Hochschule Zittau/Görlitz
UNIVERSITY OF APPLIED SCIENCES

Institute of Process Technology, Process Automation and Measuring Technology

IPM
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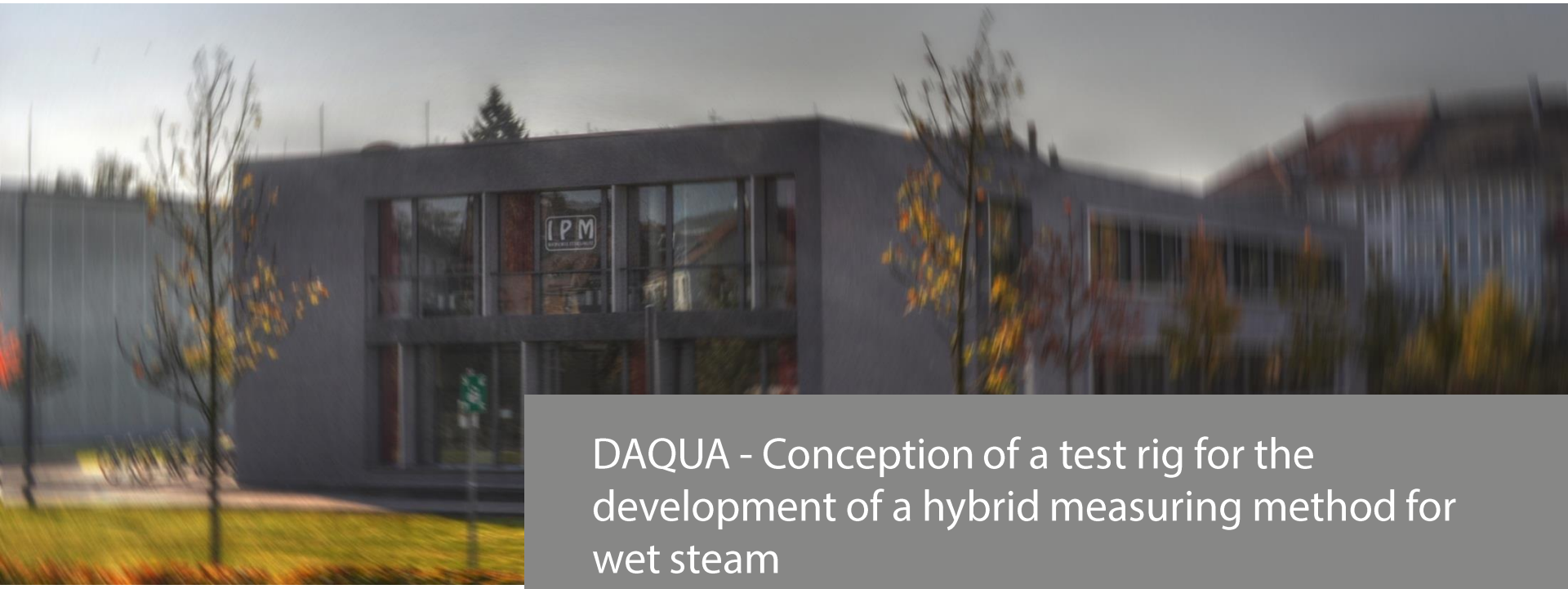


DAQUA - Conception of a test rig for the development of a hybrid measuring method for wet steam

Project duration: 07/2019 – 06/2022
Project leader: Prof. Dr.-Ing. A. Kratzsch
Project partner: E. Schleicher (HZDR Innovation GmbH)

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

HZDR INNOVATION

Agenda

1. Introduction
2. Boundary conditions
3. Draft test rig
4. First sensor concepts
5. Summary

Content and work plan project DAQUA

Goals:

- **Development** of a **hybrid measuring method** for the determination of the vapor content (steam quality), the flow rate and the enthalpy of two-phase steam flows in energy systems
- **Combination** of electrical, thermo-, and fluid dynamic measuring principles
- **Graduation** + transfer of knowledge into **teaching**

Work plan:

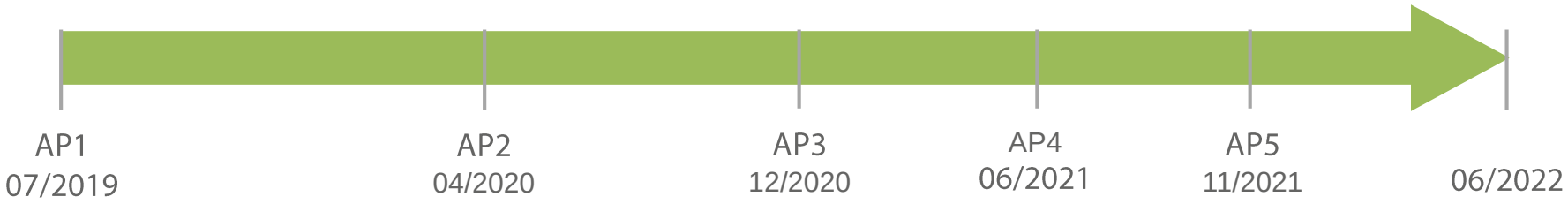
AP1: Development of a test rig for experimental investigation and validation

AP2: Development of a technical measurement solution for the combined measurement

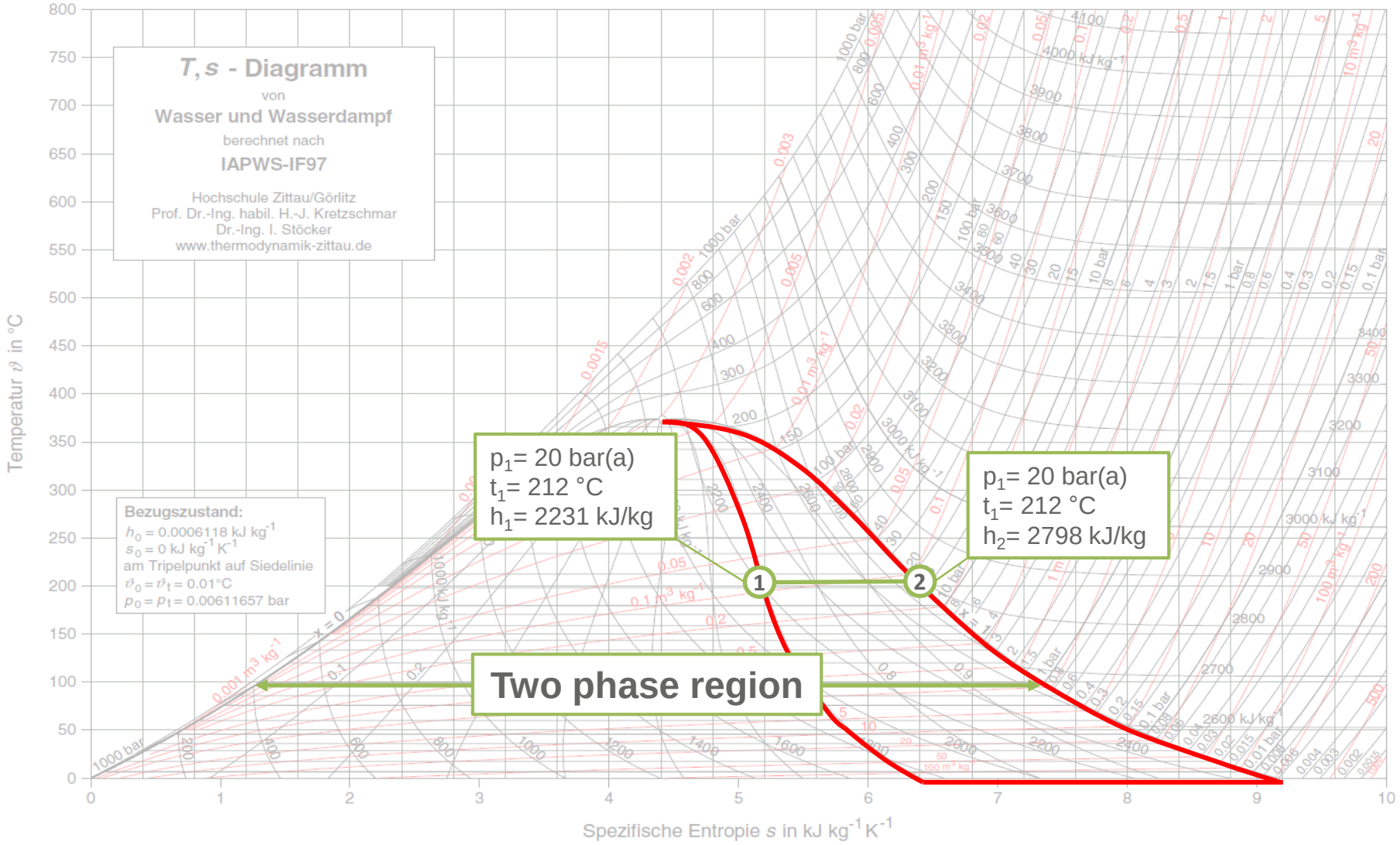
AP3: CFD simulations

AP4: Preparation of dynamic balances

AP5: Design prototype and validation



Motivation


T, s - Diagramm
von
Wasser und Wasserdampf
berechnet nach
IAPWS-IF97
Hochschule Zittau/Görlitz
Prof. Dr.-Ing. habil. H.-J. Kretzschmar
Dr.-Ing. I. Stöcker
www.thermodynamik-zittau.de
Bezugszustand:
h_0 = 0.0006118 kJ kg^{-1}
s_0 = 0 kJ kg^{-1} K^{-1}
am Tripelpunkt auf Siedelinie
$\vartheta_0 = \vartheta_t$ = 0.01°C
$p_0 = p_t$ = 0.00611657 bar
p_1= 20 bar(a)
t_1= 212 °C
h_1= 2231 kJ/kg
p_1= 20 bar(a)
t_1= 212 °C
h_2= 2798 kJ/kg
1
2
Two phase region
Temperatur ϑ in °C
Spezifische Entropie s in kJ kg^{-1} K^{-1}

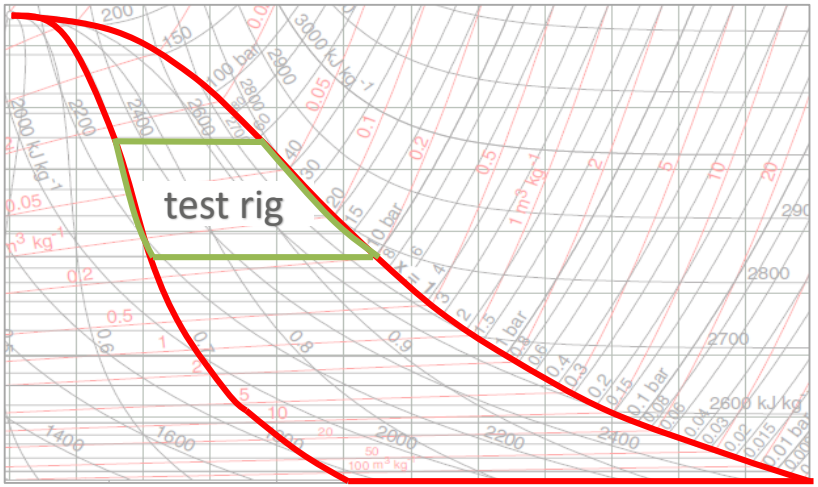
2. Boundary conditions

Boundary conditions

- flow vapor content **x >= 0,7**
- suitable for high operating pressures Ps > 60 bar(a); in test rig DAQUA **Ps <= 55 bar(a)**
- suitable for high operating temperatures Ts < 350 °C; in test rig DAQUA **Ts <= 280 °C**
- small **measuring error <= 1 %** related to the end of measuring range
- **horizontal** and **insulated pipe DN25**
- Application of a differential pressure measurement method according to **DIN EN 5167**

Other:

- short inlet and outlet lengths
- simple and cost-effective
- easy installation, exchangeable, retrofittable



Flow patterns in the horizontal pipe DN25 PN100

Parameters test rig:

- mass flow rate: 360 kg/h
- pipe diameter: 26.5 mm
- steam content: x > 0.7
- inclination angle: 1 °

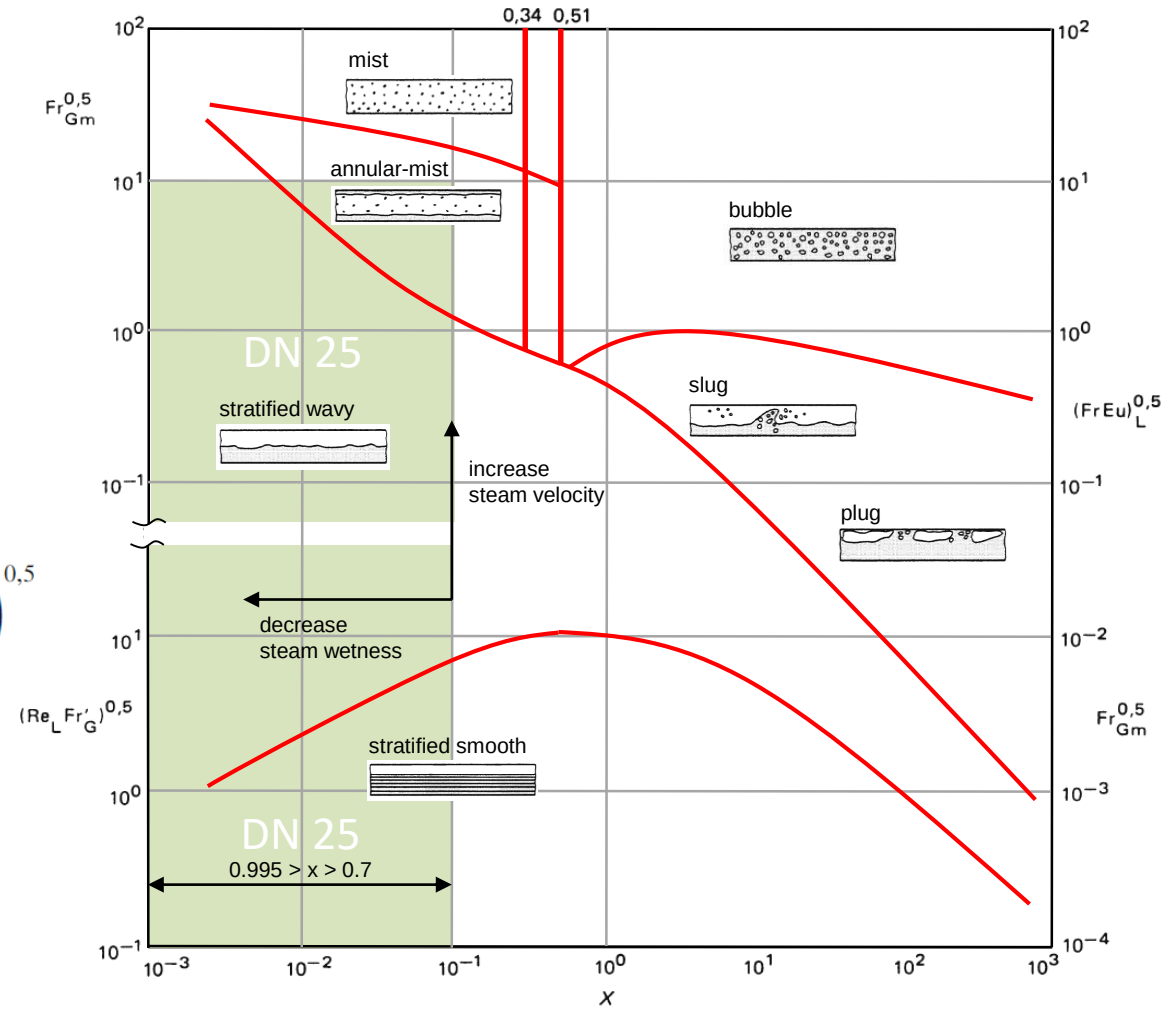
Modified Froude-numbers:

$$\mathrm{Fr}_{\mathrm{Gm}}^{0,5} = \left(\frac{\dot{m}^2\, \dot{x}^2}{g\, d\, \rho_{\mathrm{L}}\, \rho_{\mathrm{G}}} \right)^{0,5}$$

$$\left(\mathrm{Re}_{\mathrm{L}}\, \mathrm{Fr}'_{\mathrm{G}}\right)^{0,5} = \left(\frac{\dot{m}^3\, \dot{x}^2\, (1-\dot{x})}{\rho_{\mathrm{G}}\, (\rho_{\mathrm{L}} - \rho_{\mathrm{G}})\, \eta_{\mathrm{L}}\, g\, \cos\, \Theta} \right)^{0,5}$$

Lockhard-Martinelli Parameter:

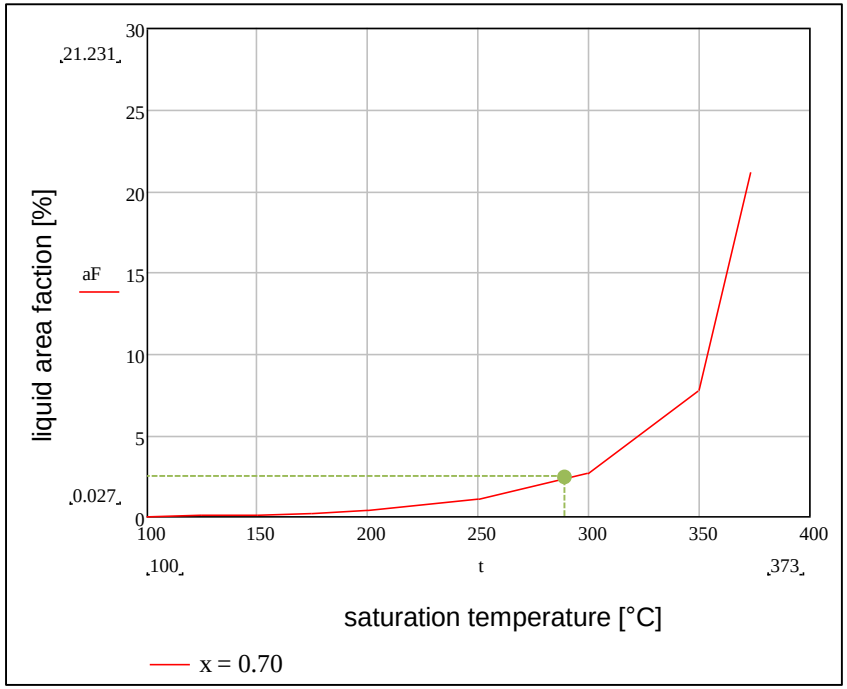
$$X = \left(\frac{1-\dot{x}}{\dot{x}} \right)^{0,875} \left(\frac{\rho_{\mathrm{G}}}{\rho_{\mathrm{L}}} \right)^{0,5} \left(\frac{\eta_{\mathrm{L}}}{\eta_{\mathrm{G}}} \right)^{0,125}$$

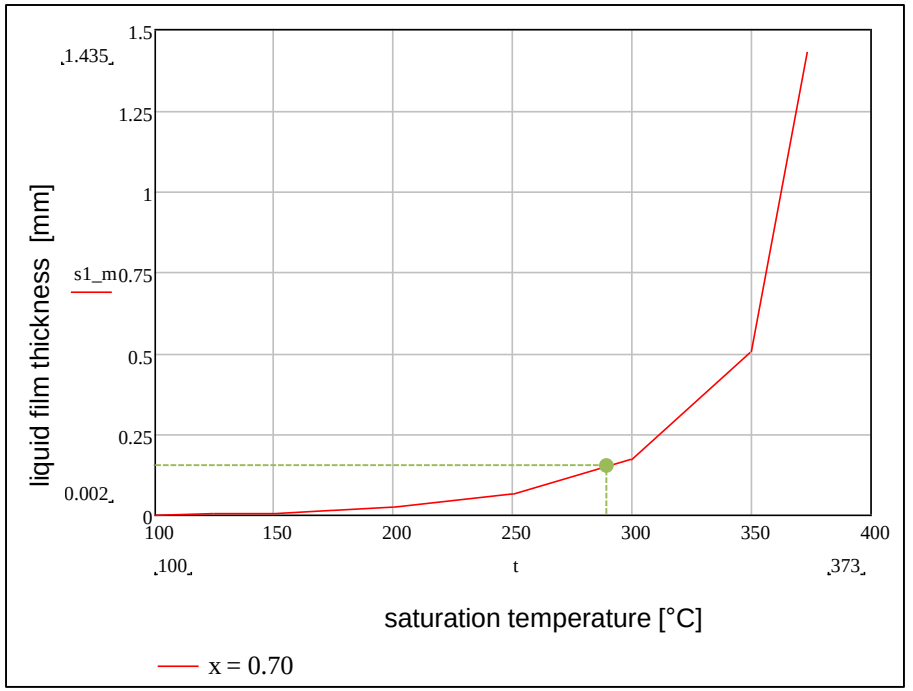


[2] VDI-HeatAtlas, 10. Edition, page 673

Liquid area fraction and average film thickness for wet steam (x = 0.7) in a horizontal pipe DN25

- Liquid area fraction
- Uniformly distributed film thickness of the liquid film on the inner wall of the pipe (annular flow)

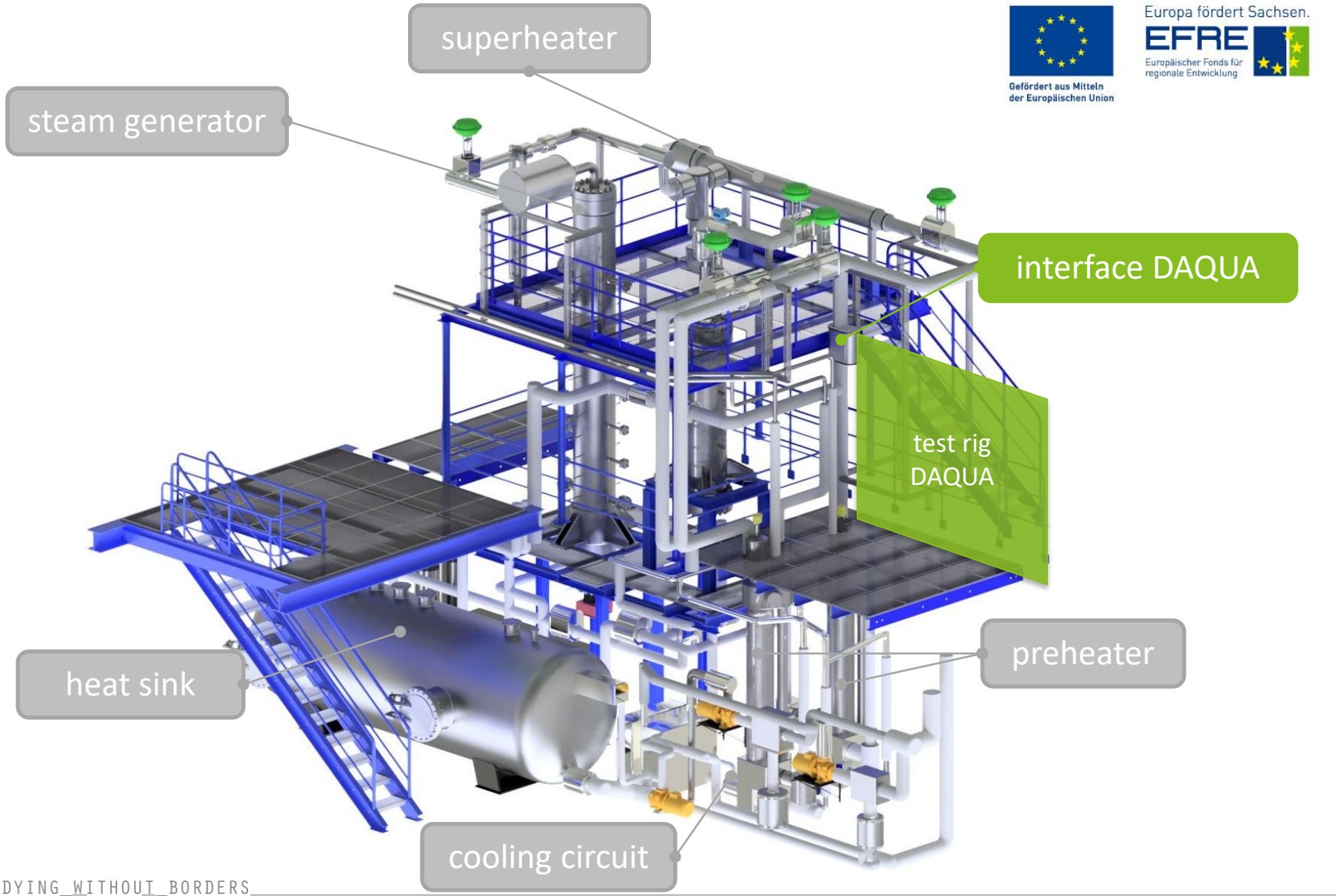




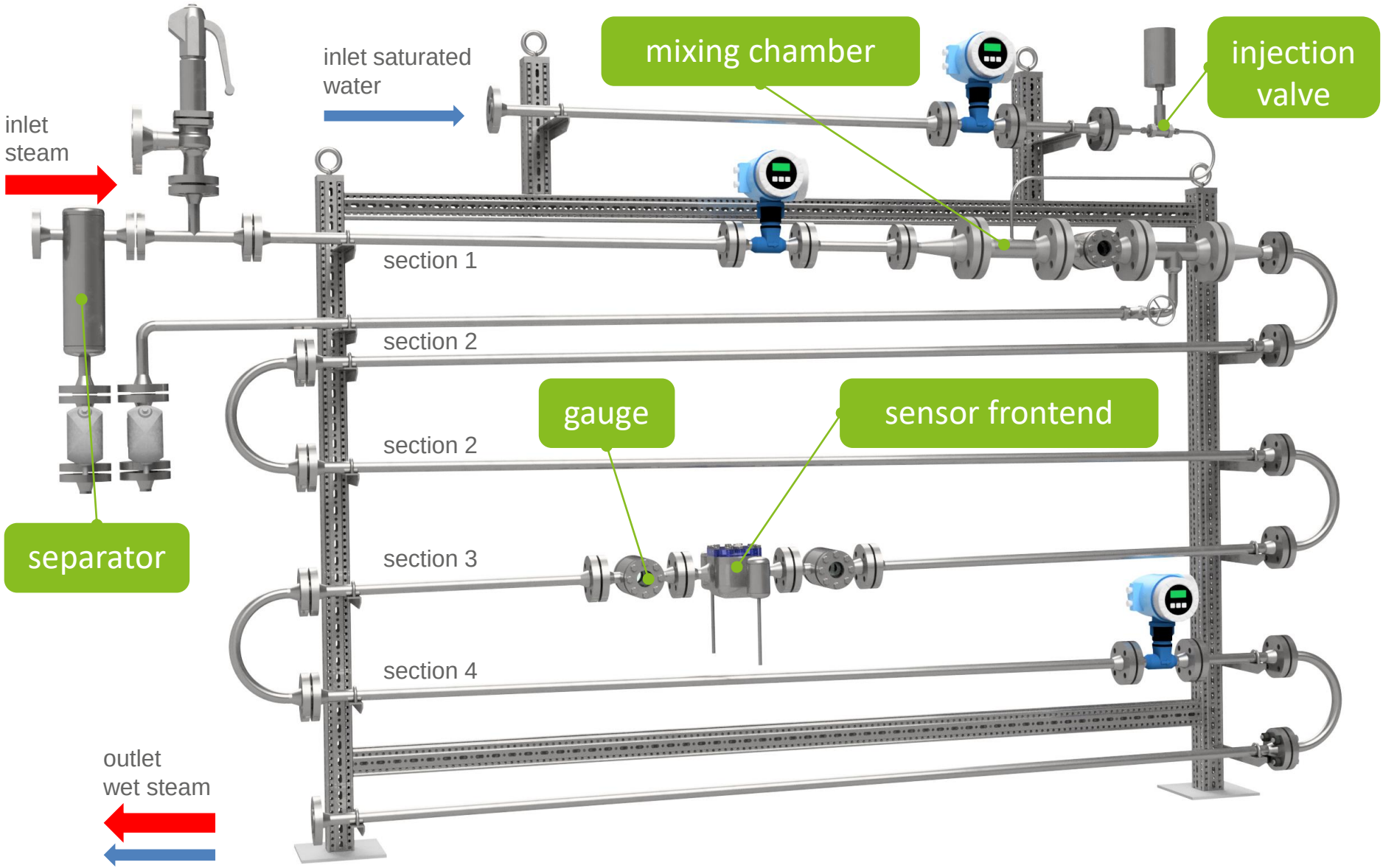
3. Test rig

Test rig THERESA

Gefördert aus Mitteln der Europäischen Union
Europa fördert Sachsen. EFRE Europäischer Fonds für regionale Entwicklung



Draft test rig DAQUA



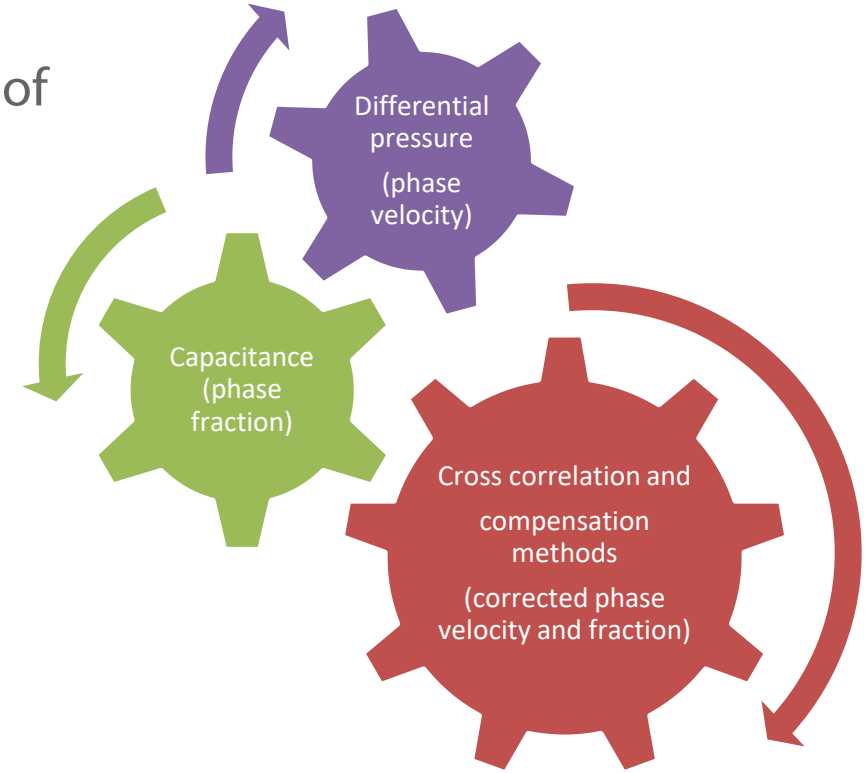
4. First sensor concepts

Current selected measurement methods

- **Differential pressure measurement DIN EN 5167**
  (v-cone, venturi tube, orifice, wedge) for measurement of vapor velocity with compensation methods

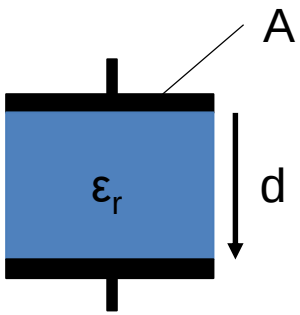
- **Electrical capacitance measurement**
  (relative permittivity) for measurement of liquid phase fraction and liquid phase velocity with cross correlation

- **Optional** liquid droplet (mist) separation by **swirl generator** to optimize the capacitance measurement

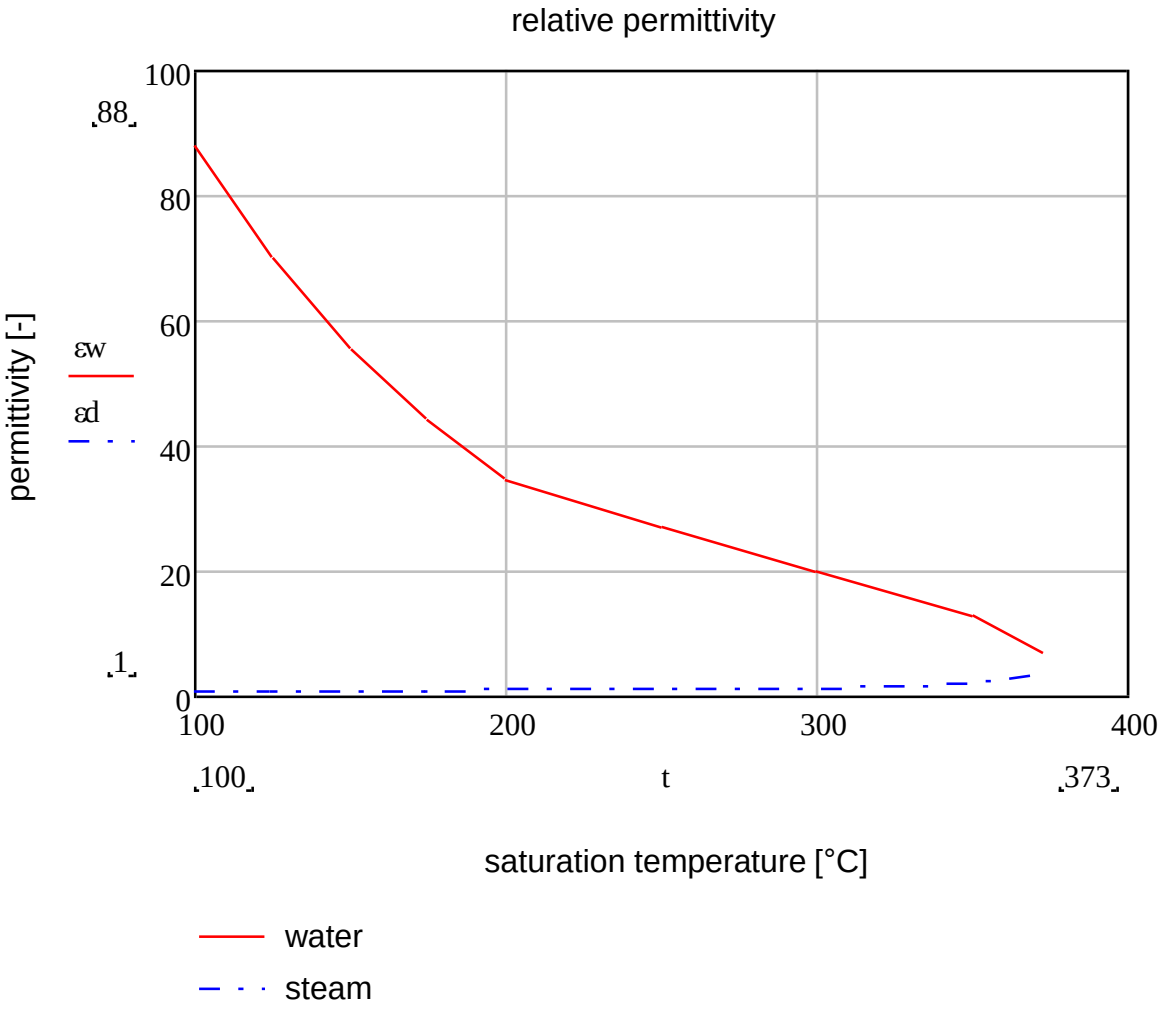


Capacitance of saturated steam and water

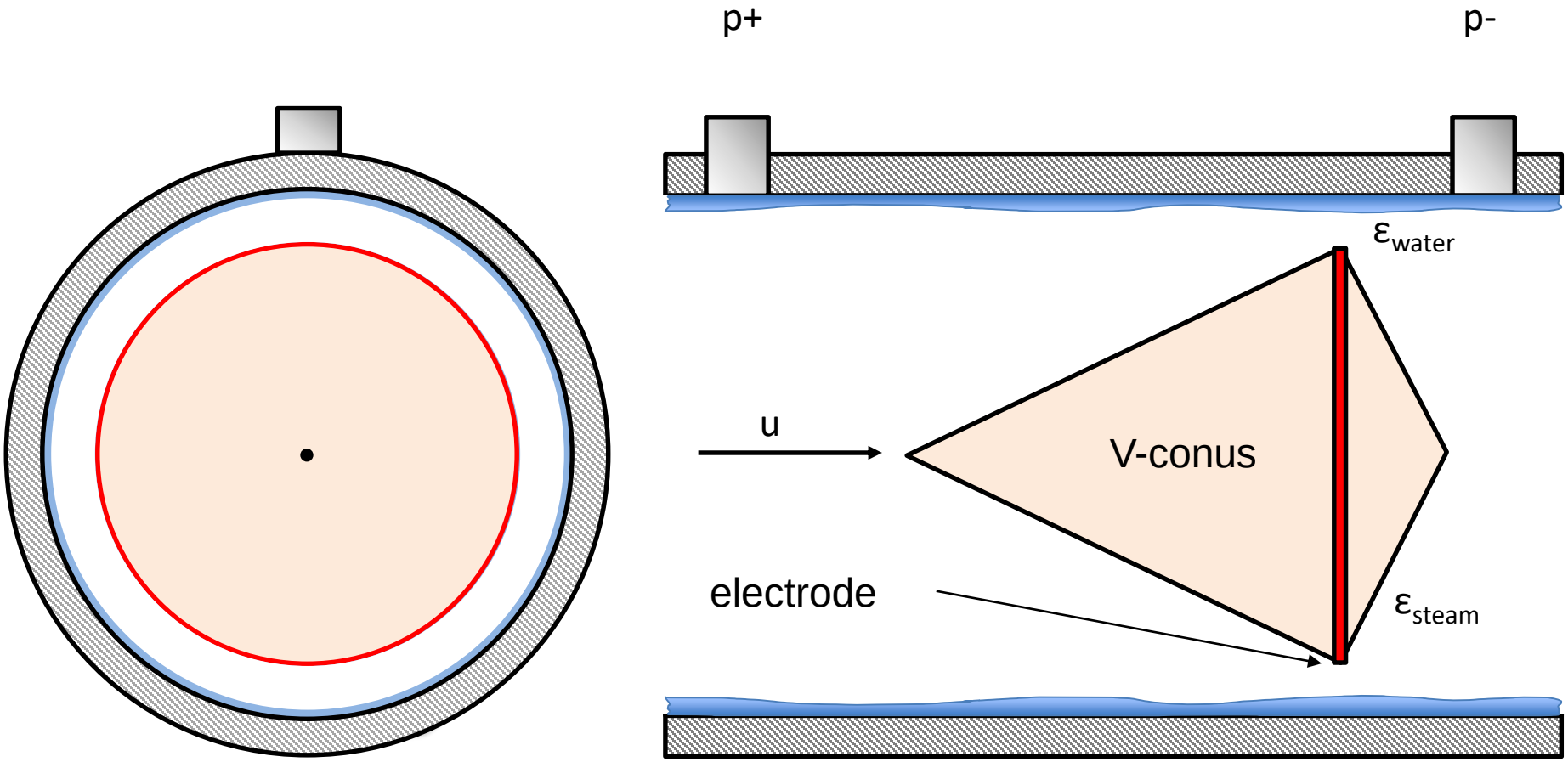
plate capaciator:



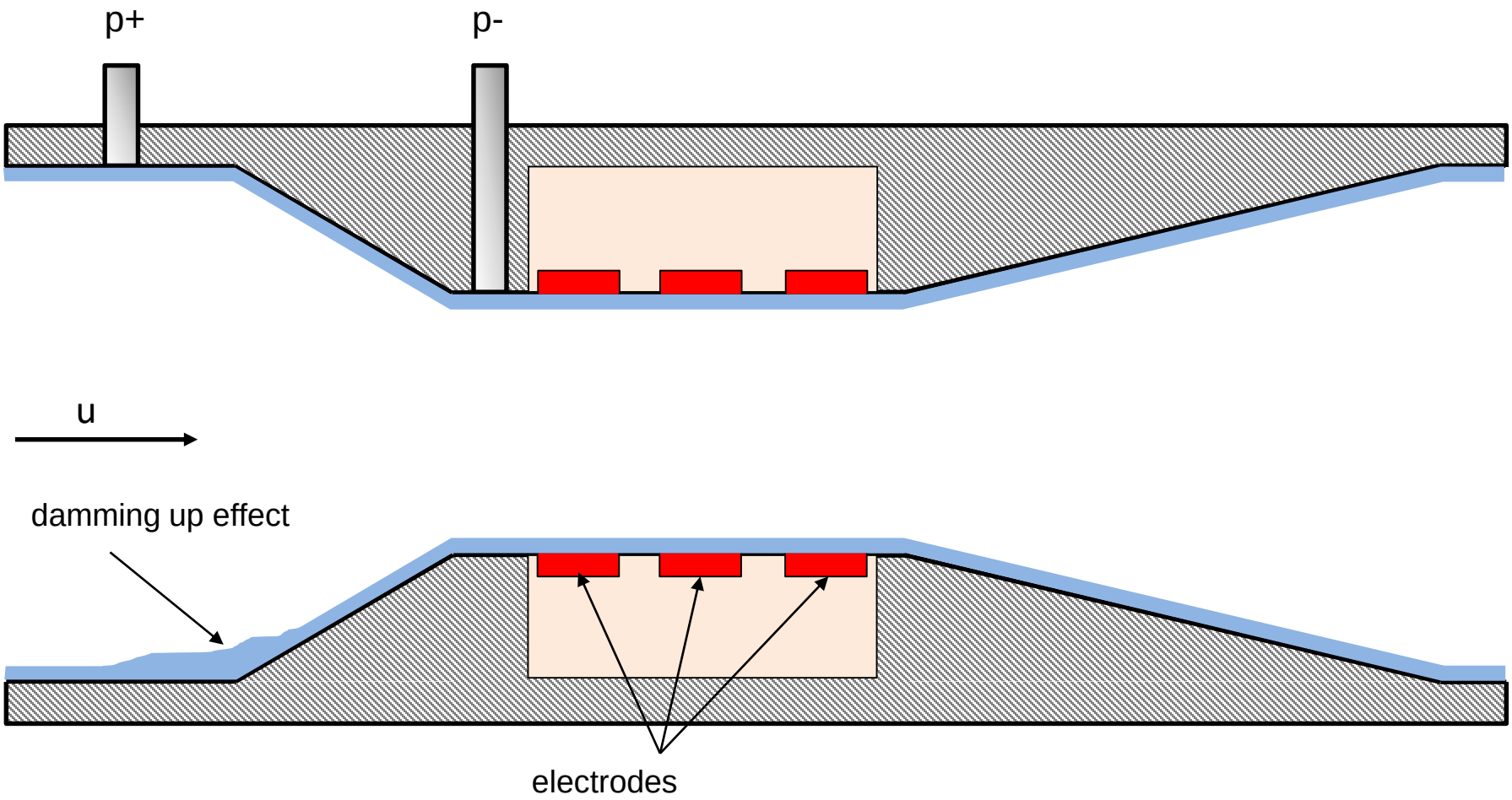
$$C = \varepsilon_r \cdot \varepsilon_0 \cdot \frac{A}{d}$$



Draft diff. pressure and capacitance measurement with V-conus



Draft diff. pressure and capacitance measurement with venturi-pipe



5. Summary

- Expected **flow patterns: stratified, wavy and annular**
- The **DAQUA test rig was designed** and the instrumentation planned
- The **combination of differential pressure and capacitance** measurement methods allows the measurement of phase fractions and phase velocities
- **V-cone and venturi** differential pressure transducers are very **well suited** for high-pressure **wet steam** measurements

Acknowledgment

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FKZ: 13FH163PX8

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Weiterhin bedanken wir uns für die Unterstützung durch das Unternehmen
HZDR-Innovation GmbH

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Bundesministerium für Bildung und Forschung

Vielen Dank für Ihr Interesse!

Kontakt:

Ansprechpartner/-in:

Prof. Dr.-Ing. A. Kratzsch
Direktor
Institut für Prozeßtechnik, Prozeßautomatisierung und Meßtechnik

Telefon: +49 3583 – 612 4282
Telefax: +49 3583 – 612 3449
E-Mail: a.kratzsch@hszg.de
Web: www.hszg.de/ipm

Hausanschrift:

Hochschule Zittau/Görlitz
IPM
Theodor-Körner-Allee 16
02763 Zittau

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