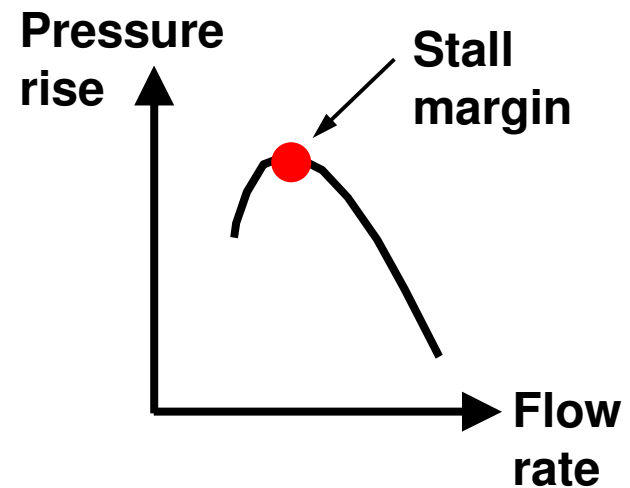# **AMESim** simulation model of the case study
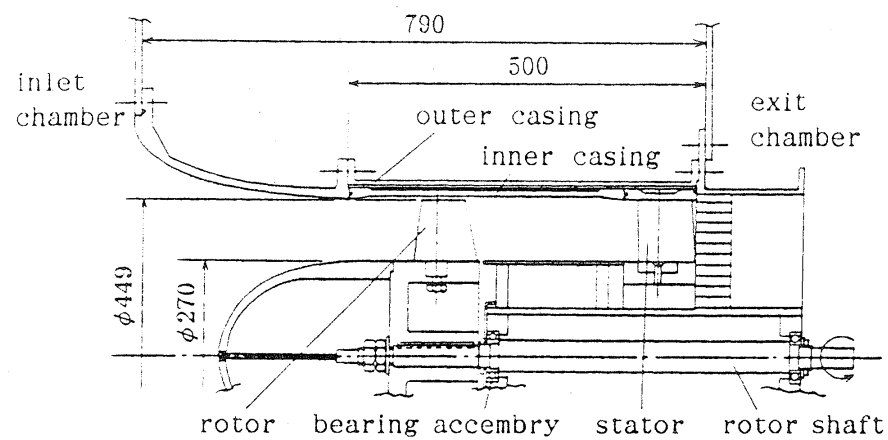

Dr. János VAD: Flow measurements
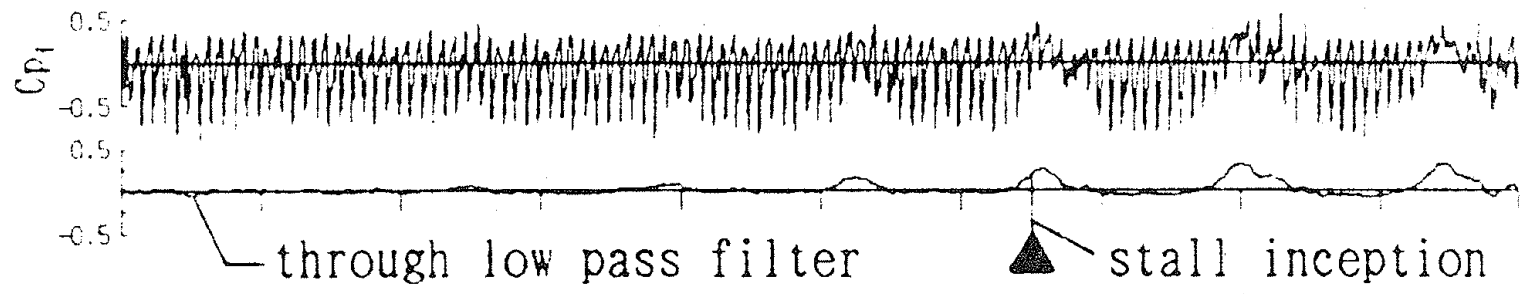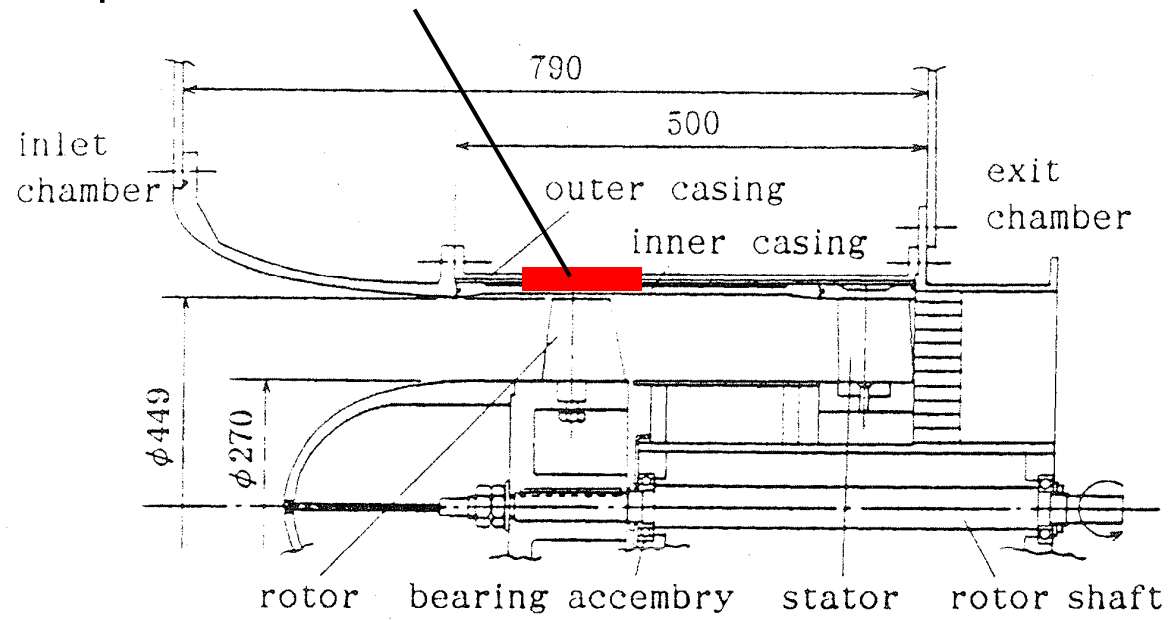
Dr. János VAD: Flow measurements

•Measurement of **turbulence-related** pressure fluctuations

Axial flow fan / compressor:

Zone of pressure transducers

790

500

inlet chamber

outer casing

inner casing

exit chamber

$\phi 449$

$\phi 270$

rotor   bearing accembry   stator   rotor shaft

Cp_1

0.5

-0.5

0.5

-0.5

through low pass filter   stall inception

Dr. János VAD: Flow measurements
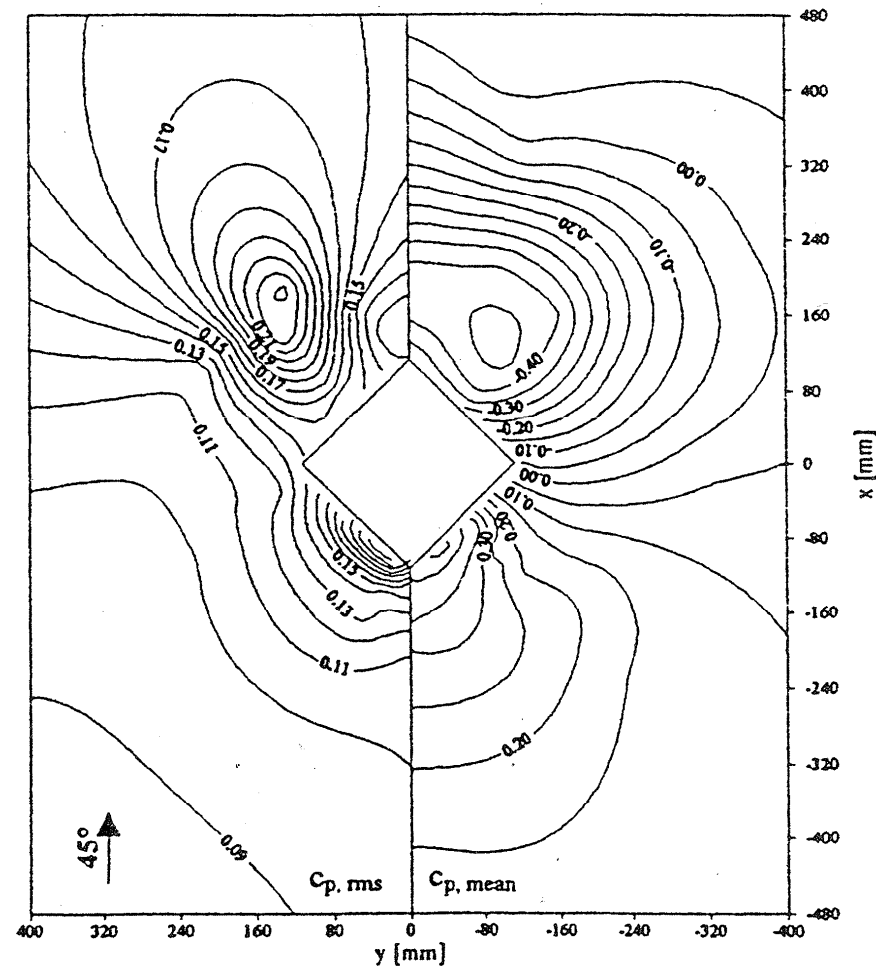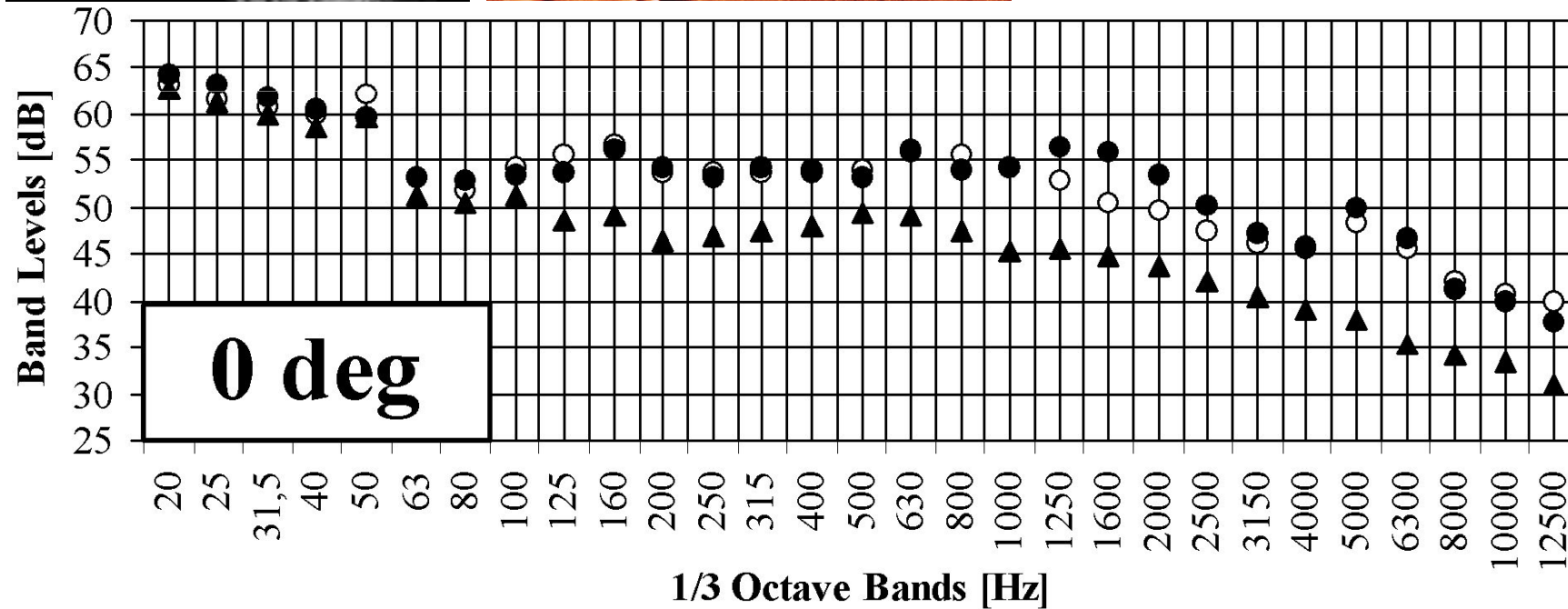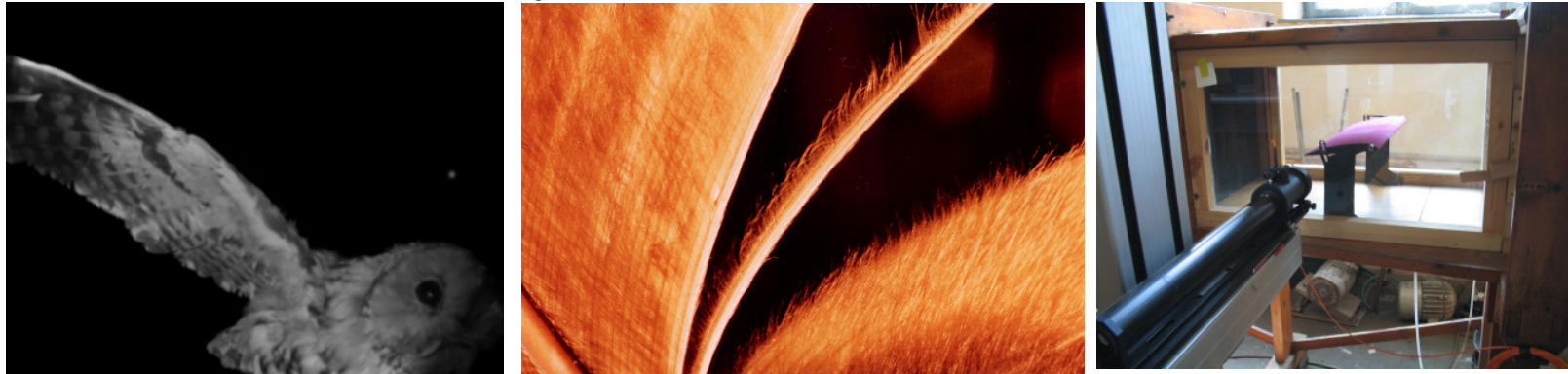
- Fluid mechanics R&D. Measurements for validation and further development of turbulence models and CFD tools.

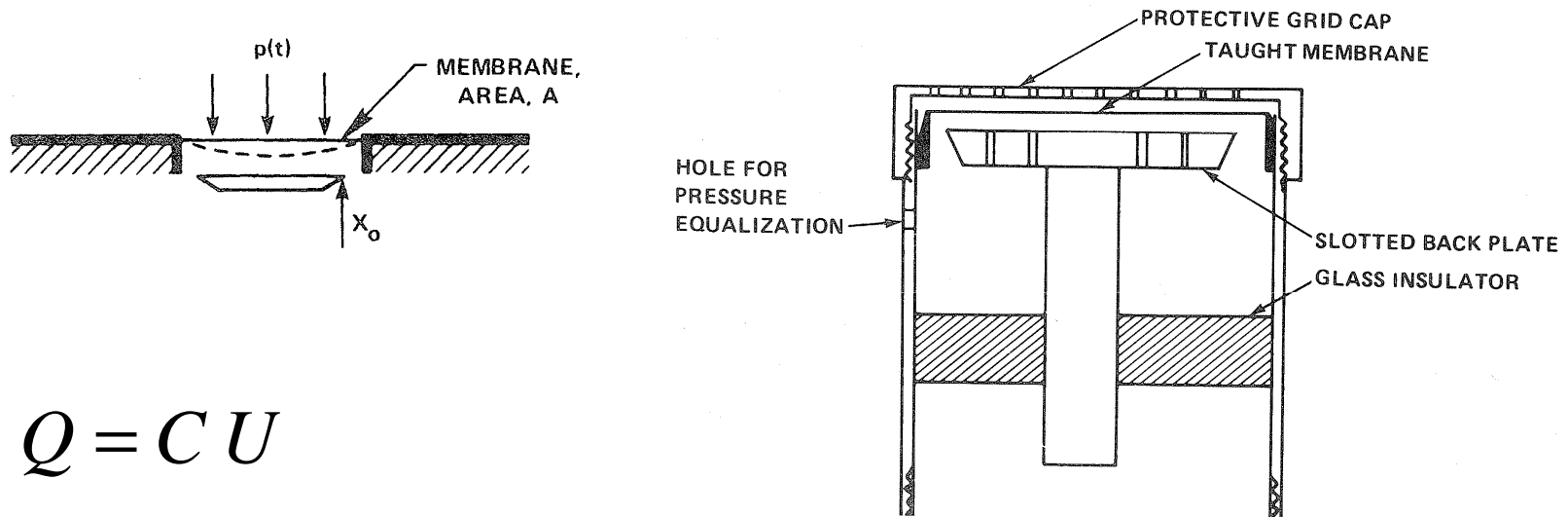Wind tunnel measurements: flow past a building block model

Dr. János VAD: Flow measurements

•Acoustics, sound pressure level measurements, spectral distribution of sound pressure

Dr. János VAD: Flow measurements

5.2. Instruments

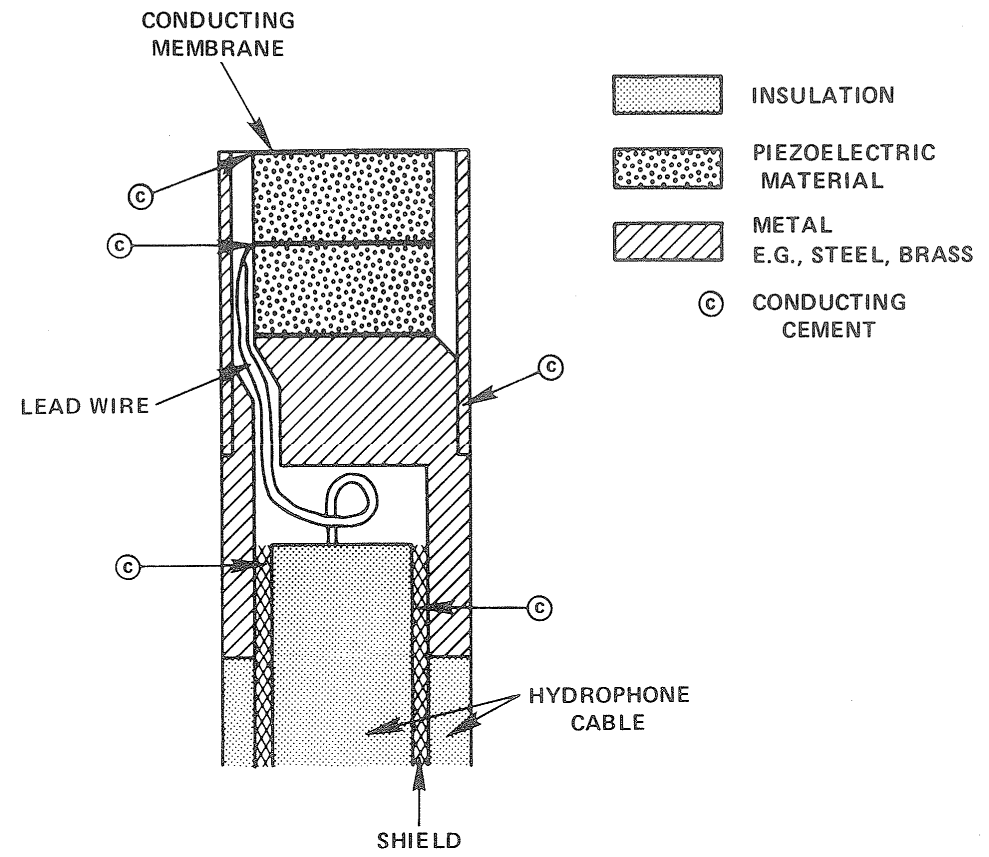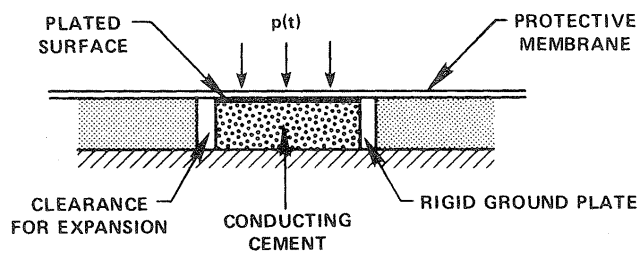## 5.2.1. Capacitor principle (condenser microphone)

$$Q = C\,U$$

$$L = 20\,\lg\frac{p}{p_0}$$
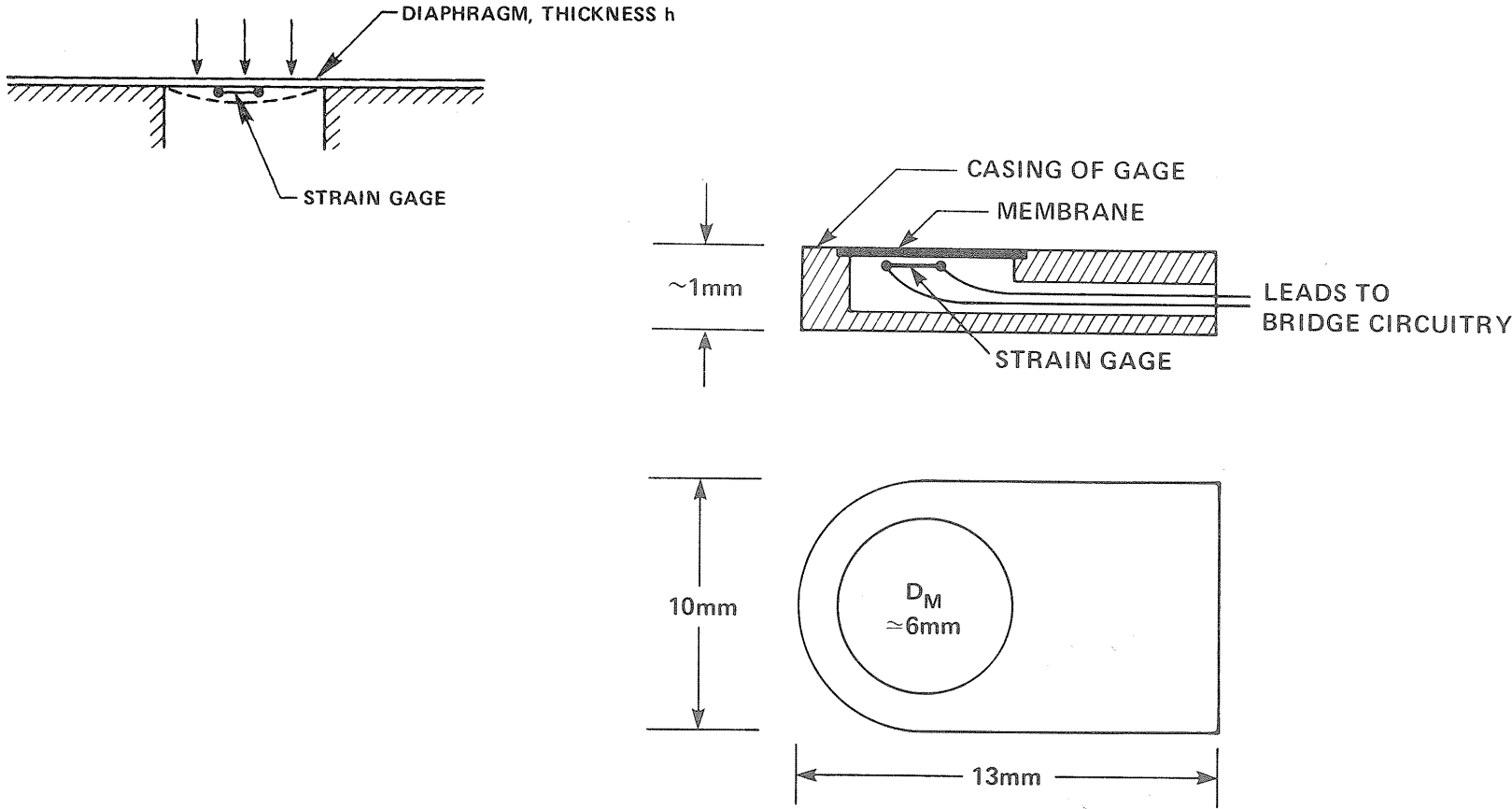
0 ÷ 120 dB: 6 orders of magnitude!

5.2.2. Piezo-inductive principle

- •Hydrophones
- •Indication of IC engines

PLATED SURFACE

p(t)

PROTECTIVE MEMBRANE

CLEARANCE FOR EXPANSION

CONDUCTING CEMENT

RIGID GROUND PLATE

„Acceleration canceling"
⇔ Accelerometers!

CONDUCTING MEMBRANE

INSULATION

PIEZOELECTRIC MATERIAL

METAL E.G., STEEL, BRASS

Ⓒ CONDUCTING CEMENT

LEAD WIRE

Ⓒ

HYDROPHONE CABLE

SHIELD

5.2.3. Piezo-resistive principle

DIAPHRAGM, THICKNESS h

STRAIN GAGE

CASING OF GAGE

MEMBRANE

~1mm

LEADS TO
BRIDGE CIRCUITRY

STRAIN GAGE

10mm

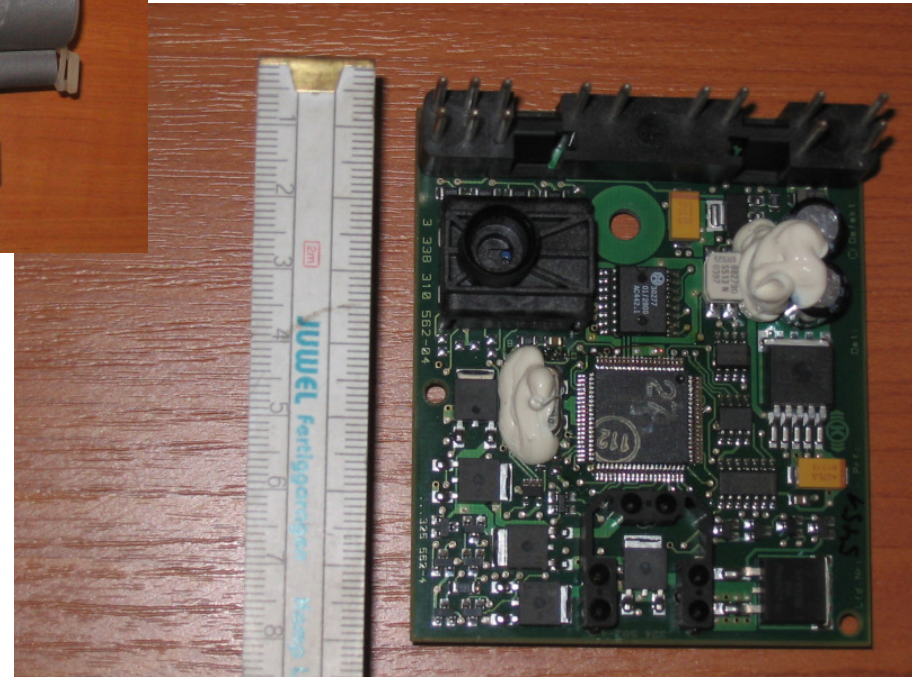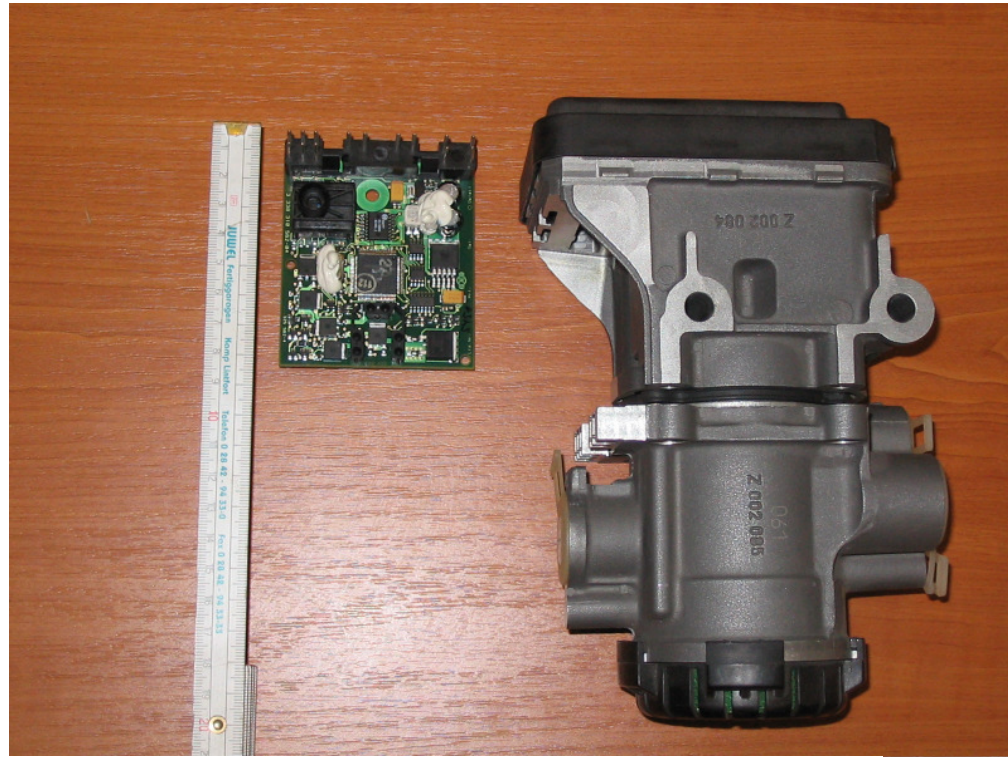D_M
≃6mm

13mm

Dr. János VAD: Flow measurements

Kulite sensor
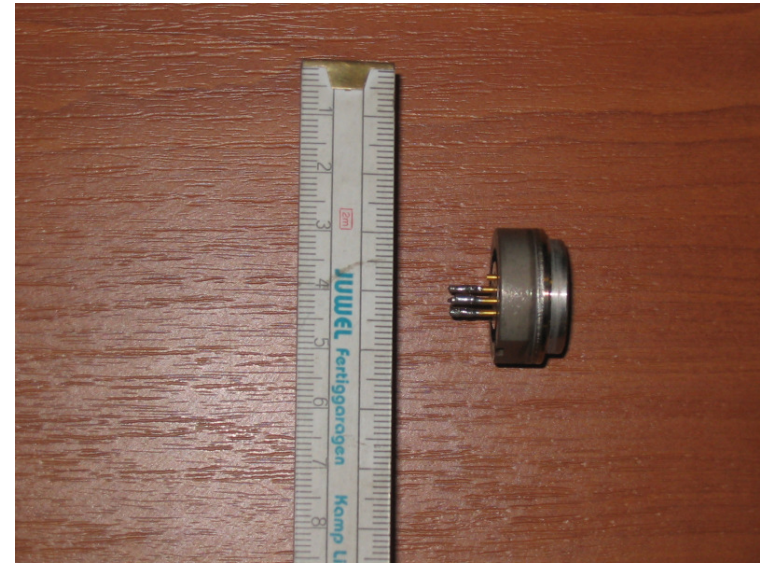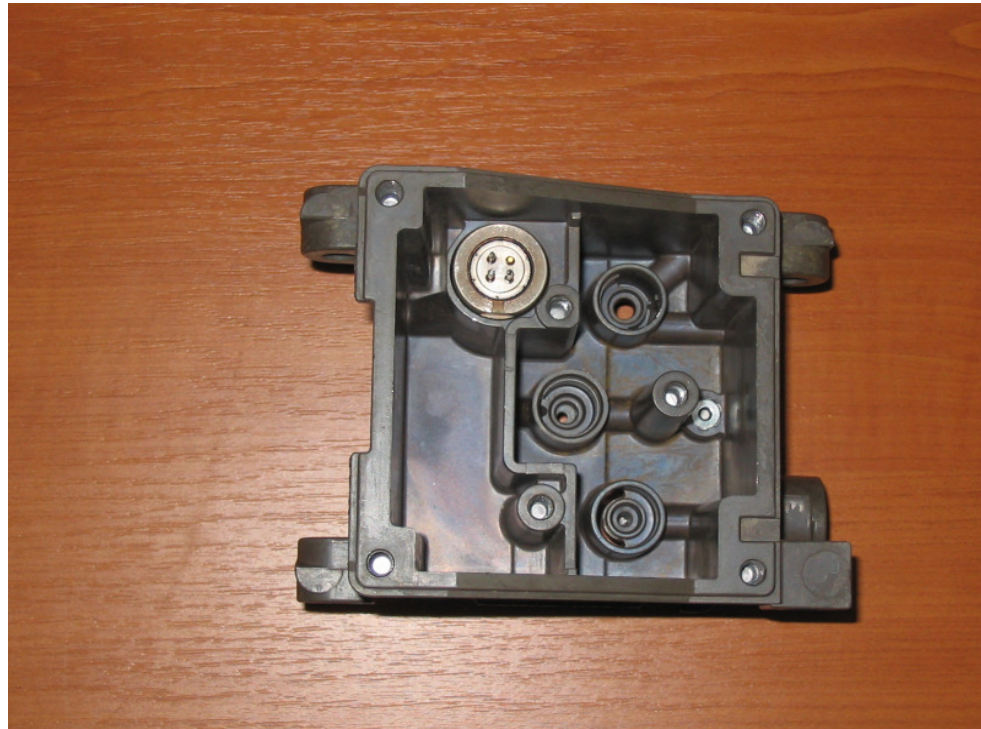
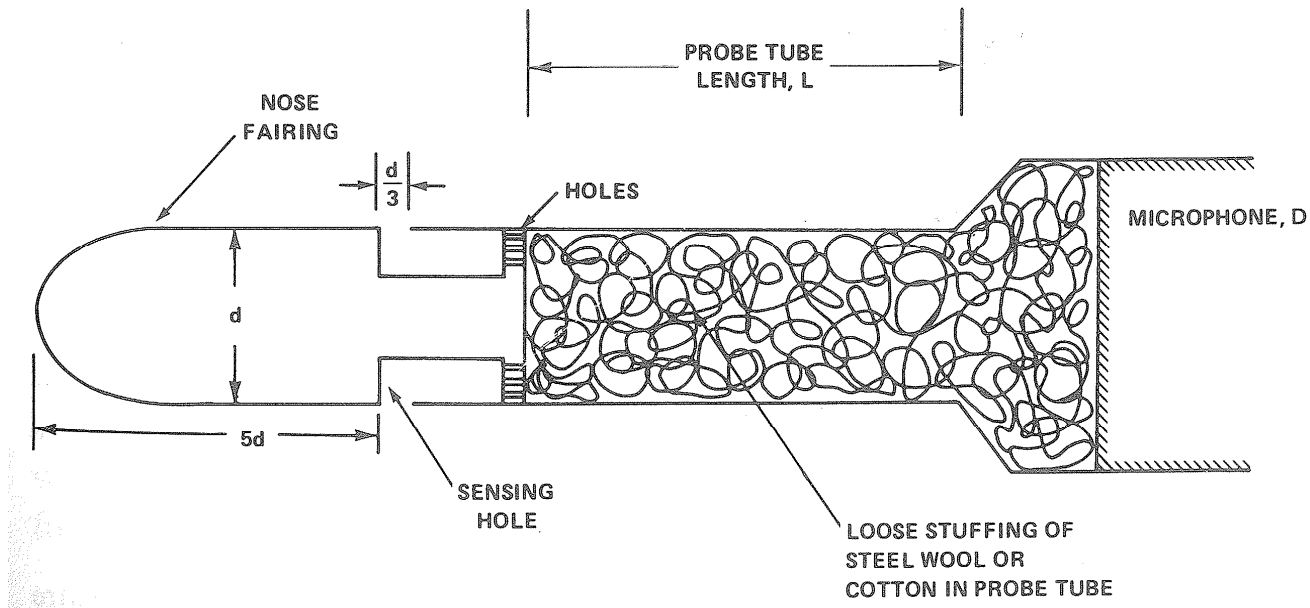• EBS modulators

Dr. János VAD: Flow measurements

Dr. János VAD: Flow measurements

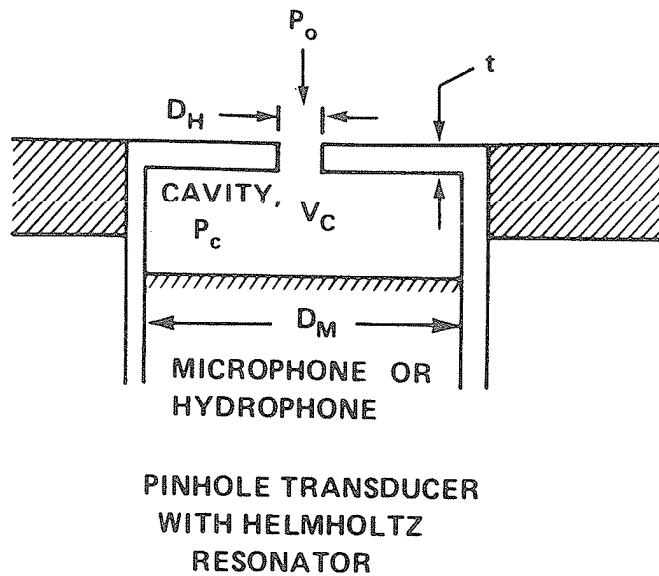# 5.3. Applications in acoustics and in turbulence studies

Pressure waves:

$$\lambda = \frac{a}{f} \approx \frac{340\ m/s}{10^4\ Hz} \approx 30\ mm$$

Dr. János VAD: Flow measurements

Turbulent pressure fluctuations:

$$\lambda = \frac{v}{f} \approx \frac{1\,m/s}{1000Hz} \approx 1\,mm$$

P$_o$

D$_H$ → t

CAVITY, V$_C$
P$_c$

D$_M$

MICROPHONE OR
HYDROPHONE

PINHOLE TRANSDUCER
WITH HELMHOLTZ
RESONATOR

Helmholtz resonator:

$$f_{Helm} \approx \frac{a}{2\pi} \sqrt{\frac{D_H^2\,\pi/4}{V_C\left(t+D_H\right)}}$$

$$f = \frac{f_{Helm}}{2}$$