Physikalisch-Technische Bundesanstalt
Department Flame Transmission Processes

Analysis of the flame quenching property of porous structures

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Overview

- Introduction
- Flame arrester elements
- Flame transmission
- Flame quenching property of porous structures
- Application
- Conclusion

Introduction

Flame arrester elements used in

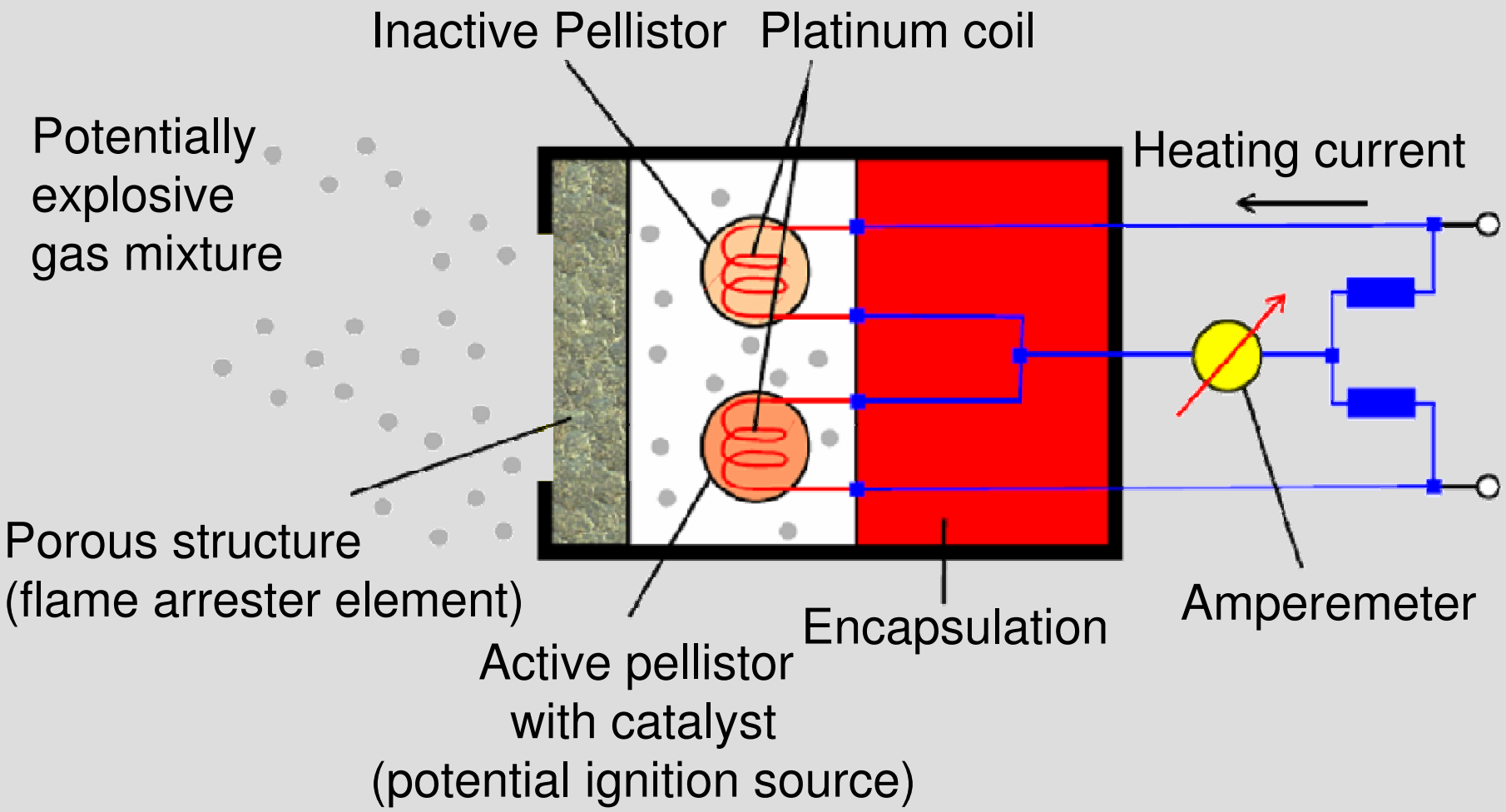
- Breathing devices
- Flame arresters

are important components in the field of explosion protection.

A proceeding to characterize flame arrester elements concerning their flame quenching property will be introduced.

Breathing device

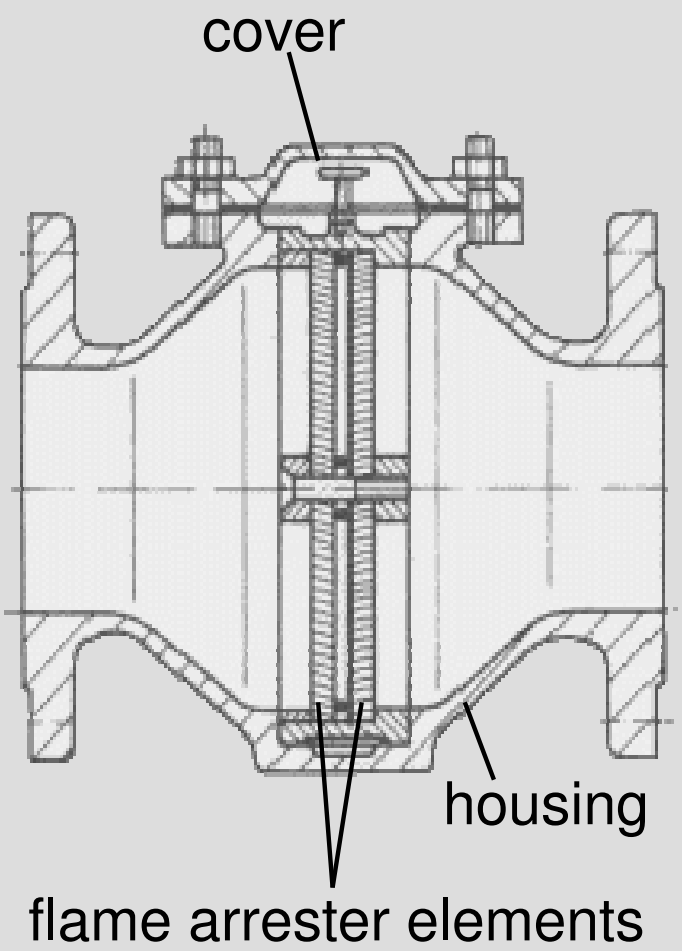
Gas sensor type of protection flameproof enclosure:

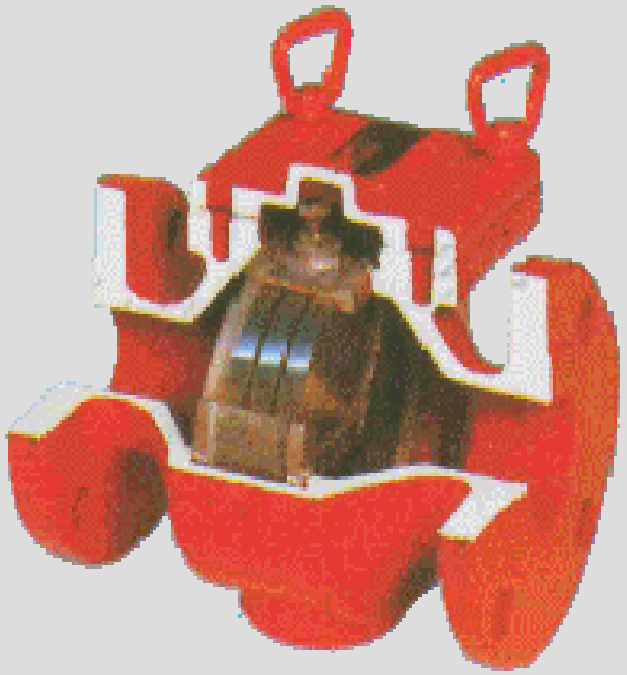


Source: www.draeger-safety.com, 08.12.2006.

Flame arrester

In-line flame arrester:

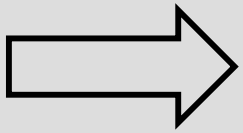




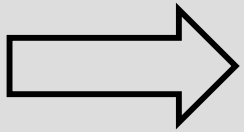
Source: brochure of Protego – Braunschweiger Flammfilter GmbH

Flame arrester elements

- Flame arrester elements consist of permeable materials with narrow gaps

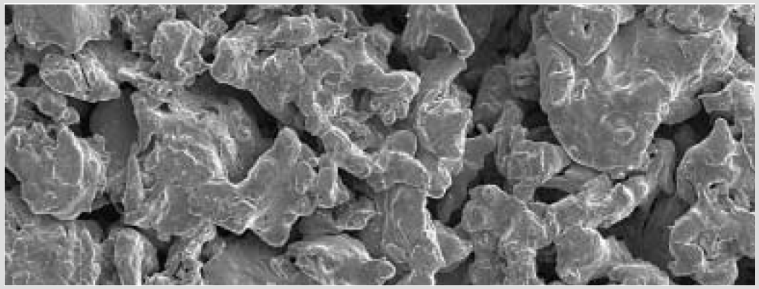


- Quenching of flames
  - Cooling of the reaction zone
  - Reduction of reactive radicals

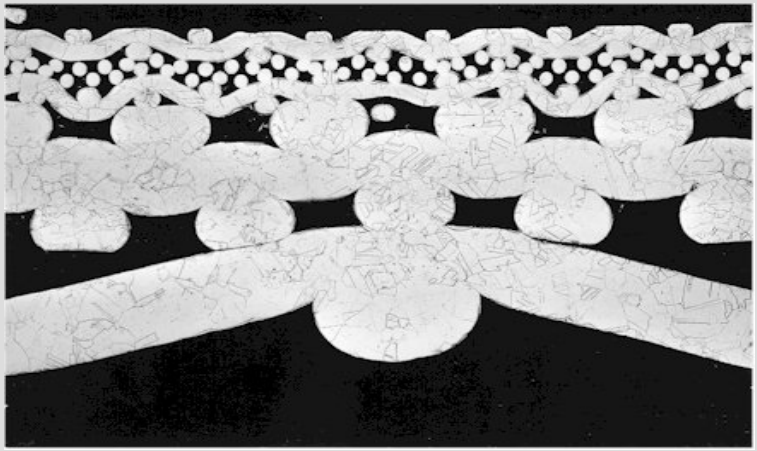


- Different kinds of porous structures can be used as flame arrester elements

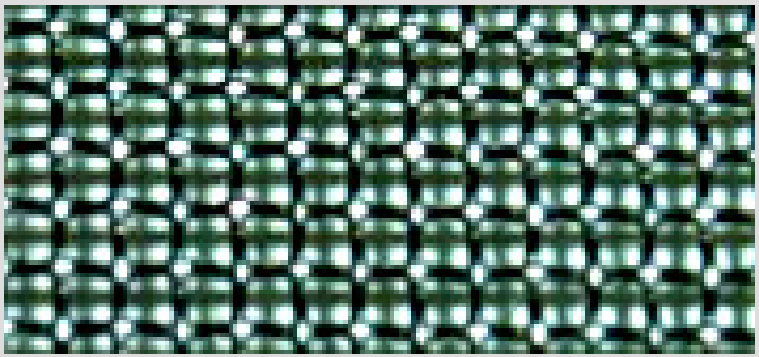
Porous structures (1/2)



Powder metallurgically manufactured sintered metal



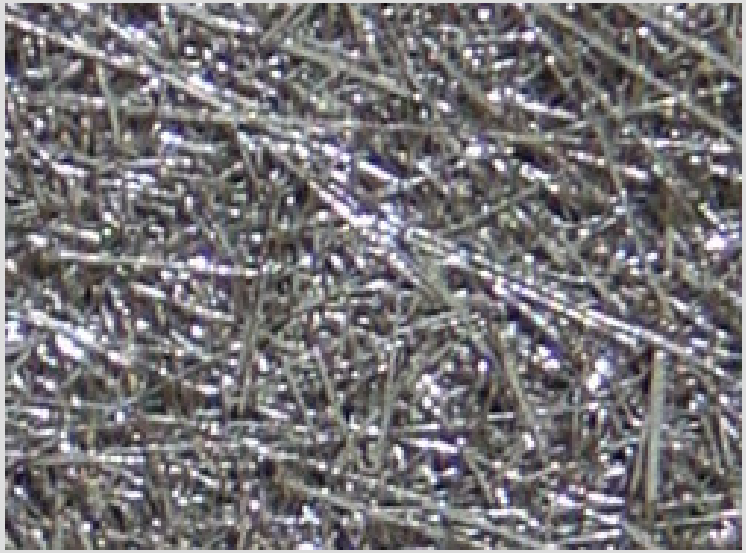
Sintered woven wire structure



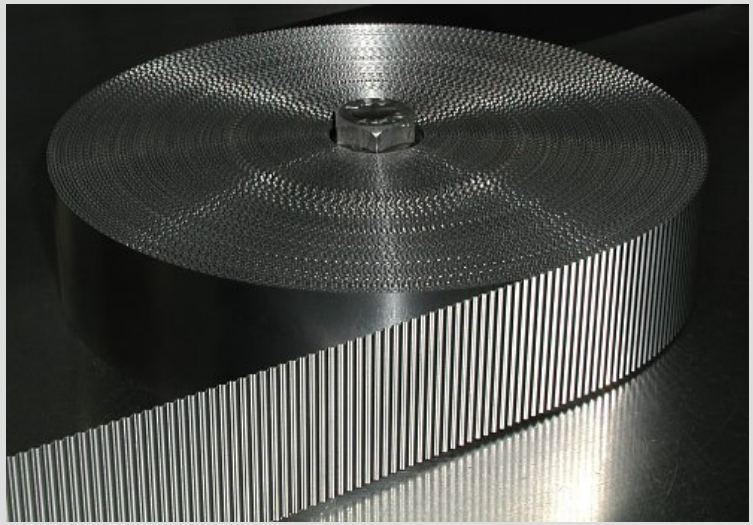
Several woven wire structures in loose layers

Source: www.gkn-filters.com/products/sika-r-ax/index.html, 02.01.07
www.diedrahtweber.com/en/applications-products.html, 02.01.07

Porous structures (2/2)



High temperature resistant
sintered fiber structure

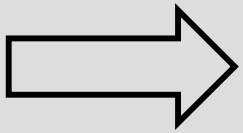


Crimped ribbon
flame arrester element

Source: www.kito.de/deutsch/kito-flammensperre.html, 10.04.07

Requirements

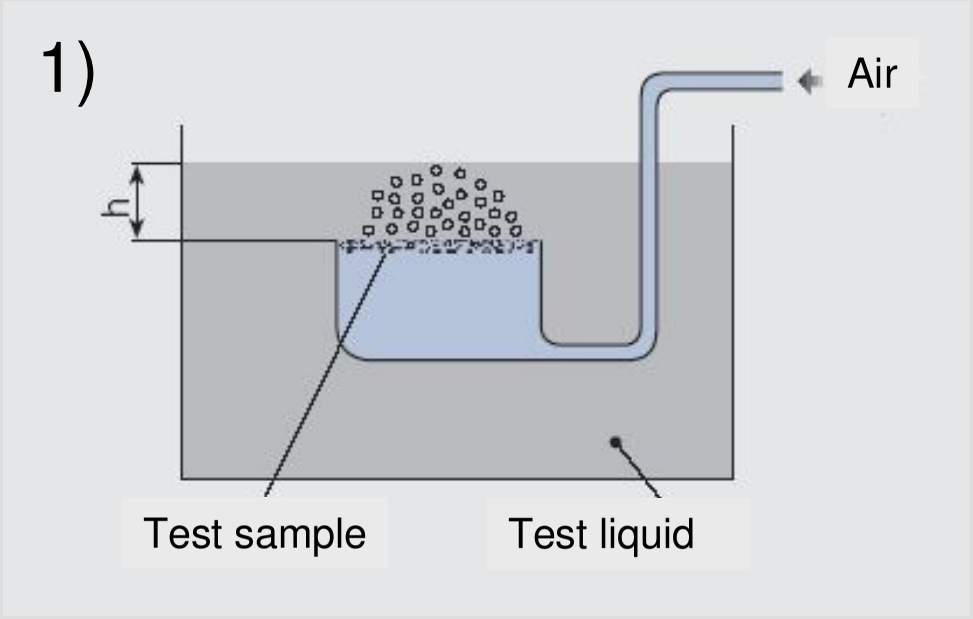
- Requirements of flame arrester elements
  - concerning their function
    - Quenching of flames
    - Low flow resistance
  - concerning their material
    - Temperature resistance
    - Corrosion resistance
    - Mechanical strength

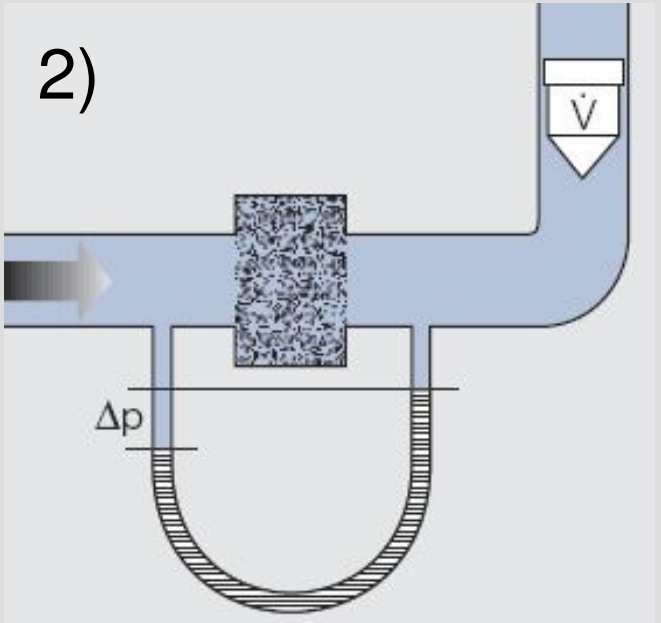


- Task
  - Introducing of a proceeding to measure the flame quenching property of porous structures

IEC 60079-1: Quality assurance

- Determination of technical characteristics
  - Maximum pore size *d* (bubble test pore size [1])
  - Density ρ
  - Permeability α (fluid permeability [2])

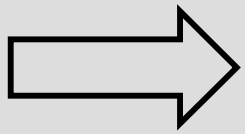




Source: www.gkn-filters.com/products/sika-r-as/brochures.html, 12.05.06

Quenching property

- Knowledge of d, ρ and α
  - allows to compare flame arrester elements of the same type with respect to flame transmission
  - But: no information concerning the quenching property, if different types of porous structures are compared

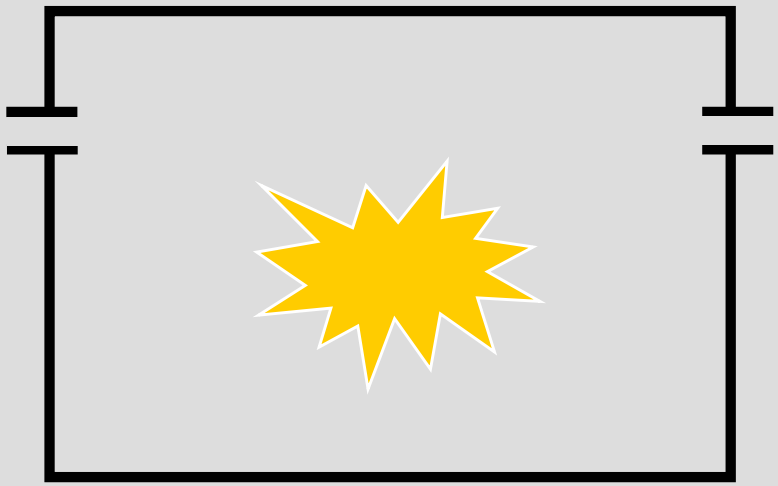


- New technical characteristic required!

Flame transmission

Influences on the flame transmission behavior of an internal ignition inside an enclosure:

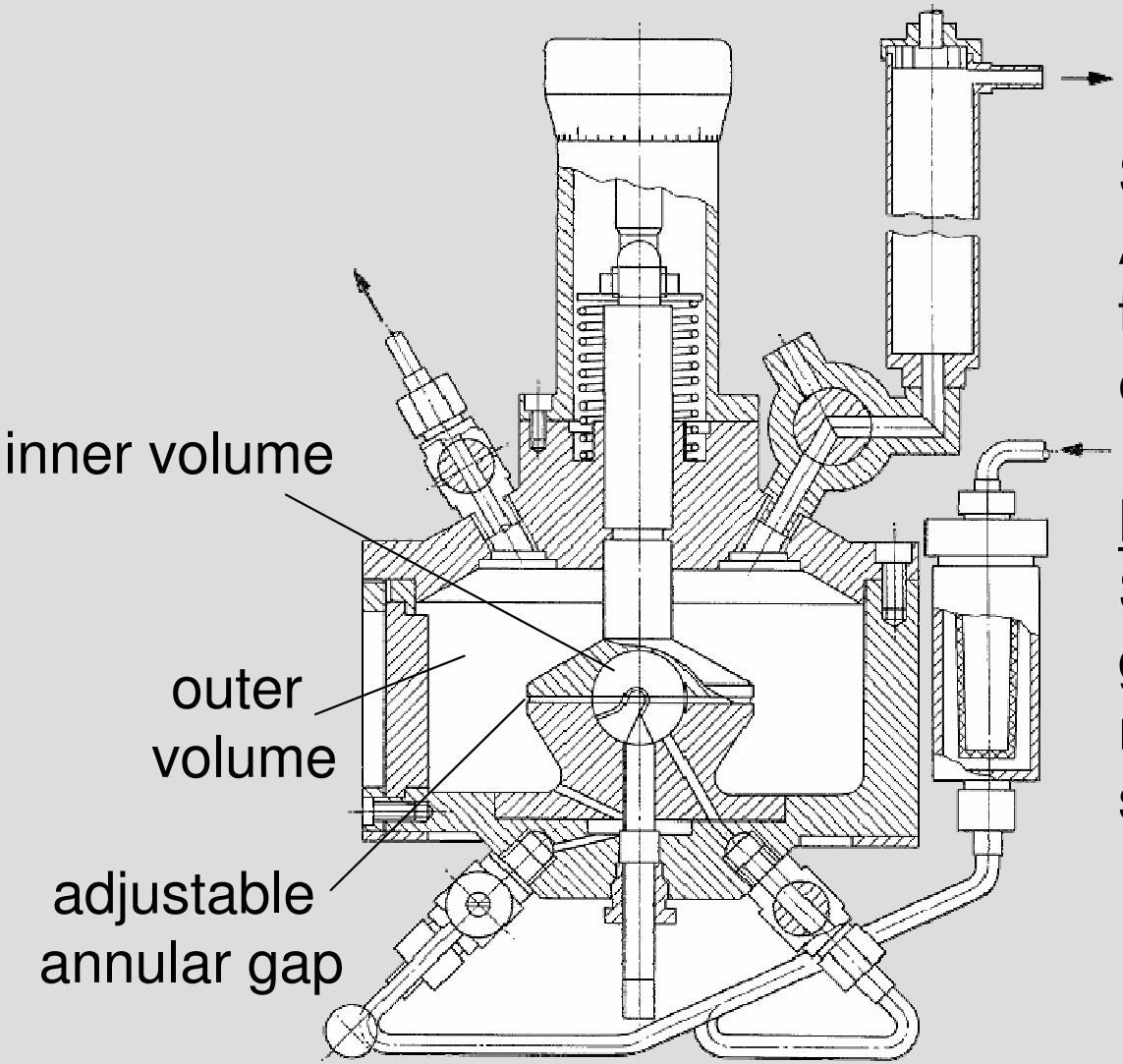
Enclosure:
- geometry of inner volume
- size of inner volume
- geometry of gap
- length of gap
- width of gap



Gas/air mixture:
- gas
- concentration
- initial pressure
- temperature

Qualification of gas/air mixtures

MESG-testing apparatus concerning IEC 60079-1-1



Safe gap:
A flame transmission just fails to occur in ten consecutive experiments

Maximum Experimental Safe Gap:
Smallest safe gap of a specific gas/air mixture, measured with the most incendive mixture under standard conditions

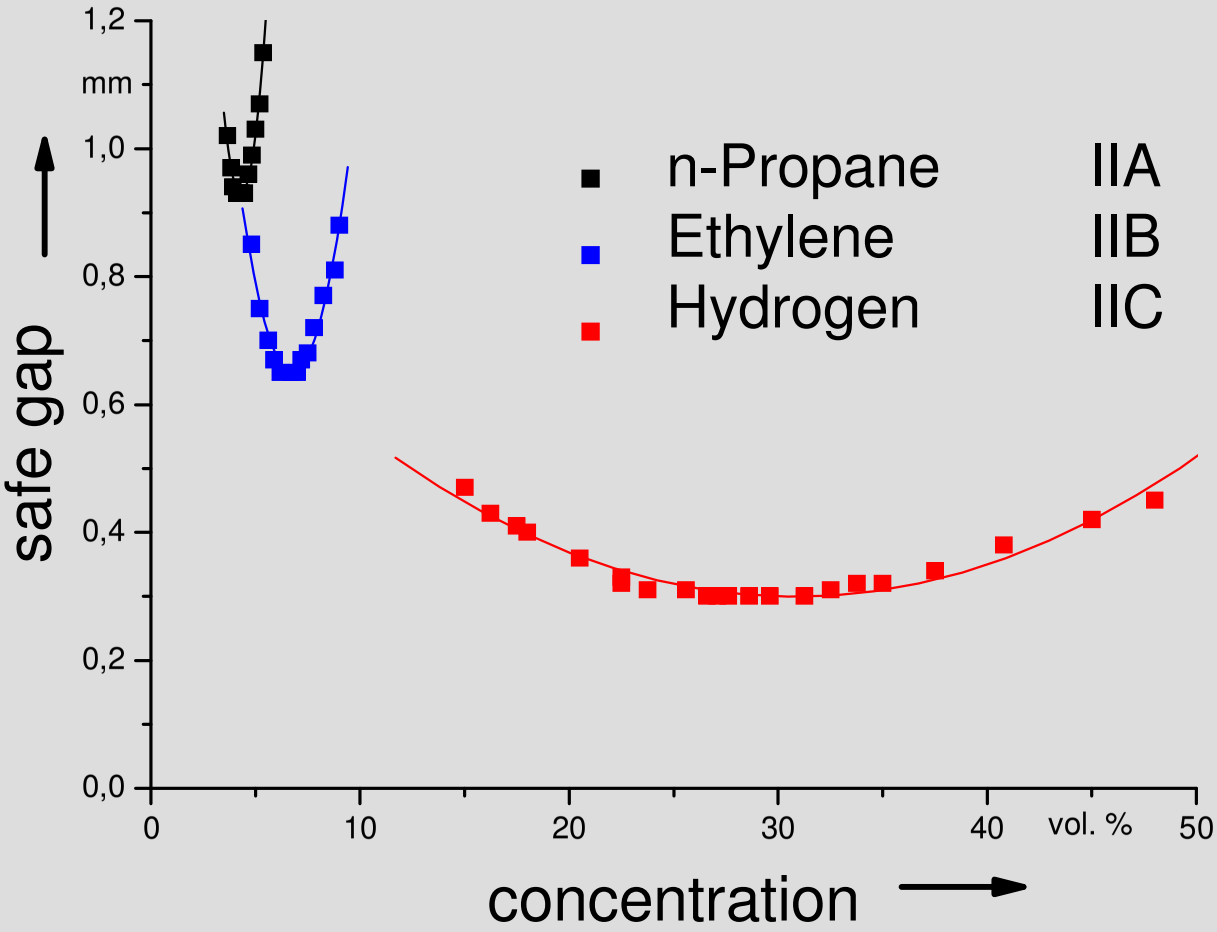
Source: standard IEC 60079-1-1

Use of the testing apparatus

- The MESG value leads to a classification of combustible gases in explosion groups:
  - II A: MESG > 0.9 mm
  - II B: 0.9 mm > MESG > 0.5 mm
  - II C: MESG < 0.5 mm
- The safe gap allows to determine dependencies between parameters of the gas/air mixture and the flame transmission behavior of an explosion.

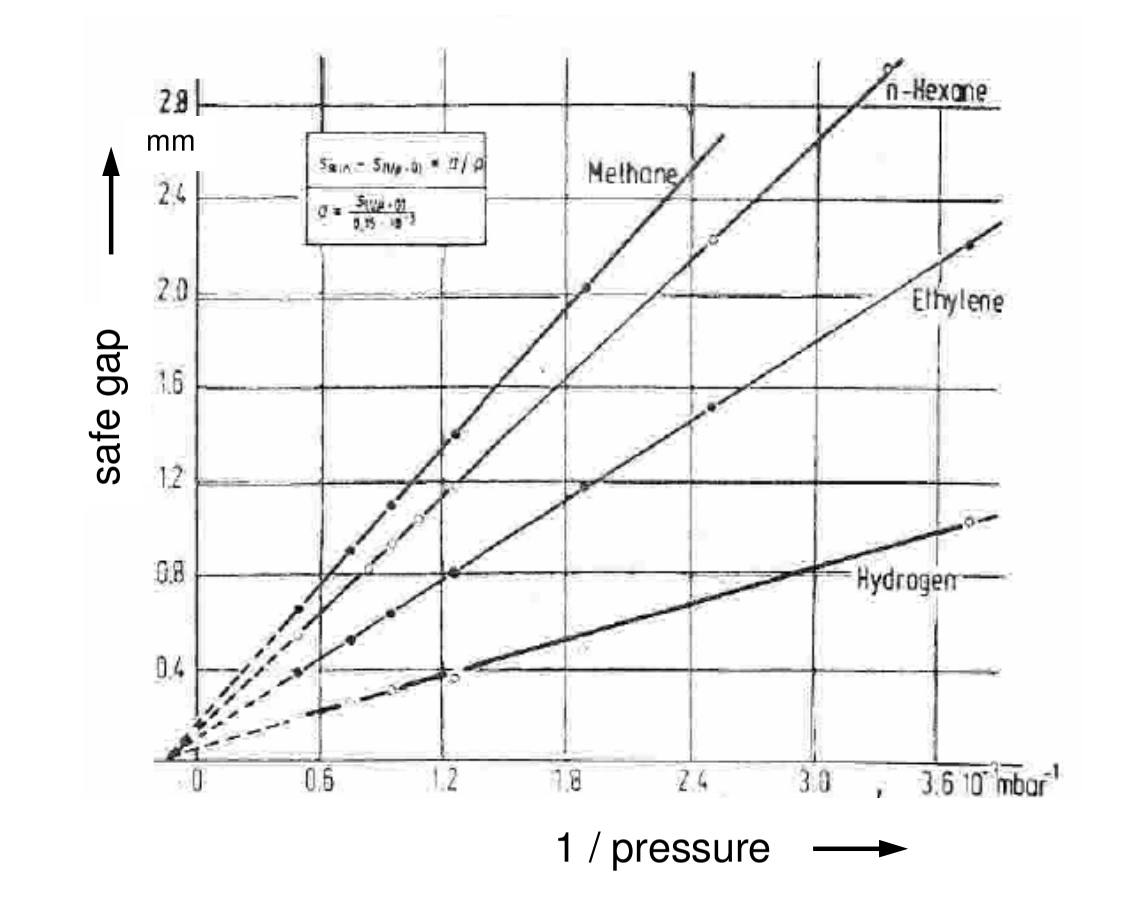
Safe gap - concentration

Influences of gas and concentration on the safe gap



Safe gap - pressure

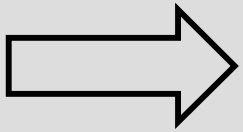
Influences of gas and initial pressure on the safe gap



Source: Redeker, T.: Classification of flammable gases and vapours by the flameproof safe gap and the incendivity of electrical sparks.

IEC 60079-1 test mixtures

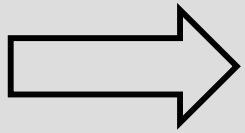
- Explosion groups
  - dependency of the safe gap on concentration and initial pressure
  - margin of safety



- Gas/air mixtures for the test of non-transmission of an internal ignition:
  - II A 55 vol. % H_2 in air
  - II B 37 vol. % H_2 in air
  - II C 27.5 vol. % H_2 in air; initial pressure 1.5 bar

Analysis of porous structures

- Dependency
  - between the safe gap and initial pressure
  - between the safe gap and gas concentration



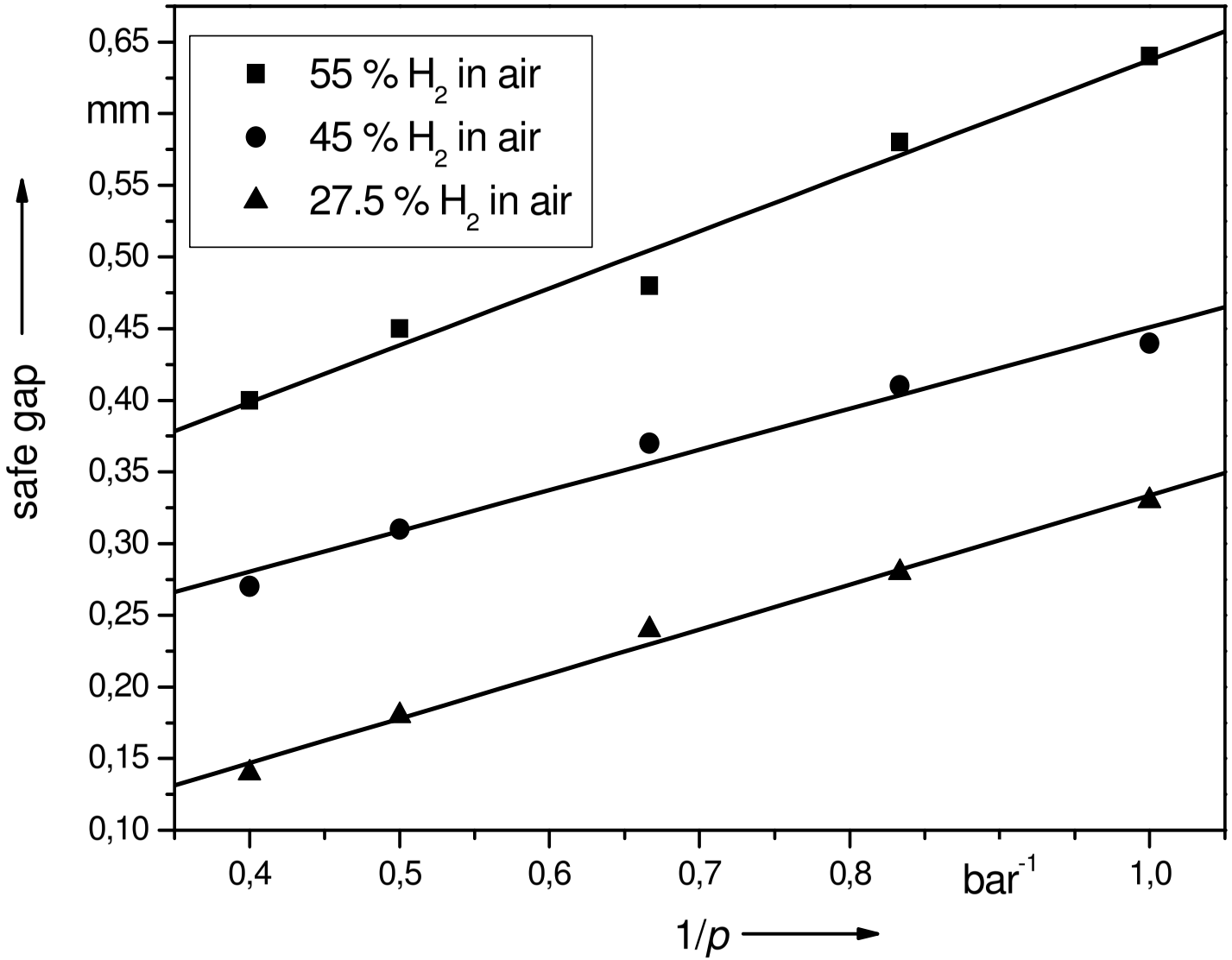
- New testing apparatus to characterize the flame quenching property of porous structures

Safe gap – safe pressure (1/3)

To relate the safe gap to the safe pressure:

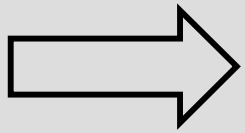
- Three H_2/air mixtures with different concentrations were examined in the MESG testing apparatus concerning their safe gap in dependency on initial pressure
- Concentrations:
  - 55 vol. % H_2
  - 45 vol. % H_2
  - 27.5 vol. % H_2
- Pressure range: 1.0 bar – 2.5 bar

Safe pressure – safe gap (2/3)



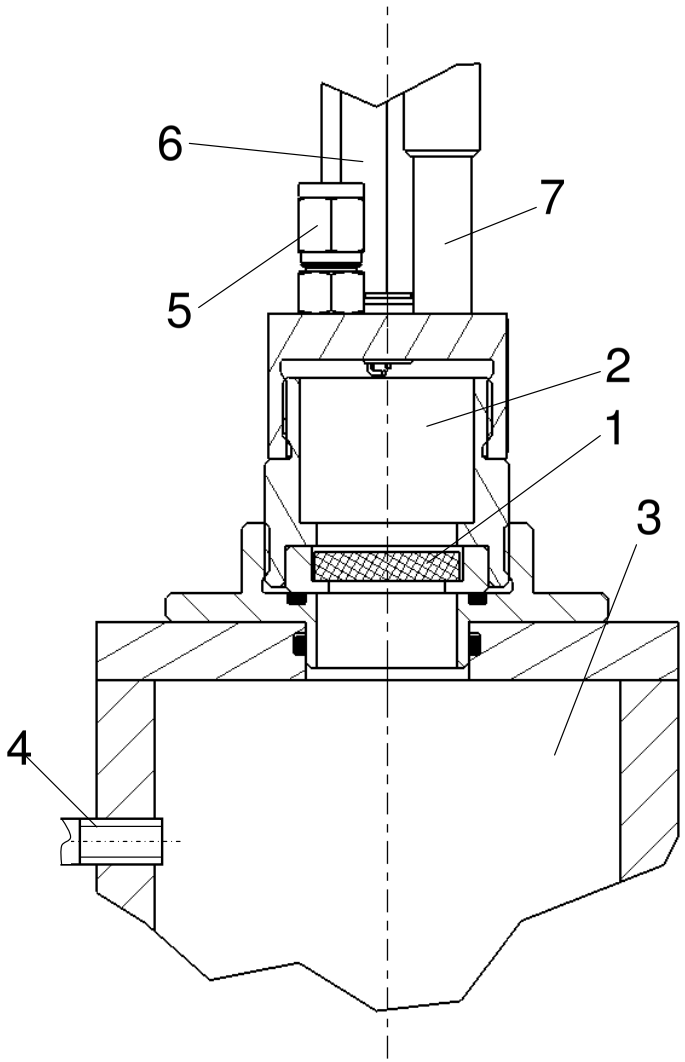
Safe pressure – safe gap (3/3)

- H_2 concentrations of
  - 55 vol. % H_2
  - 45 vol. % H_2
  - 27.5 vol. % H_2
- Initial pressure ranging from 1.0 bar to 2.5 bar



- Safe gaps ranging from 0.15 mm to 0.64 mm without interruption

Testing apparatus (assembly)



1: sample
2: ignition chamber
3: outer chamber
4: resistive pressure sensor (static)
5: gas inlet
6: ignition plug
7: piezoelectric pressure sensor (dynamic)

Used gas/air mixtures:
55 vol. % H_2 in air
45 vol. % H_2 in air
27.5 vol. % H_2 in air

Increasing of initial pressure:
Steps of 100 mbar
From 1.0 bar to 2.5 bar

Testing apparatus (results)

- Safe pressure of a porous structure:
  - That pressure at which a flame transmission just fails to occur in five consecutive experiments (determined with a specific H_2/air mixture)

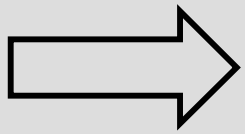
- Safe gap of a porous structure:
  - Value that can be determined from the safe pressure - safe gap diagram using the measured safe pressure as well as the used H_2 concentration

Safe gaps of test samples

No.	Kind of test sample	Safe pressure 27.5 % H_2/air in bar	Safe pressure 45 % H_2/air in bar	Safe pressure 55 % H_2/air in bar	Average safe gap in mm
1	**Fiber structure**	**+**	**+**	**+**	**< 0.15**
5	**Sintered metal**	**2.4**	**+**	**+**	**0.15**
7	**Woven wire**	**1.9**	**+**	**+**	**0.19**
8	**Fiber structure**	**1.2**	**2.1**	**+**	**0.29**
11	**Fiber structure**	**1**	**1.7**	**+**	**0.33**
12	**Fiber structure**	**1**	**1.5**	**+**	**0.34**
14	**Fiber structure**	**-**	**1**	**2.4**	**0.43**
15	**Sintered woven wire**	**-**	**-**	**2.1**	**0.44**
16	**Fiber structure**	**-**	**1**	**2**	**0.44**
17	**Woven wire**	**-**	**-**	**1.5**	**0.50**
18	**Sintered woven wire**	**-**	**-**	**-**	**> 0.64**

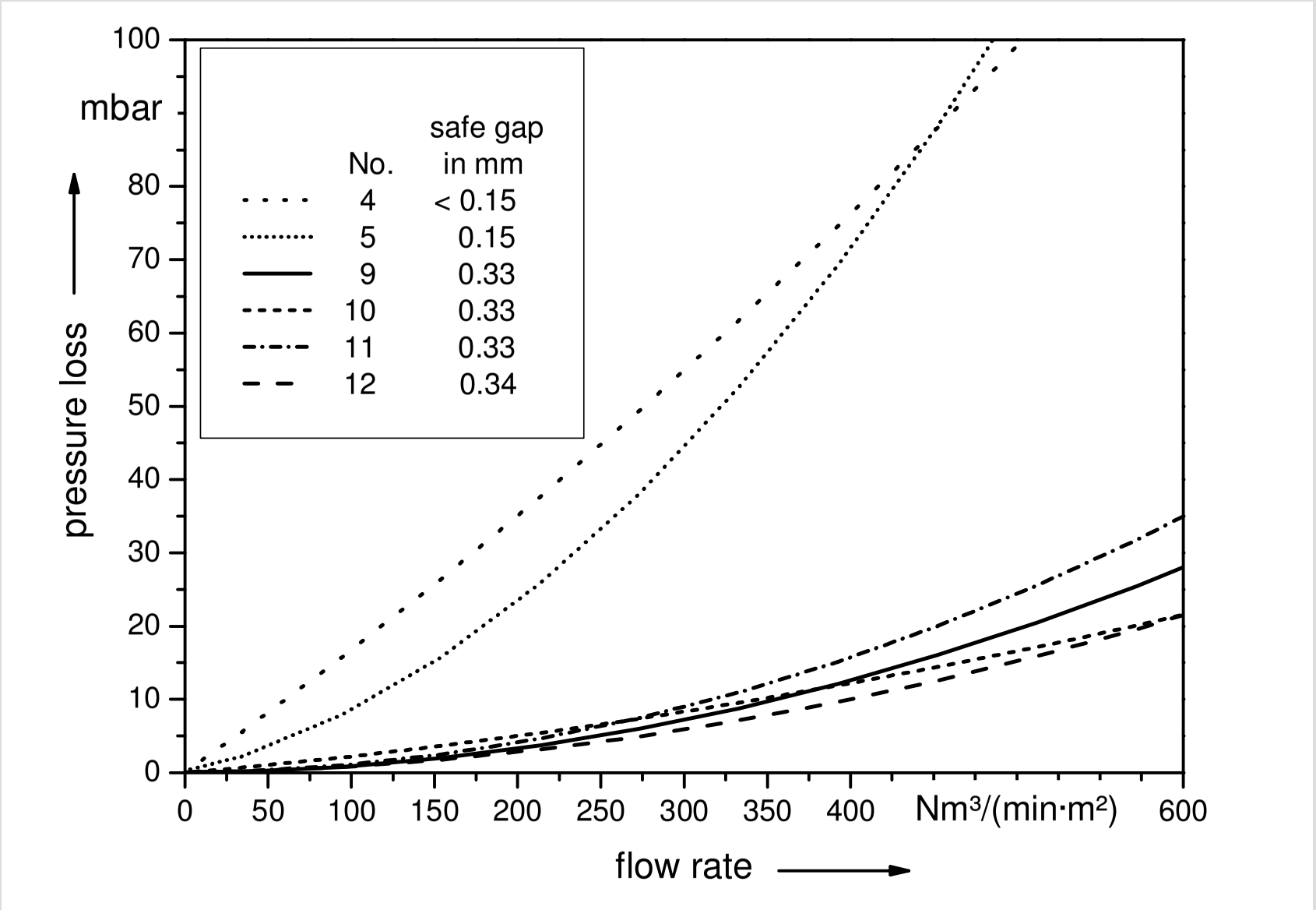
Application

- A safe gap can be related to each porous structure



- Dimensioning of flame arrester elements used in flame arresters:
  - flame quenching property as good as necessary -> safe gap
  - flow resistance as low as possible

Safety- vs. flow properties



Conclusion

- Porous structures can be characterized concerning their ability to prevent flame transmission by a safe pressure
- An equivalent safe gap results from the safe pressure
- The safe gap value depends on the used testing apparatus but the classification (test sample No. 1 is better than No. 2) may be generally valid
- Safe gap + e.g. flow resistance
  => optimization of flame arrester elements possible

Outlook

- The flame transmission process through porous structures will be examined in detail by the use of laser diagnostics (Schlieren technique and laser induced fluorescence of OH radicals).
- The classification of porous structures using the introduced testing apparatus will be compared to the results determined with a testing apparatus related to the deflagration test for in-line flame arresters concerning EN 12874.

Any questions?

Thank you!