TECHNISCHE UNIVERSITÄT DRESDEN

# Vacuum Technology
# WS 20/21
# Virtually presented
# Lecture 13, Feb. 02, 2021


## Prof. Dr. Johann W. Bartha

Inst. f. Halbleiter und Mikrosystemtechnik
Technische Universität Dresden


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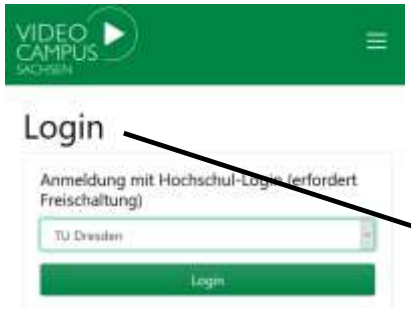


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# Review L12

## 0. Introduction

**Air pressure as a force to the walls of an empty container**

## 1. Gas kinetic

**Pressure as momentum transfer, Mol & Molvolume, Pressure units Partial pressure, Boltzmann Velocity&Energy distribution, Impingement rate, monolayer coverage time, mean free path collision rate**

## 2. Pressure Ranges

**Viscous, Knudsen, Molecular flow, Rough-, Medium-, High-, Ultrahigh-Vacuum, Heat conduction**

## 3. Vacuum technical terms

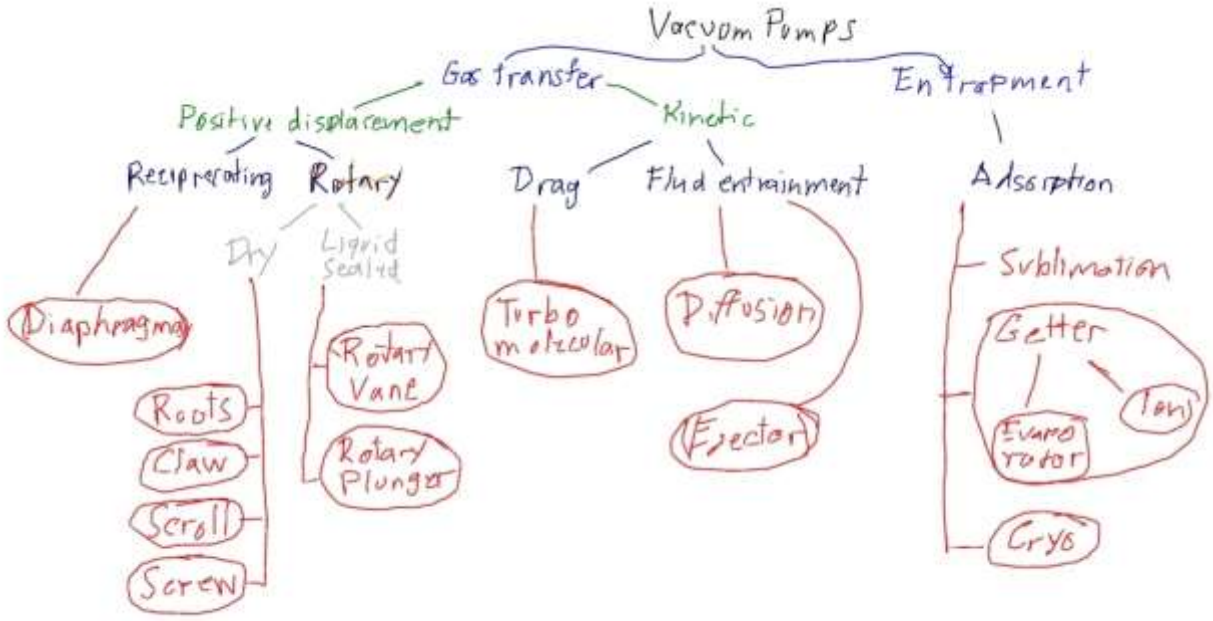
**Pumping speed, pumping power, gas-flow, residence time, gas flow conduction, impact on tube dimension**

## 4. Vacuum generation

**Genealogy of pumps, working principle, assignment to vacuum range**

## 5. Pressure measurement

**Direct / Indirect pressure measurement, Different gauges and assignement to vacuum range, Partial pressure measurement, interpretation of QMA spectra**

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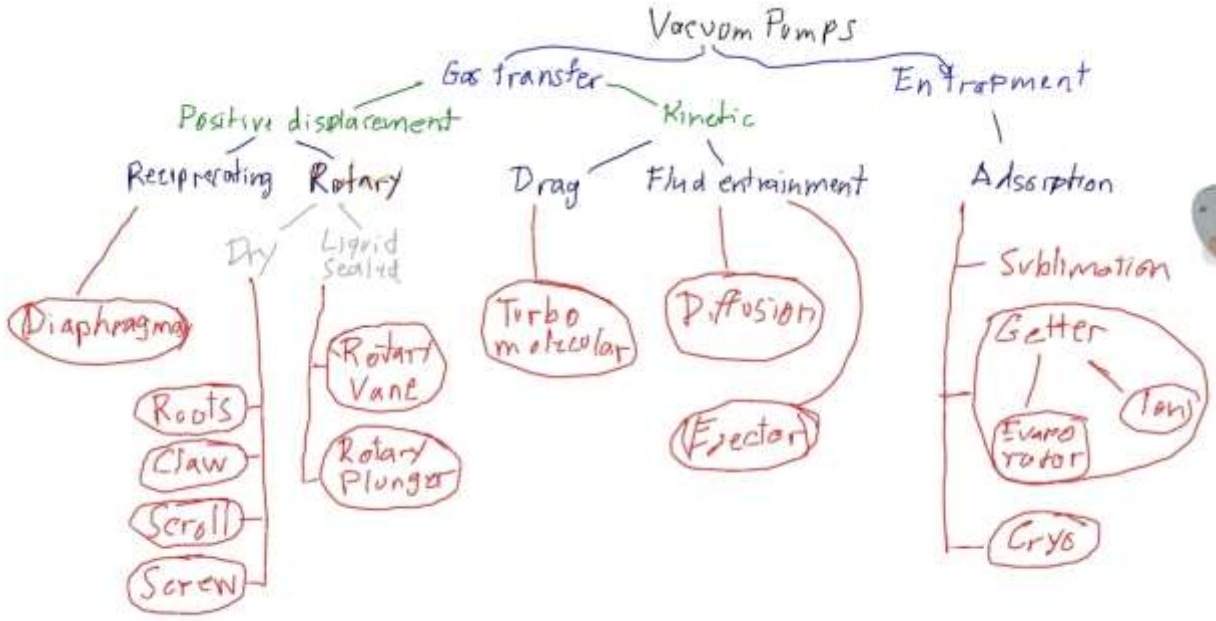


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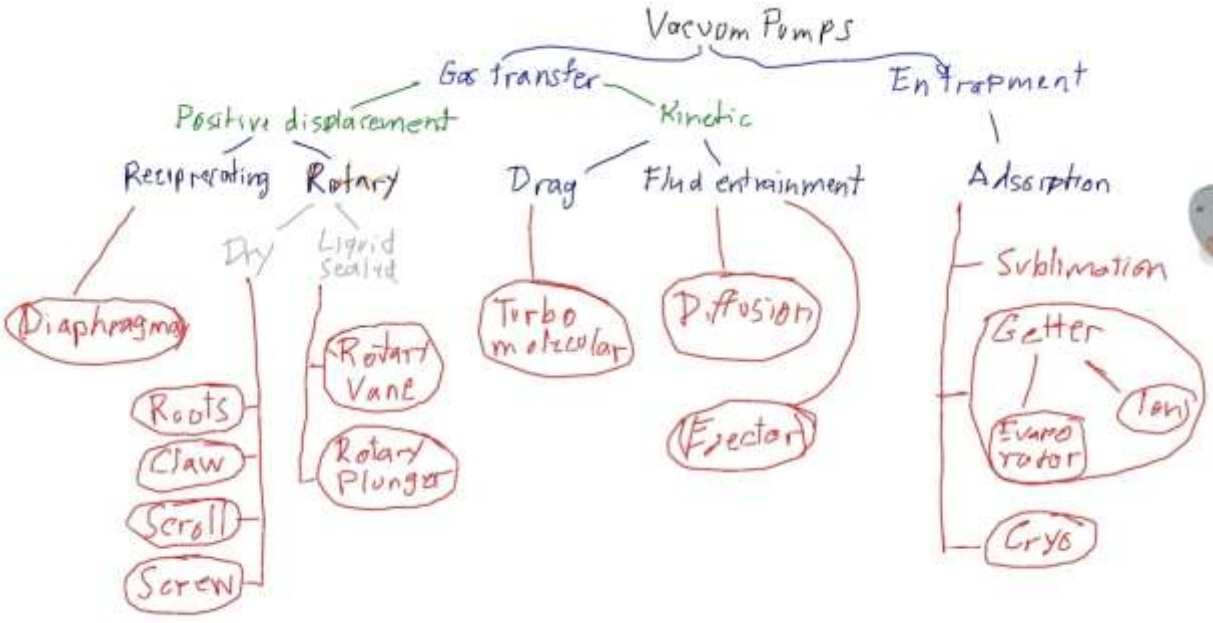


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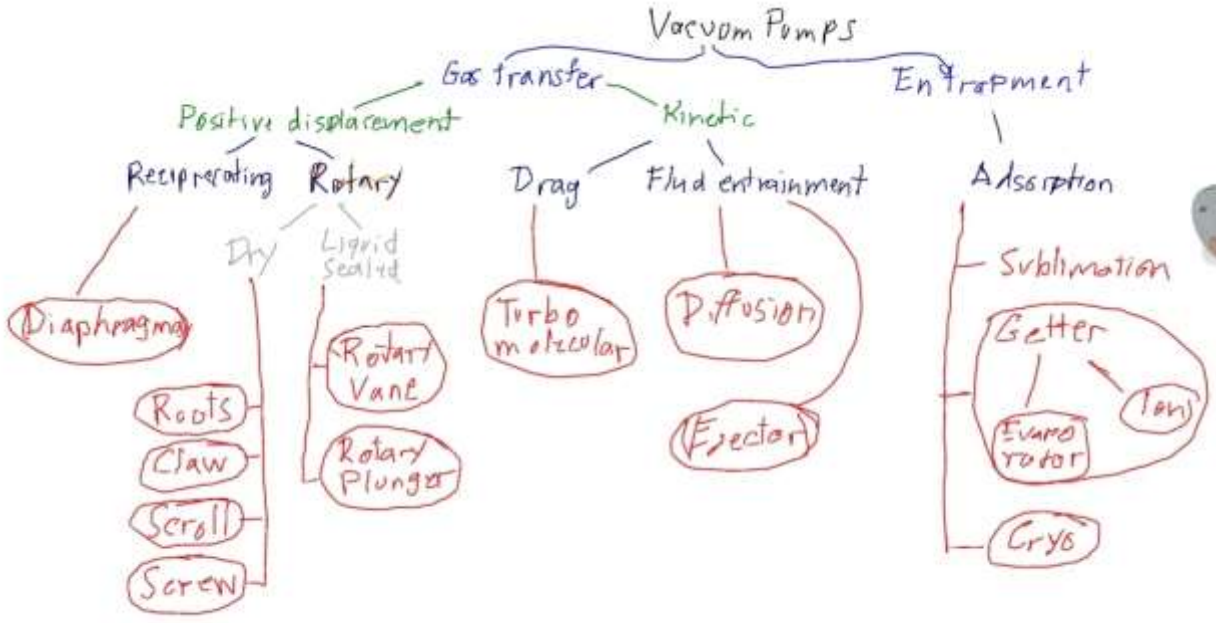


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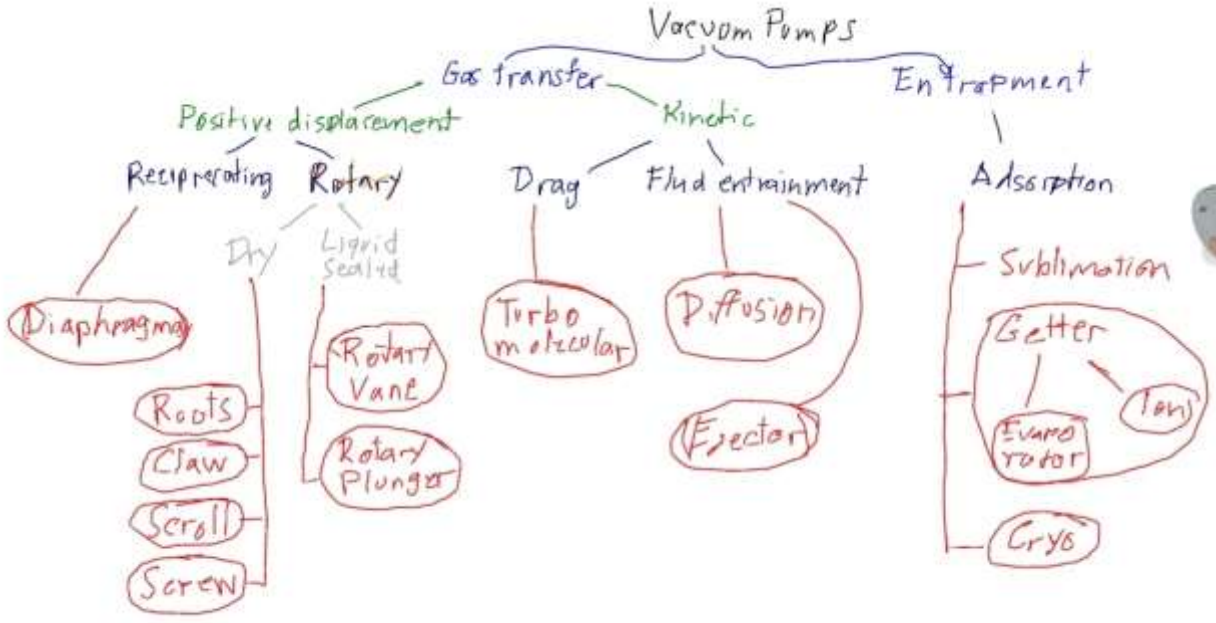


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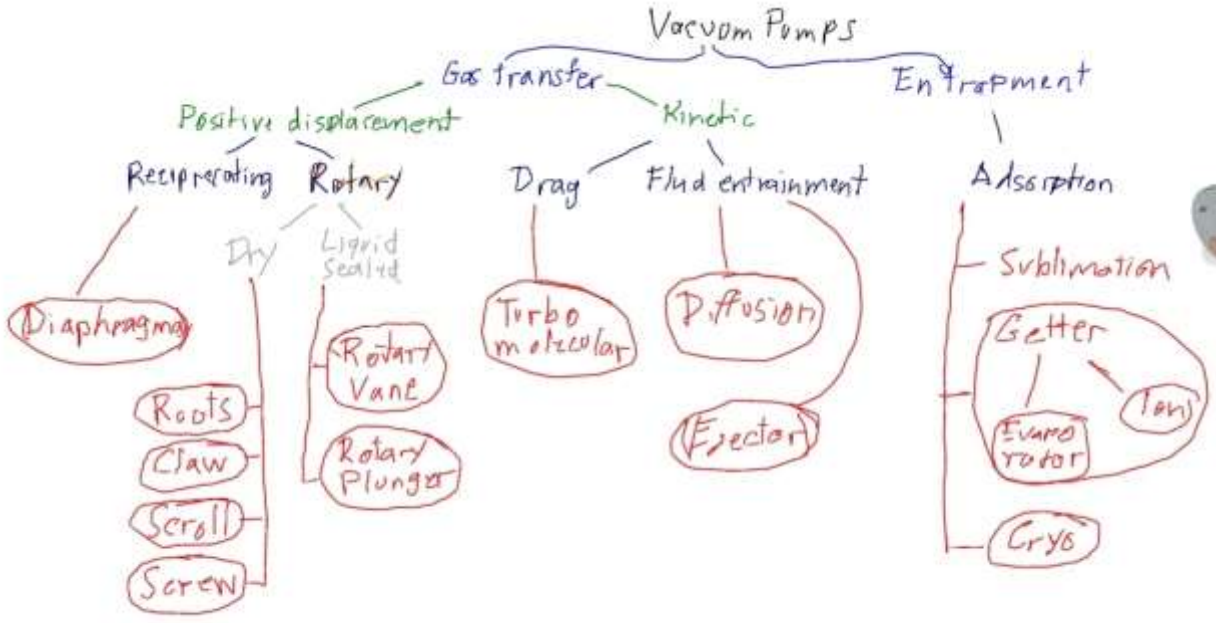


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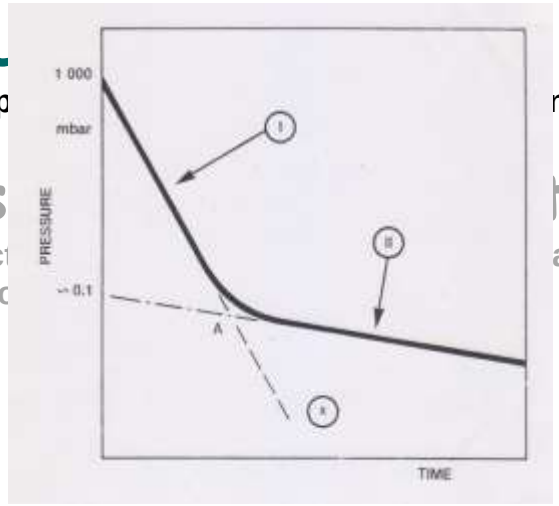


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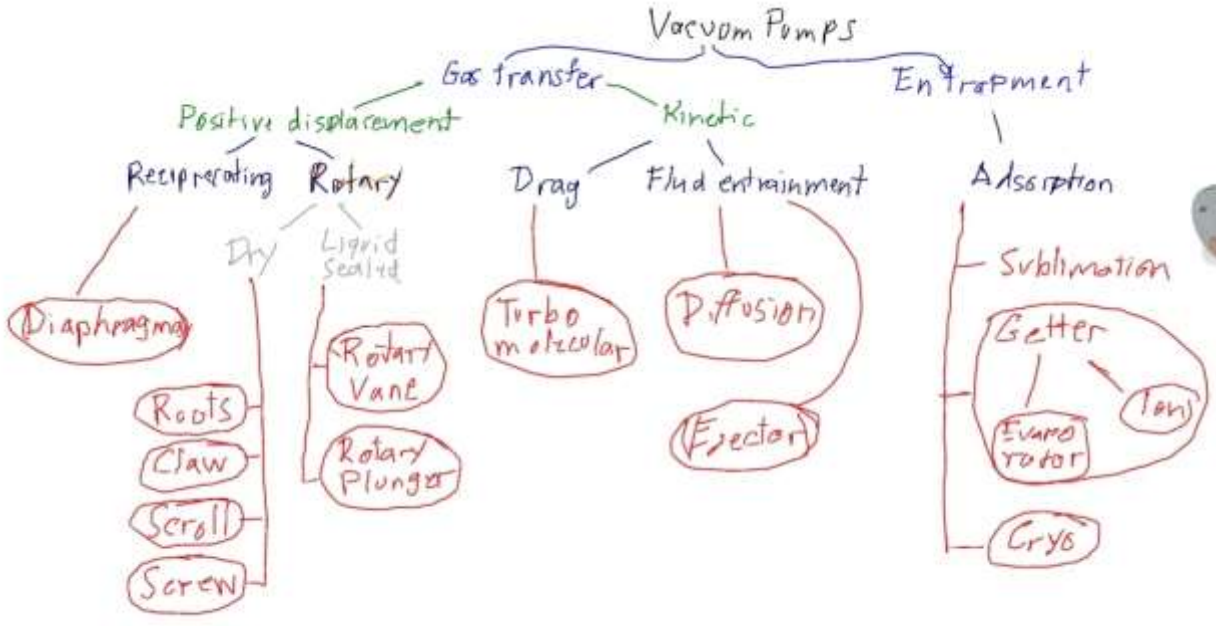


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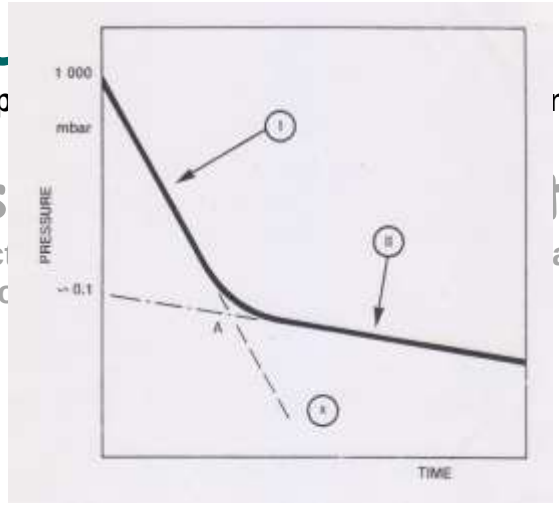


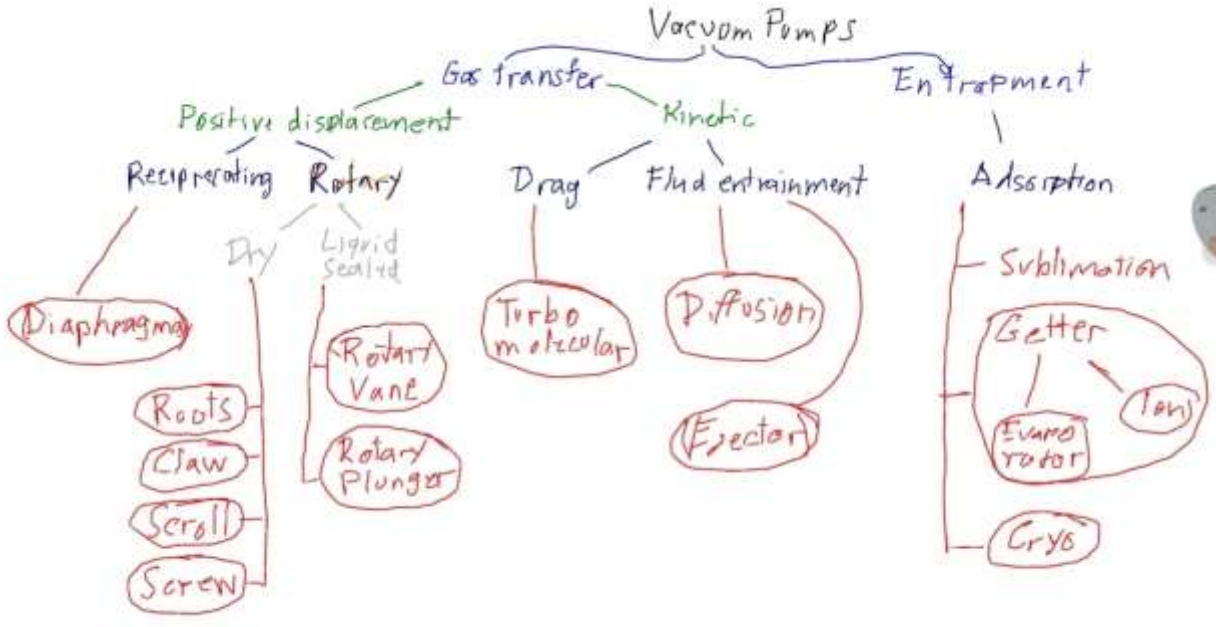


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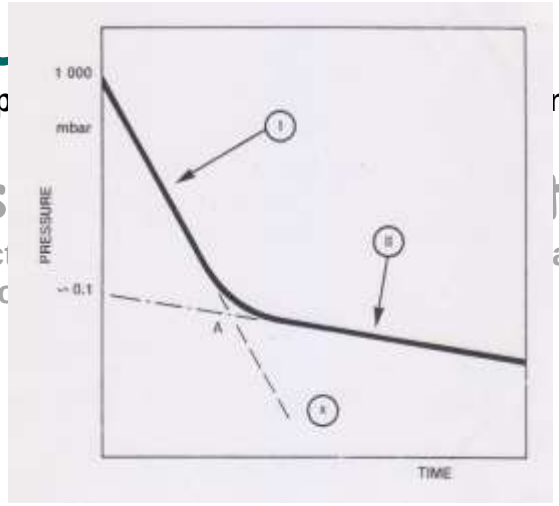


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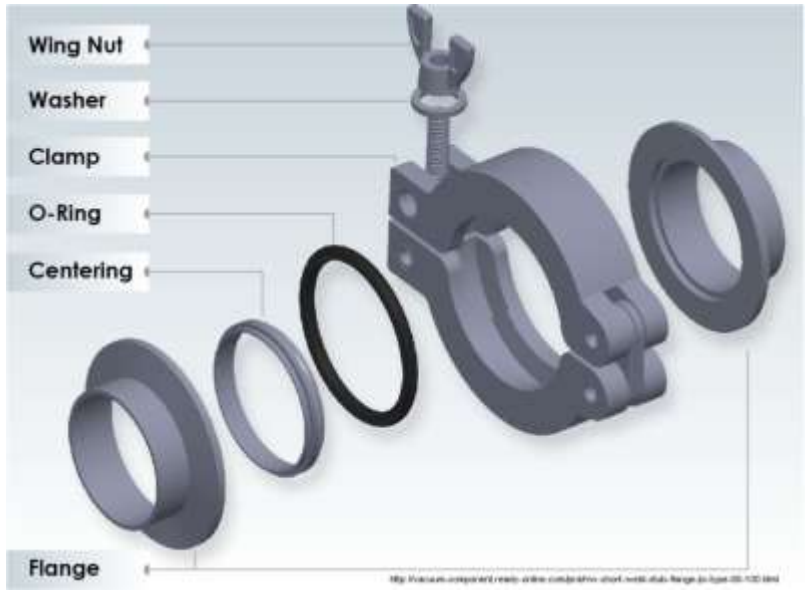
# High Vacuum flanges


Rubber based sealing



# High vacuum system

# He Leaktest: Mass spectrometer for He

## Measurement of the He partial pressure

(regular case: He partial pressure not detectable!)

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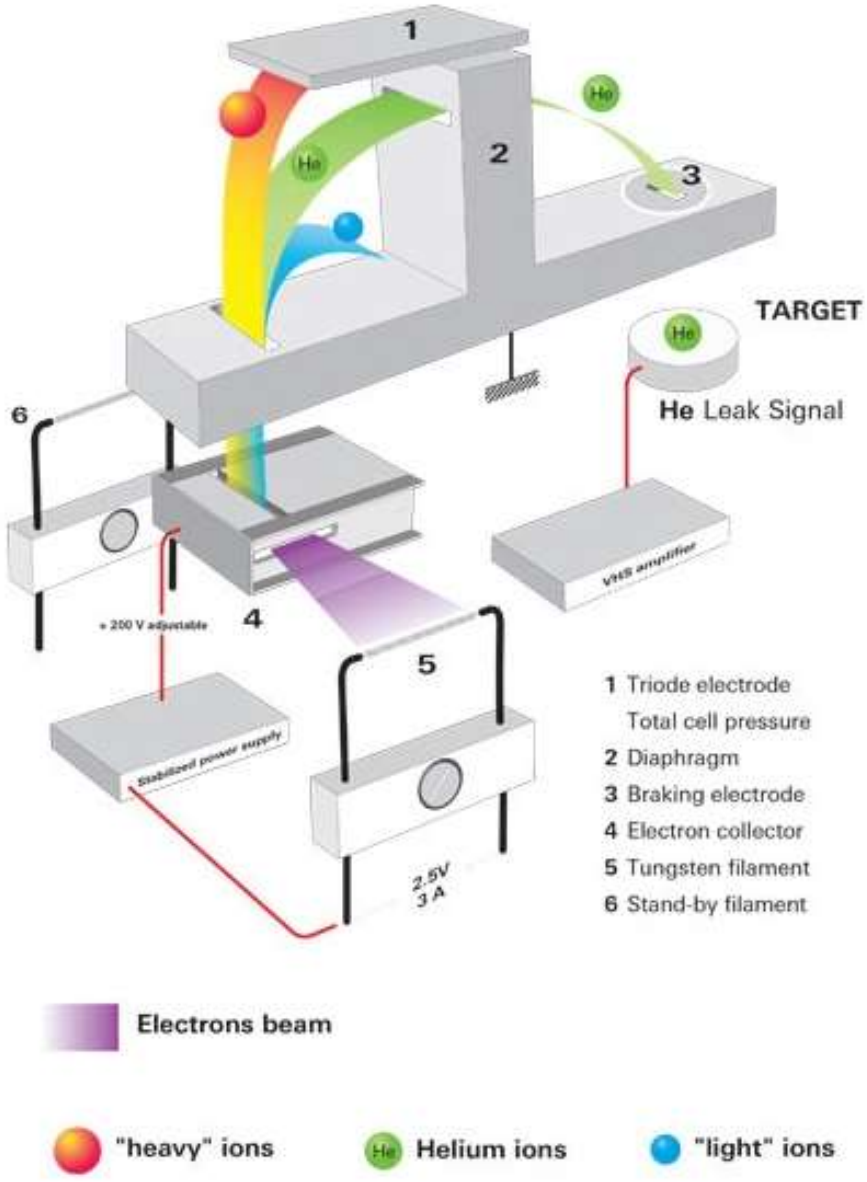
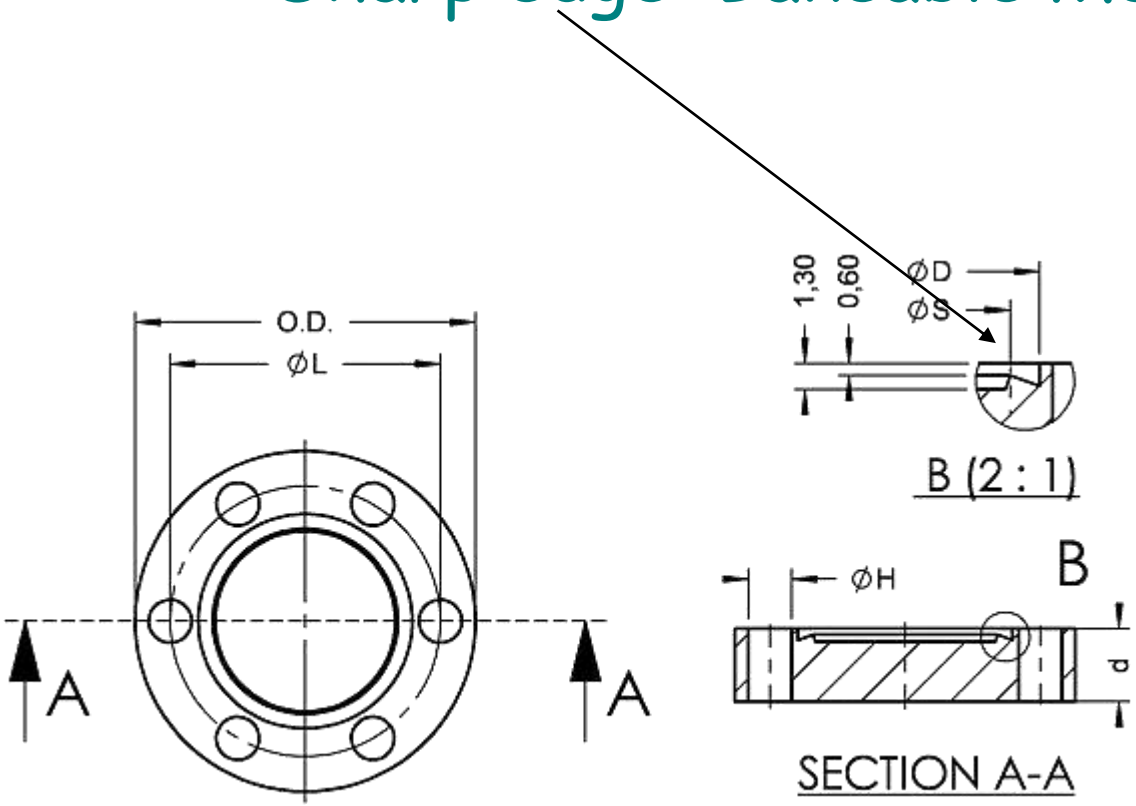


# Ultra High Vacuum

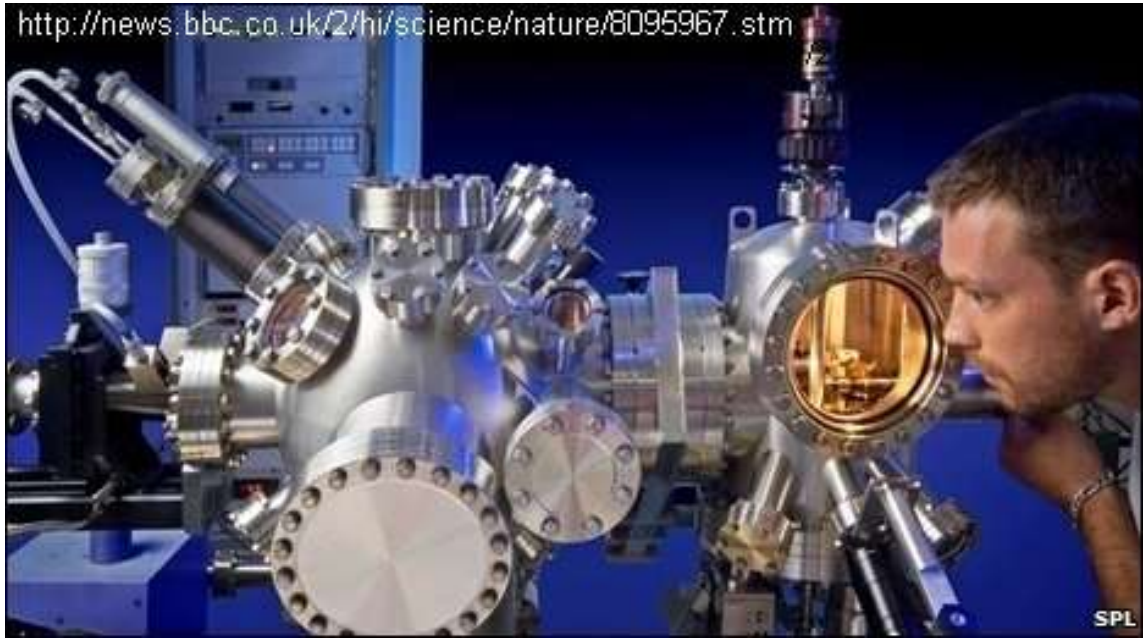
## Metal based sealing

http://gescott14.blogspot.com/2007/12/uhv-part-2-bake-out.html

# Sharp edge: Bakeable Metall-Metall join




# Ultra High Vacuum systems

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# 5.1. Pressure measurement

# 5. Vacuum measurement



## 5.1. Pressure measurement

A: Direct or absolute pressure measurement
= Force / Surface area

!! Independent of the specific gas

# 5. Vacuum measurement



## 5.1. Pressure measurement

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B: Indirect pressure measurement
= Utilization of density dependent properties

-Heat conductivity
-Ionization probability

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Mechanical:
Bending device

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Electrical:
Baratron

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-Heat conductivity
-Ionization probability

- Pirani
- Penning
- Hot cathode

# 5. Vacuum measurement

"VT L013 ^c 22:57

5.2 Gas flow

## 5.1. Pressure measurement

A: Direct or absolute pressure measurement
= Force / Surface area

!! Independent of the specific gas

Mechanical:
Bending device

Electrical:
Baratron

B: Indirect pressure measurement
= Utilization of density dependent properties

-Heat conductivity
-Ionization probability

- Pirani
- Penning
- Hot cathode

# 5. Vacuum measurement

"VT L013 ^c 22:57

5.2 Gas flow

## 5.1. Pressure measurement

5.3 Partial pressure

A: Direct or absolute pressure measurement
= Force / Surface area

!! Independent of the specific gas

B: Indirect pressure measurement
= Utilization of density dependent properties

-Heat conductivity
-Ionization probability

Mechanical:
Bending device

Electrical:
Baratron

- Pirani
- Penning
- Hot cathode

# A: Bourdon Vacuum meter

Covers the rough vacuum range

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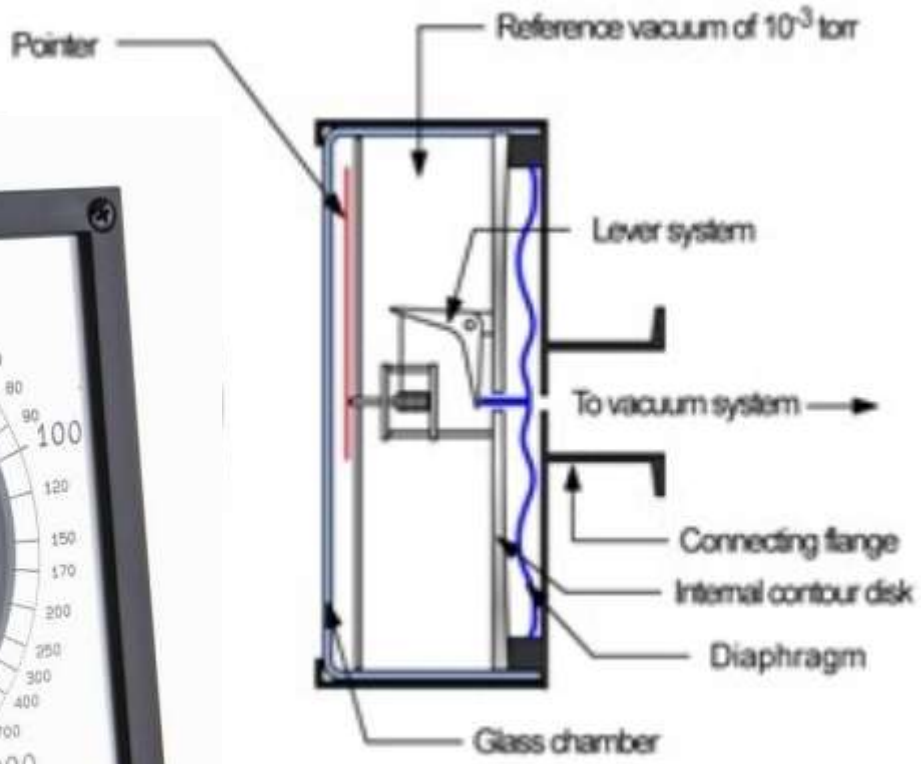
Covers the rough vacuum range



https://www.youtube.com/watch?v=nE_n1lCuz30

# A: Membrane Vacuum meter

Covers the rough vacuum range


https://www.youtube.com/watch?v=h1lroqf9IHM

# A: Baratron

Covers wide
vacuum range
1000 – $10^{-5}$ mBar

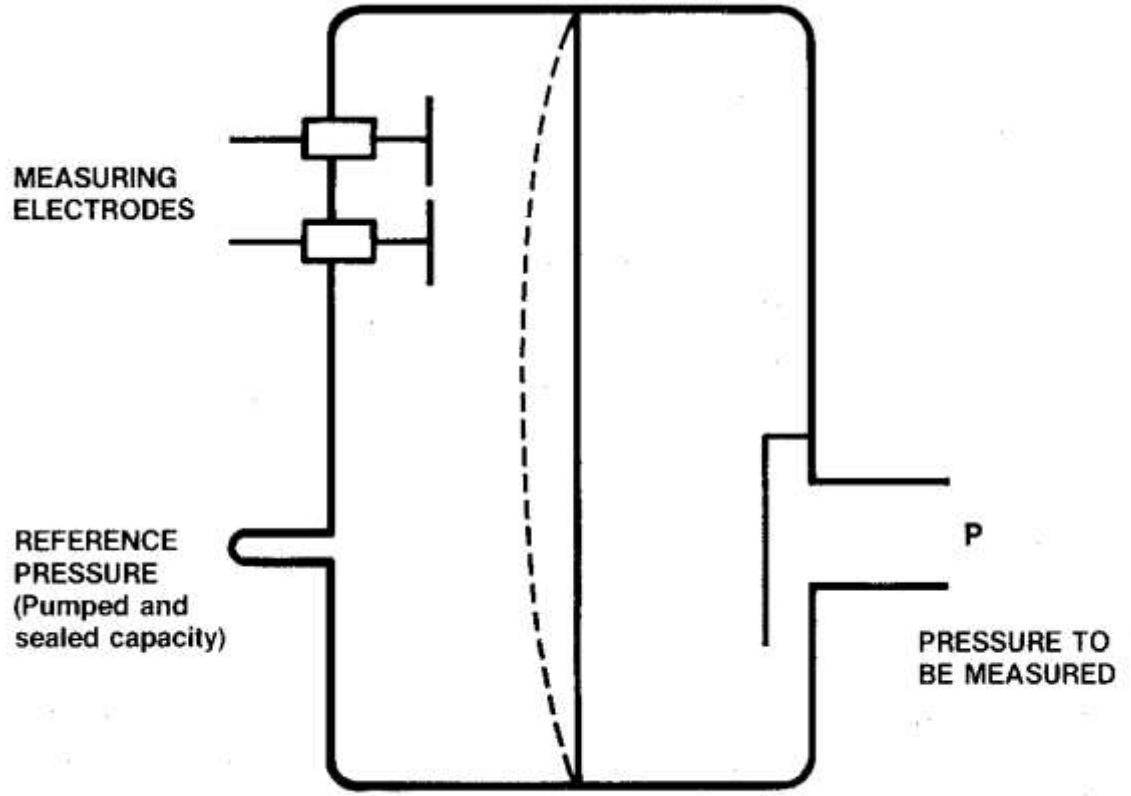



Fig. 9.5. Capacitance manometer with deformable membrane (schematic).

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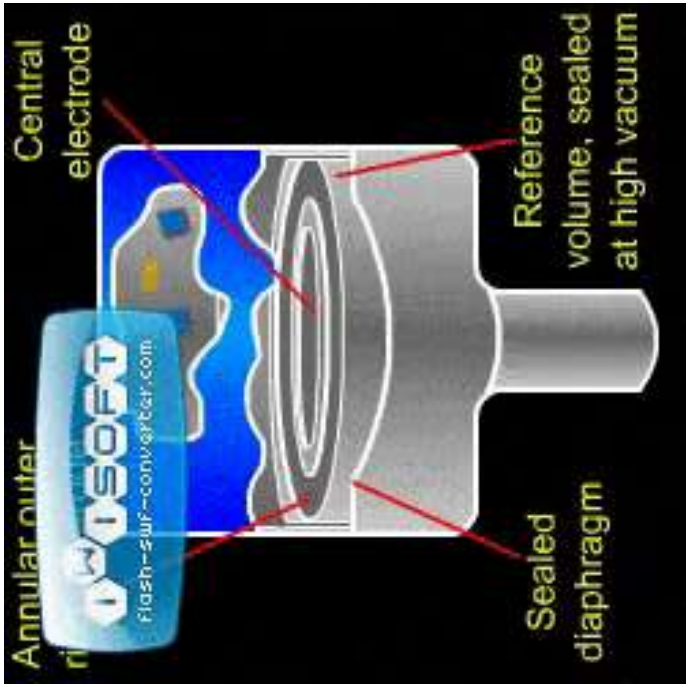


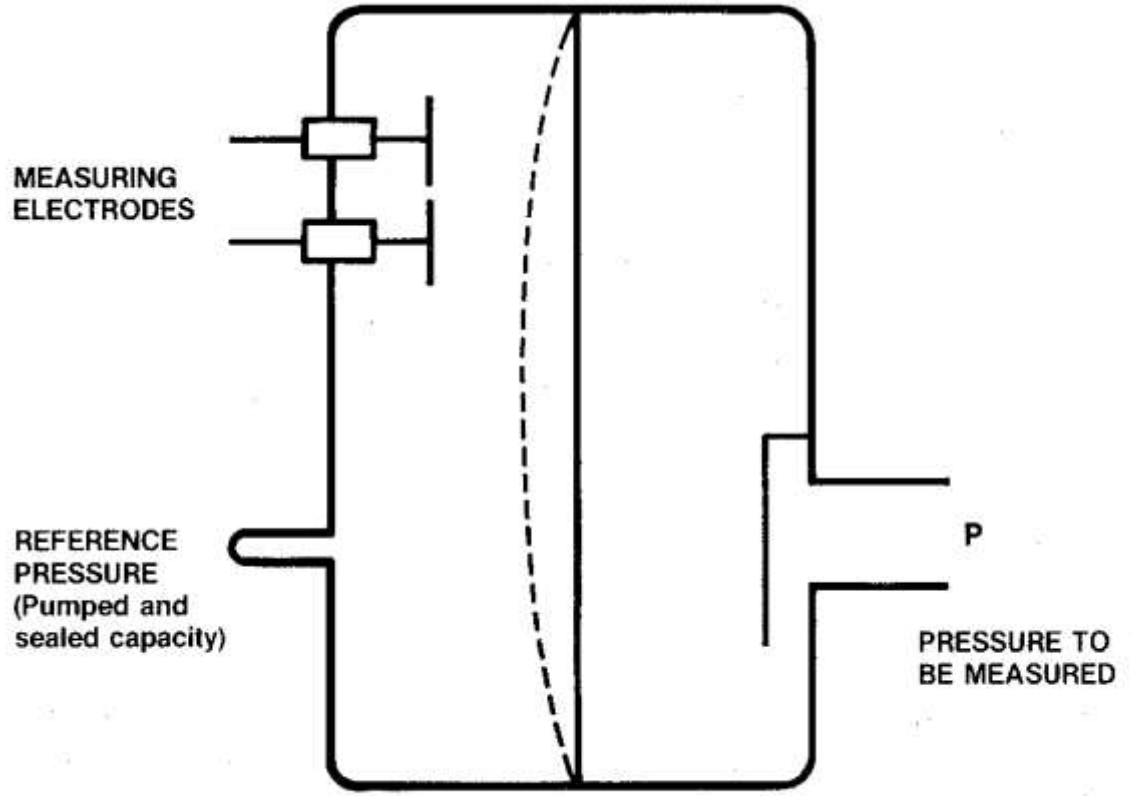


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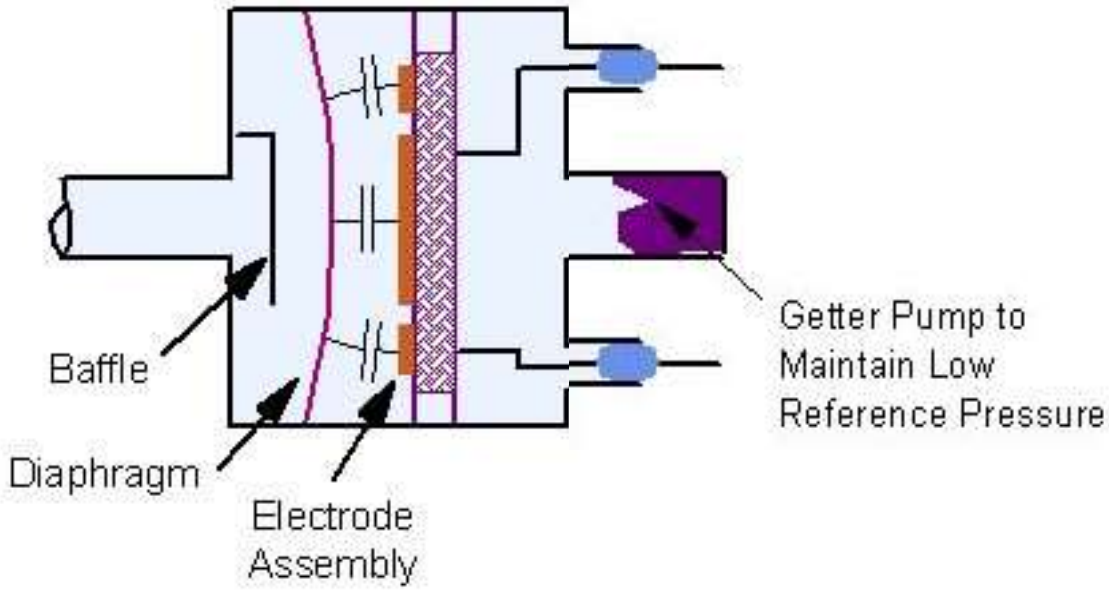
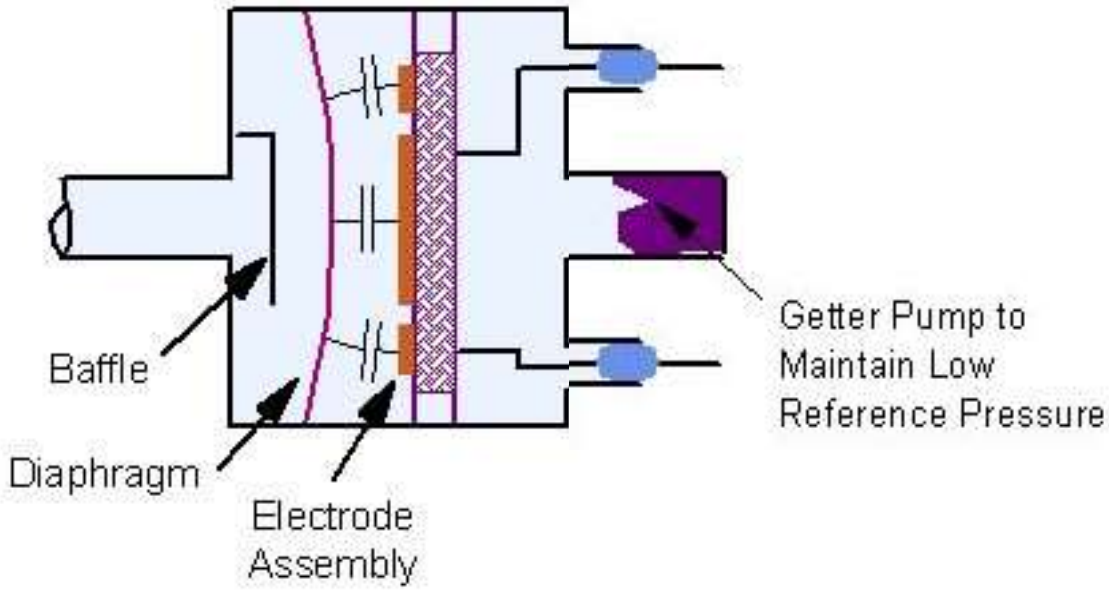



| Sensor (Full Scale) | Messbereich in mbar |
|---|---|
| 1000 | $1013 - 10^{-1}$ |
| 100 | $100 - 10^{-2}$ |
| 10 | $10 - 10^{-3}$ |
| 1 | $1 - 10^{-4}$ |
| 0,1 | $10^{-1} - 10^{-5}$ |

# A: Baratron


**Rough-, Fine- and part of High Vacuum**

| Sensor (Full Scale) | Messbereich in mbar |
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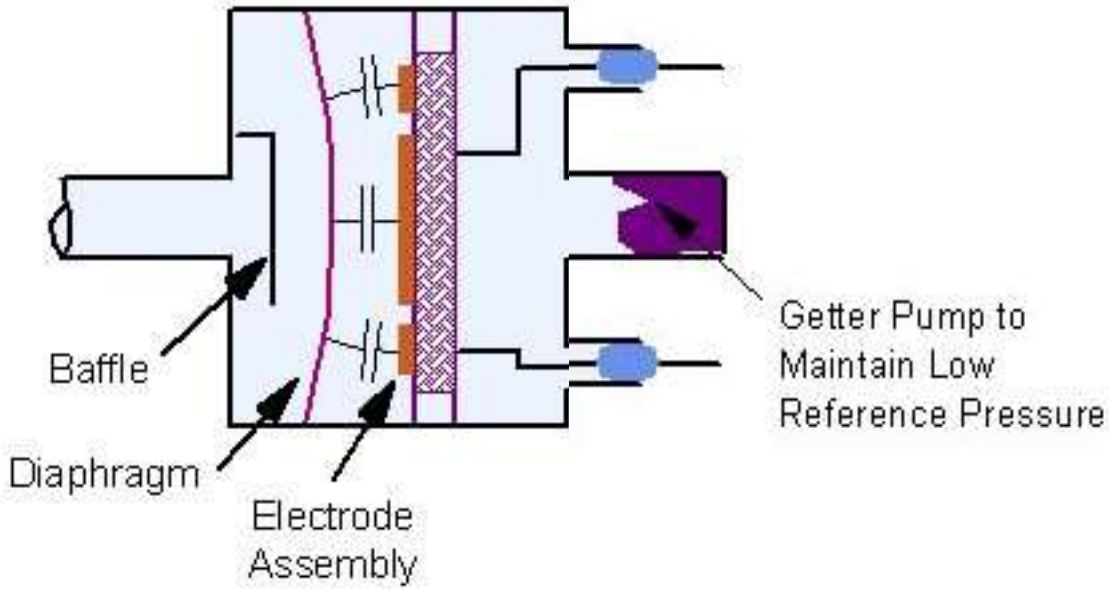


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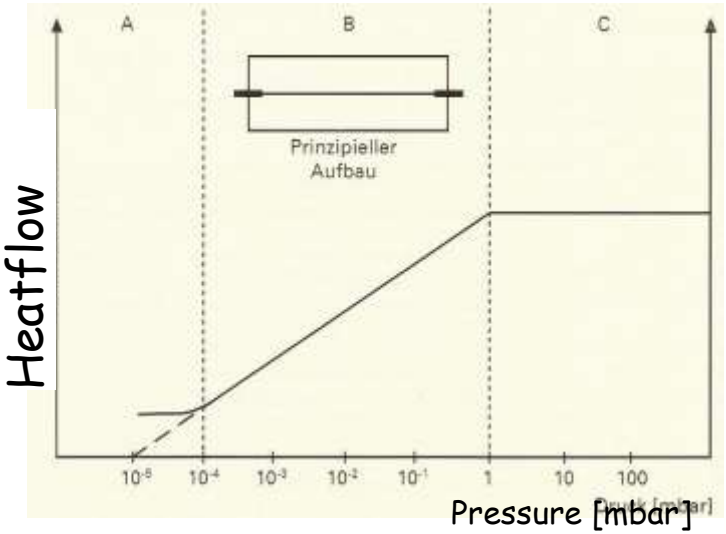
# B: Heat conduction gauge - Pirani

"VT L013 ^d 32:25



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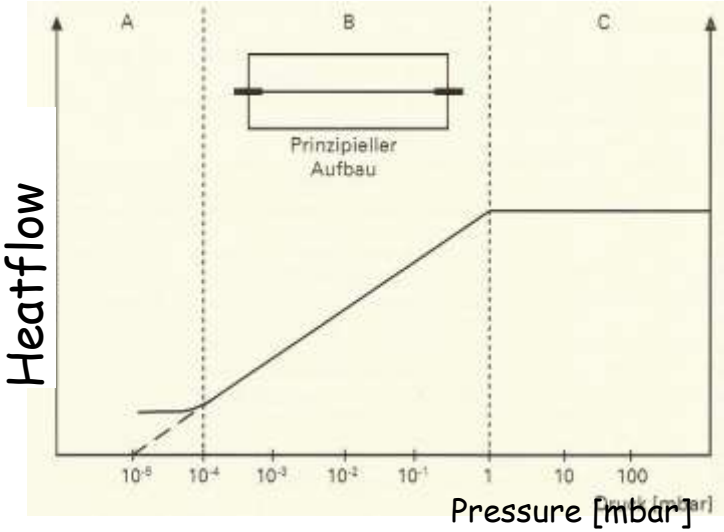


Heat flow from a heated wire inside the vacuum in regimes A,B,C by:

A: Radiation and conduction through terminals
B: As A + pressure dependent gas conduction
C: As A + pressure independent gas conduction

# B: Heat conduction gauge - Pirani

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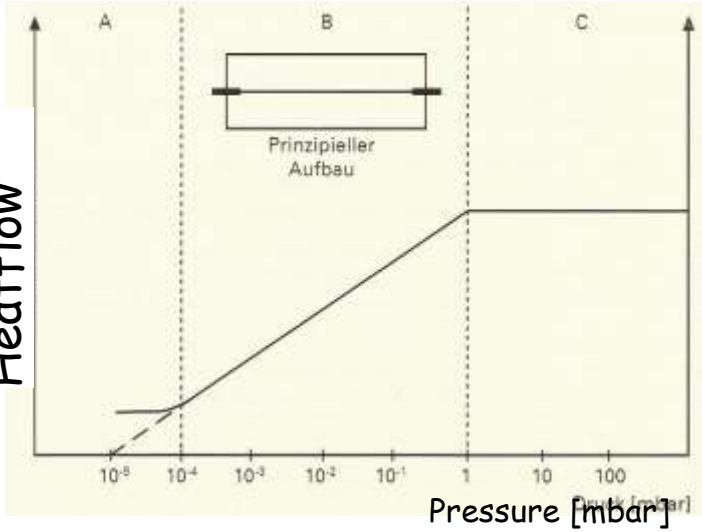


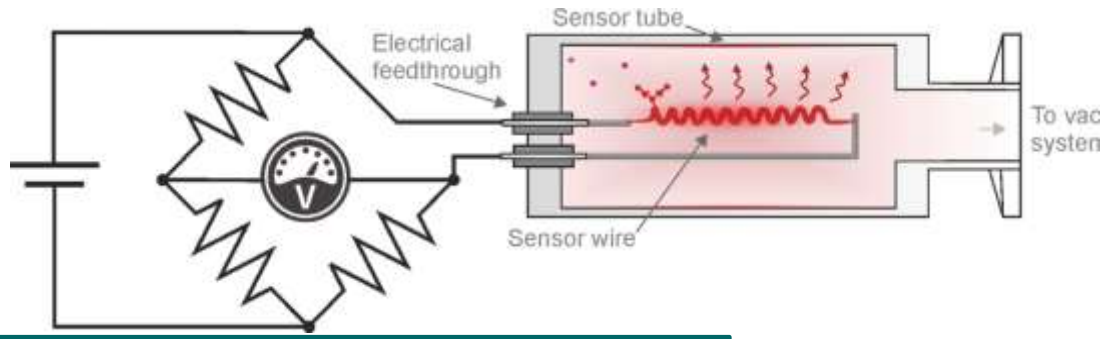


Metal wire heated by current ->
Change of pressure changes heat flow which changes the resistivity and unbalances the Wheatstone bridge.

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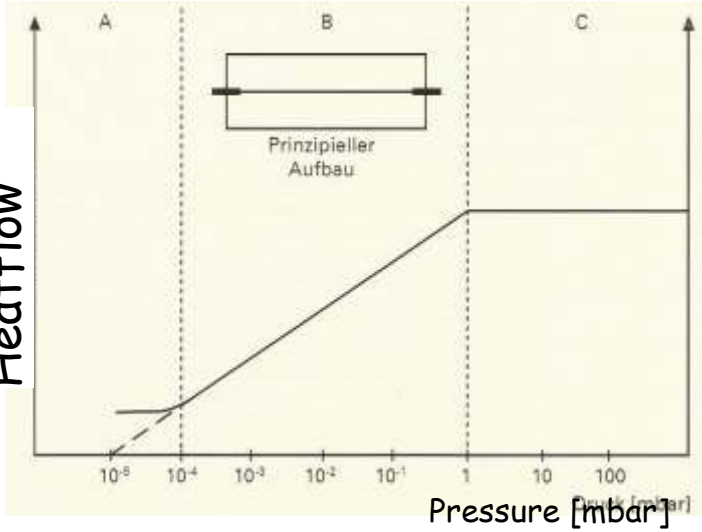


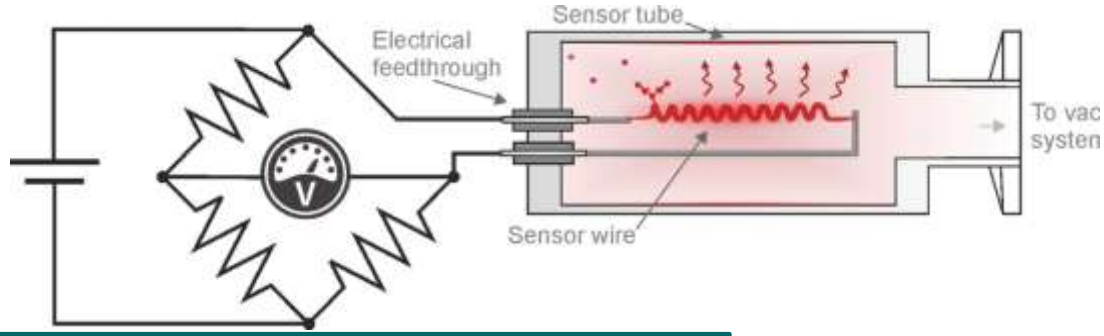


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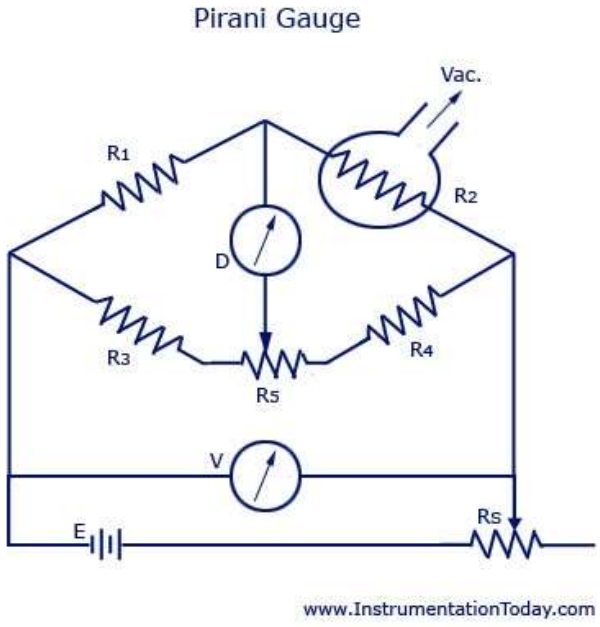

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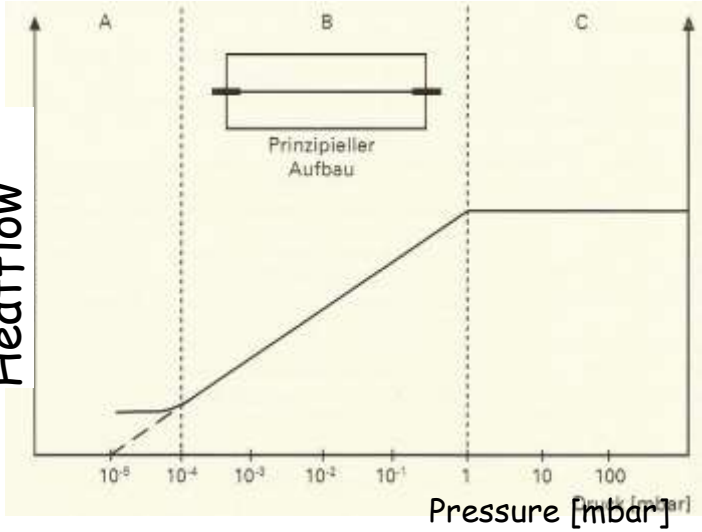


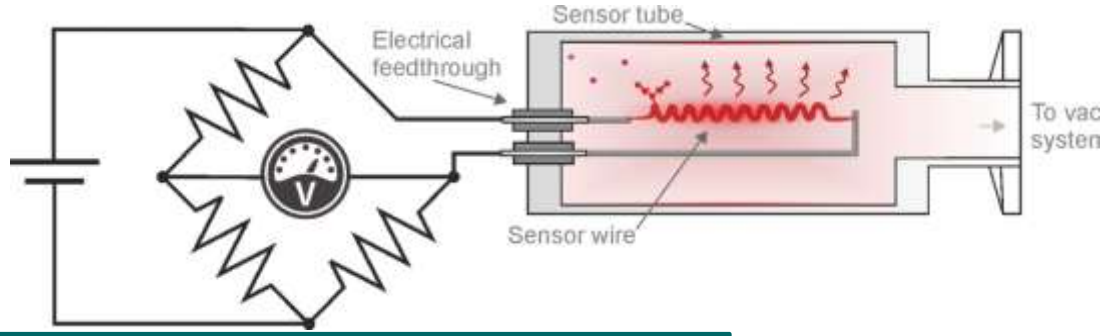


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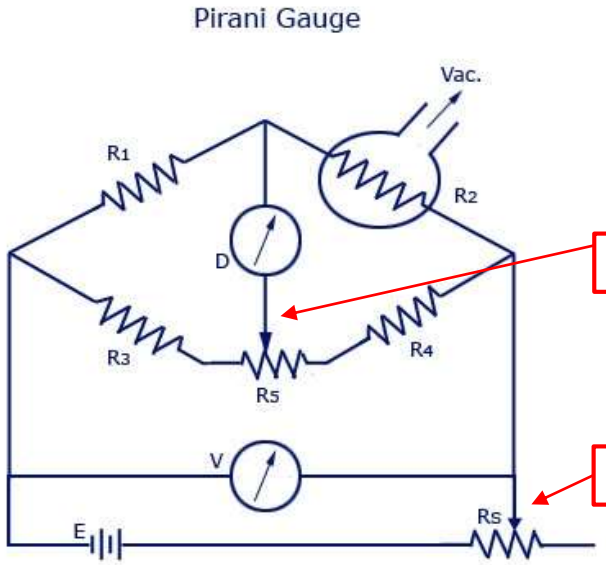


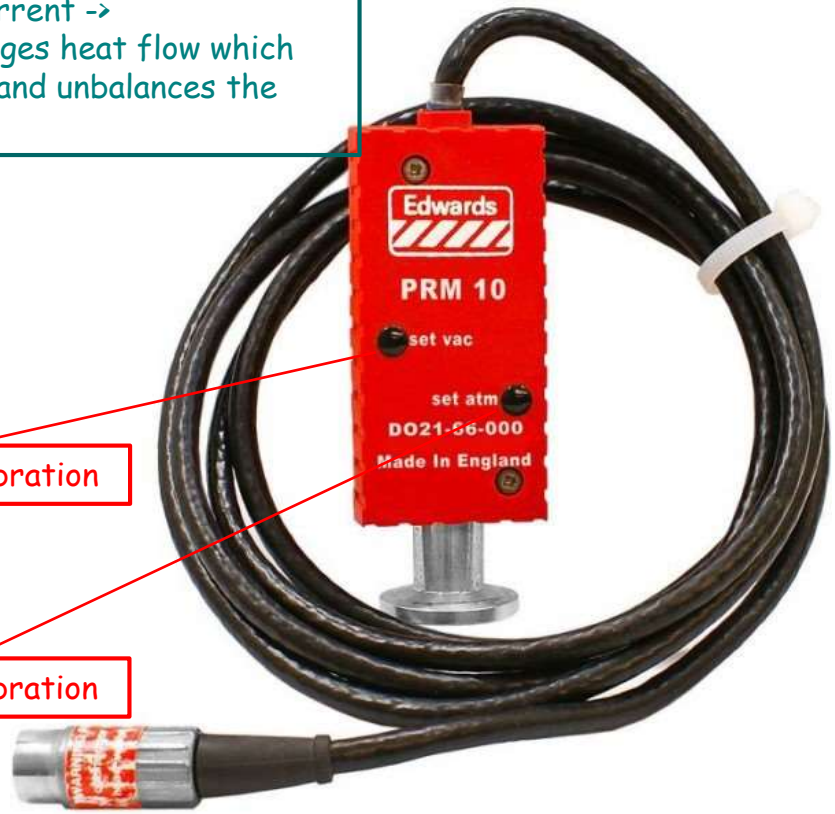

# B: Heat Conduction gauge - Pirani


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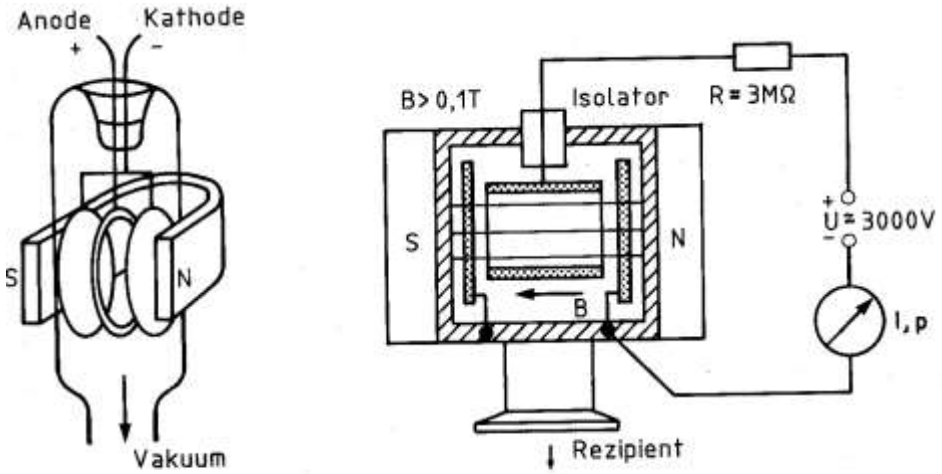
**Sensitive in medium vacuum range**


# B: Cold cathode manometer - Penning

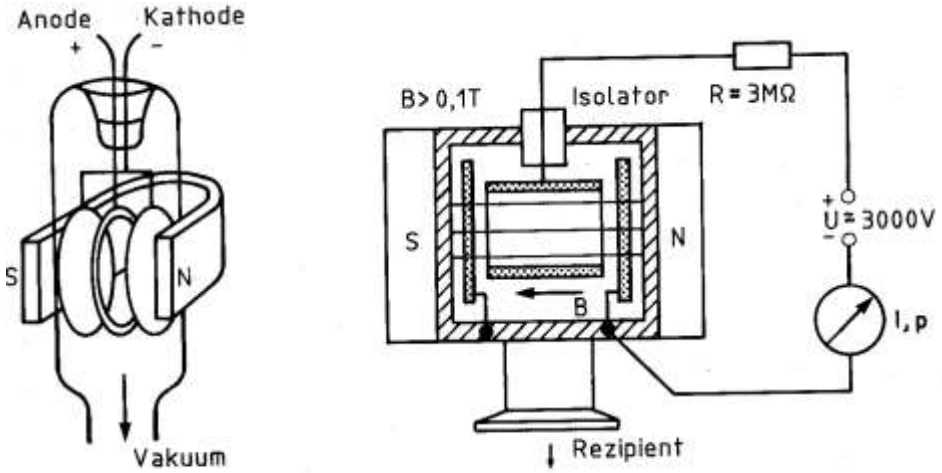
Covers the high vacuum range




Ionisationsvakuummeter mit kalter Kathode nach Penning
a) Glasausführung mit Anodenring
b) Ganzmetallausführung mit Anodenzylinder

# B: Cold cathode manometer - Penning

## Covers the high vacuum range

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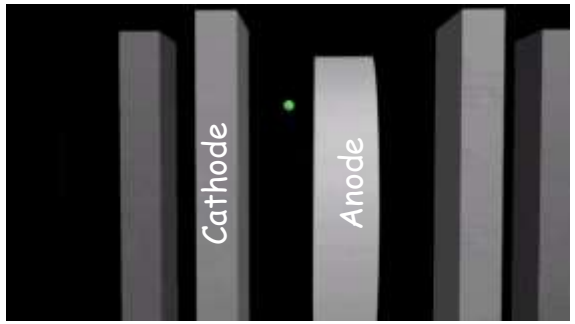
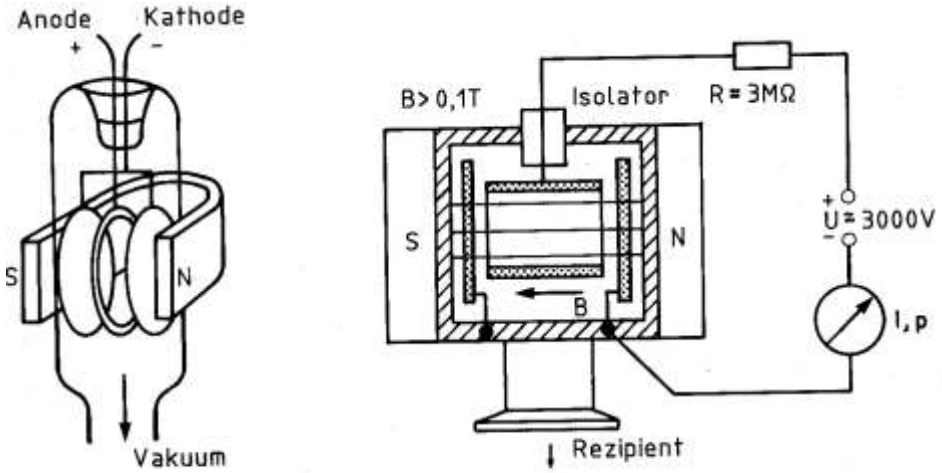


# B: Cold cathode manometer - Penning

Covers the high vacuum range

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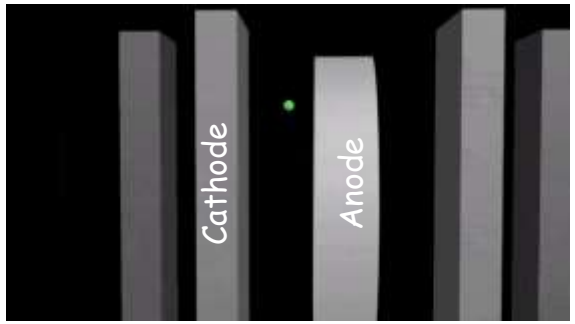
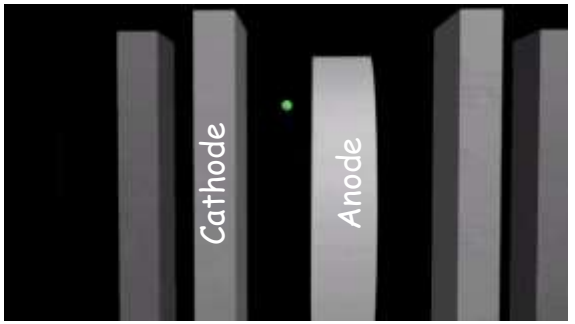
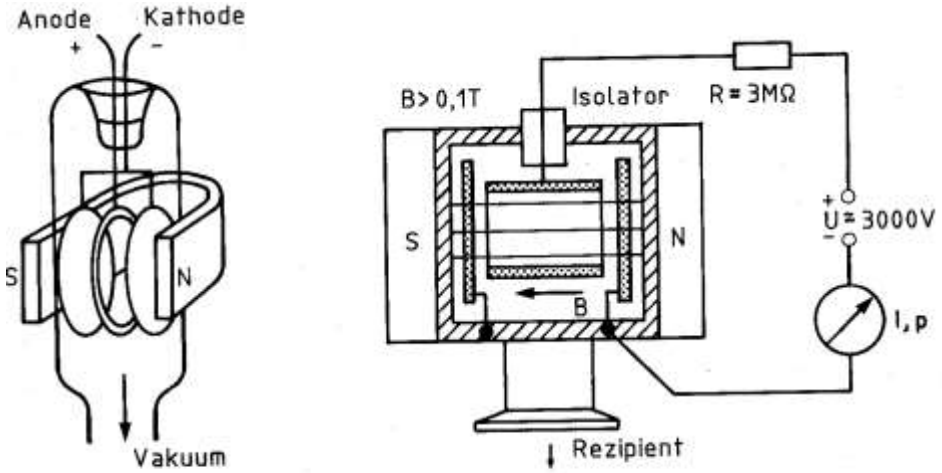



Probability for electron impact ionization in HV becomes very low => confinement of electrons in a magnetic field! Large MFP!

# B: Cold cathode manometer - Penning

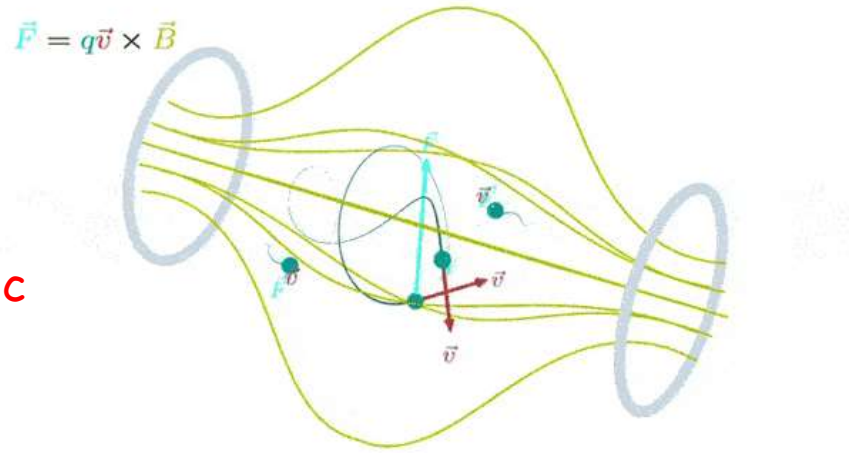
Covers the high vacuum range




Ionisationsvakuummeter mit kalter Kathode nach Penning
a) Glasausführung mit Anodenring
b) Ganzmetallausführung mit Anodenzylinder

Probability for electron impact ionization in HV becomes very low => confinement of electrons in a magnetic field! Large MFP!



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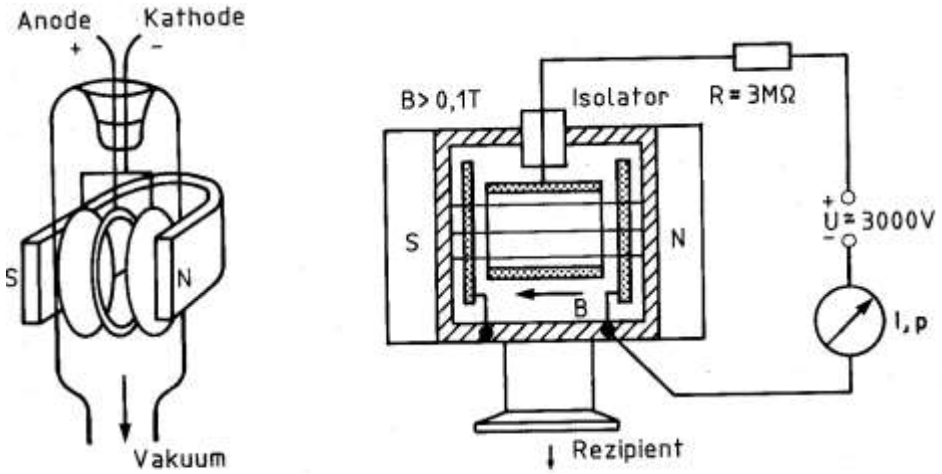


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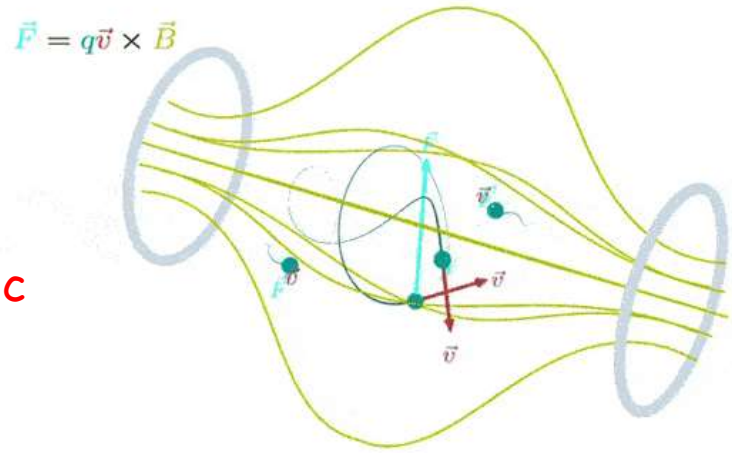
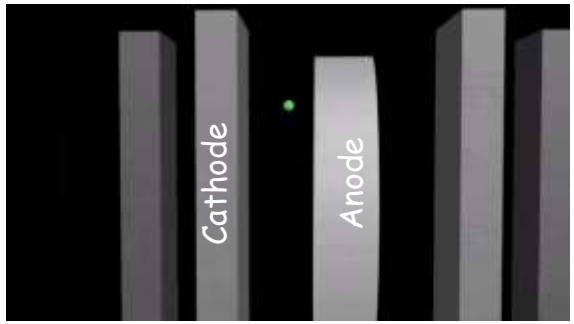
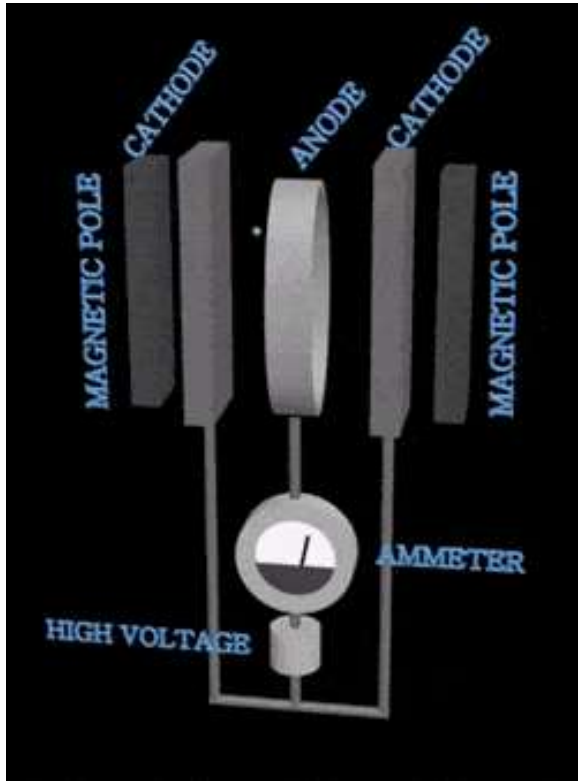


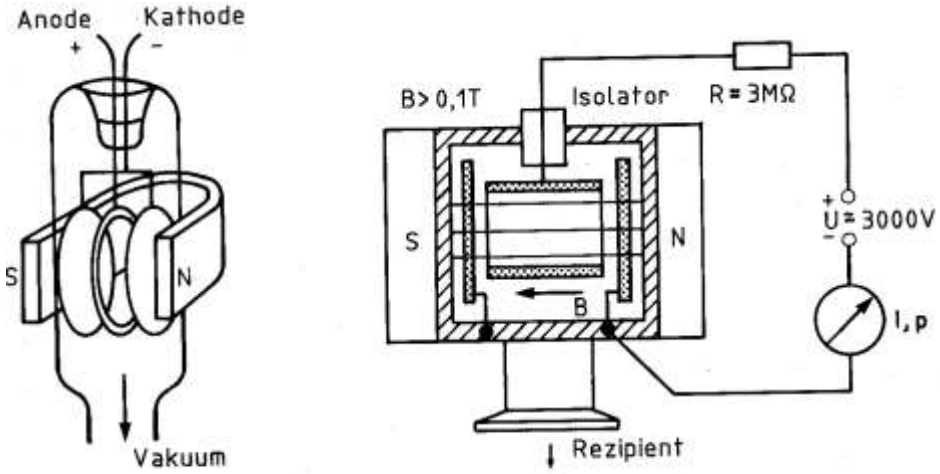




w.youtube.com/watch?v=TG9vtKK-LLw

# B: Cold cathode manometer - Penning

Covers the high vacuum range

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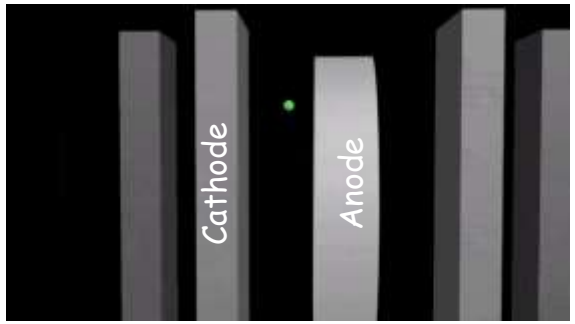


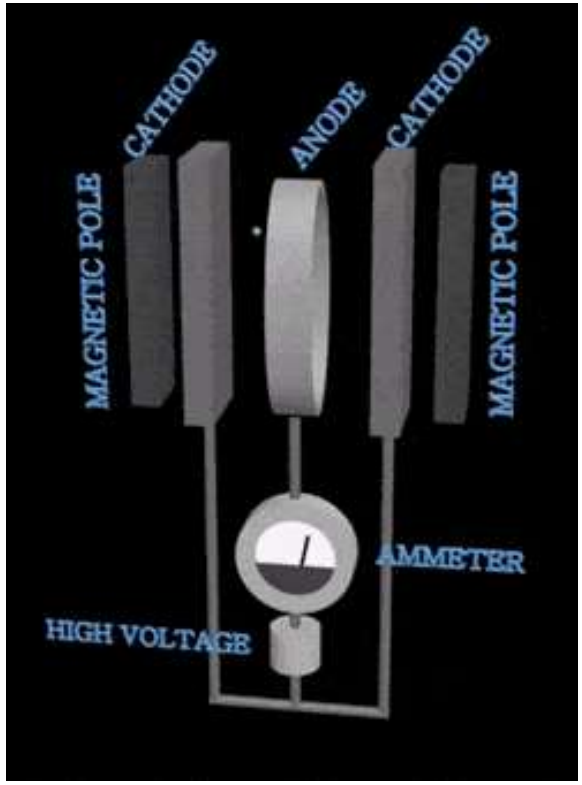


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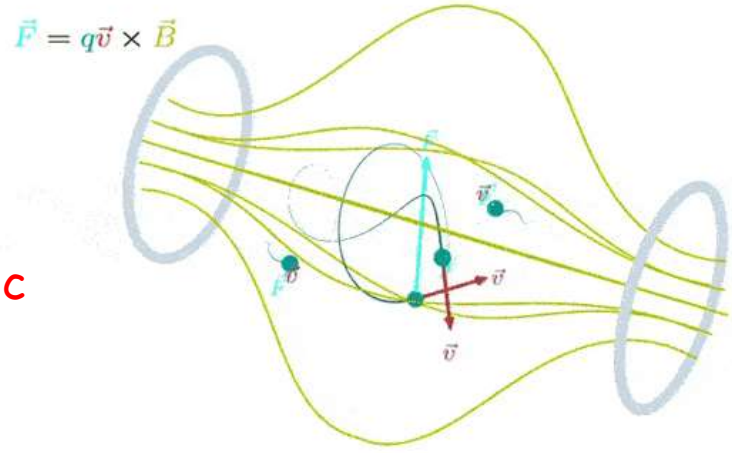
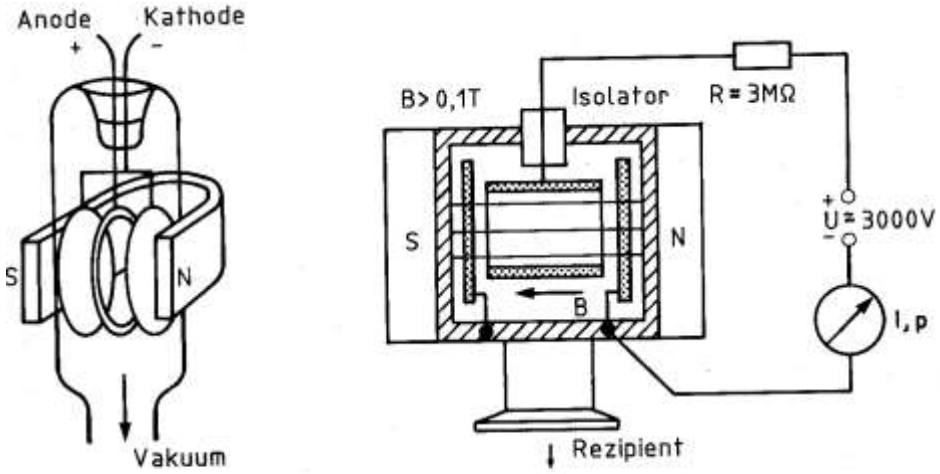



ıw.youtube.com/watch?v=TG9vtKK-LLw

# B: Cold cathode manometer - Penning

## Appears familiar?

Covers the high vacuum range

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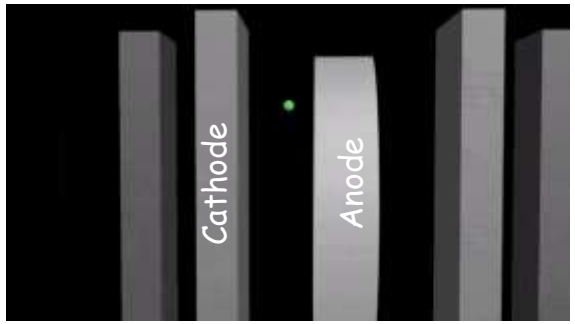


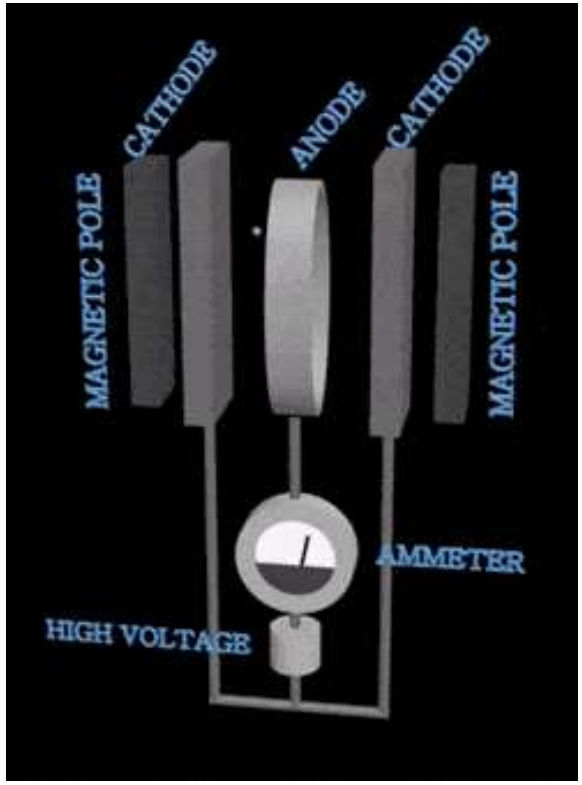


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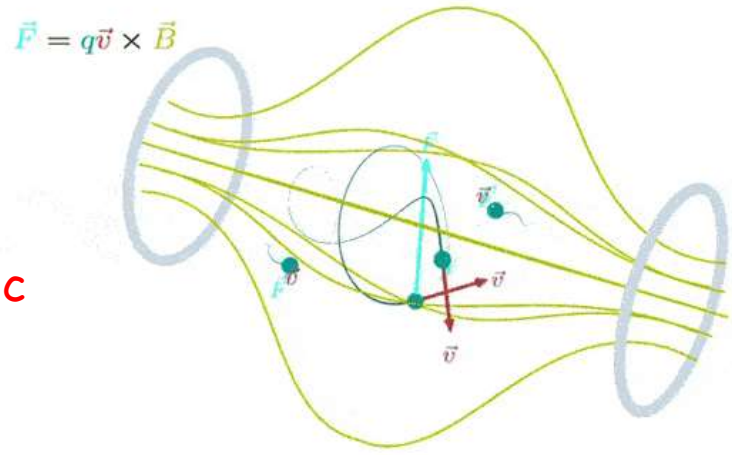



ıw.youtube.com/watch?v=TG9vtKK-LLw

# B: Cold cathode manometer - Penning



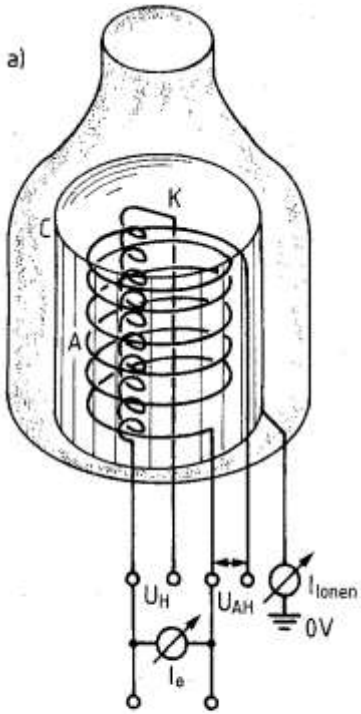
© Artisan Technology Group

# B: Cold cathode manometer - Penning

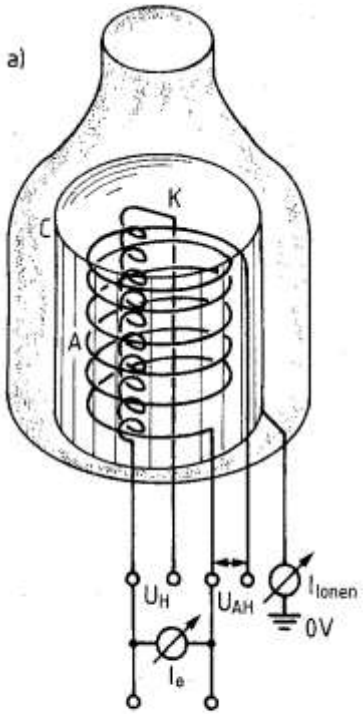

**Applied in high vacuum range**

# B: Hot filament manometer

# B: Hot filament manometer

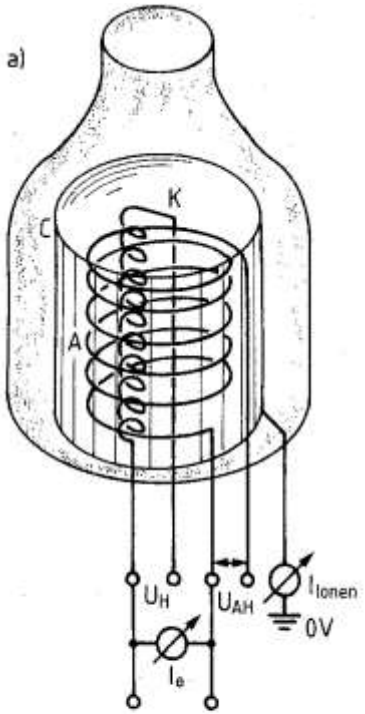


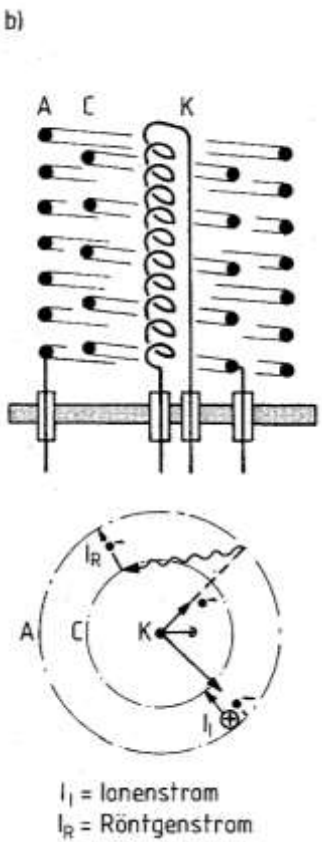
# B: Hot filament manometer




$$P = \text{const.} \cdot I_{ion}/I_{electron}$$

# B: Hot filament manometer

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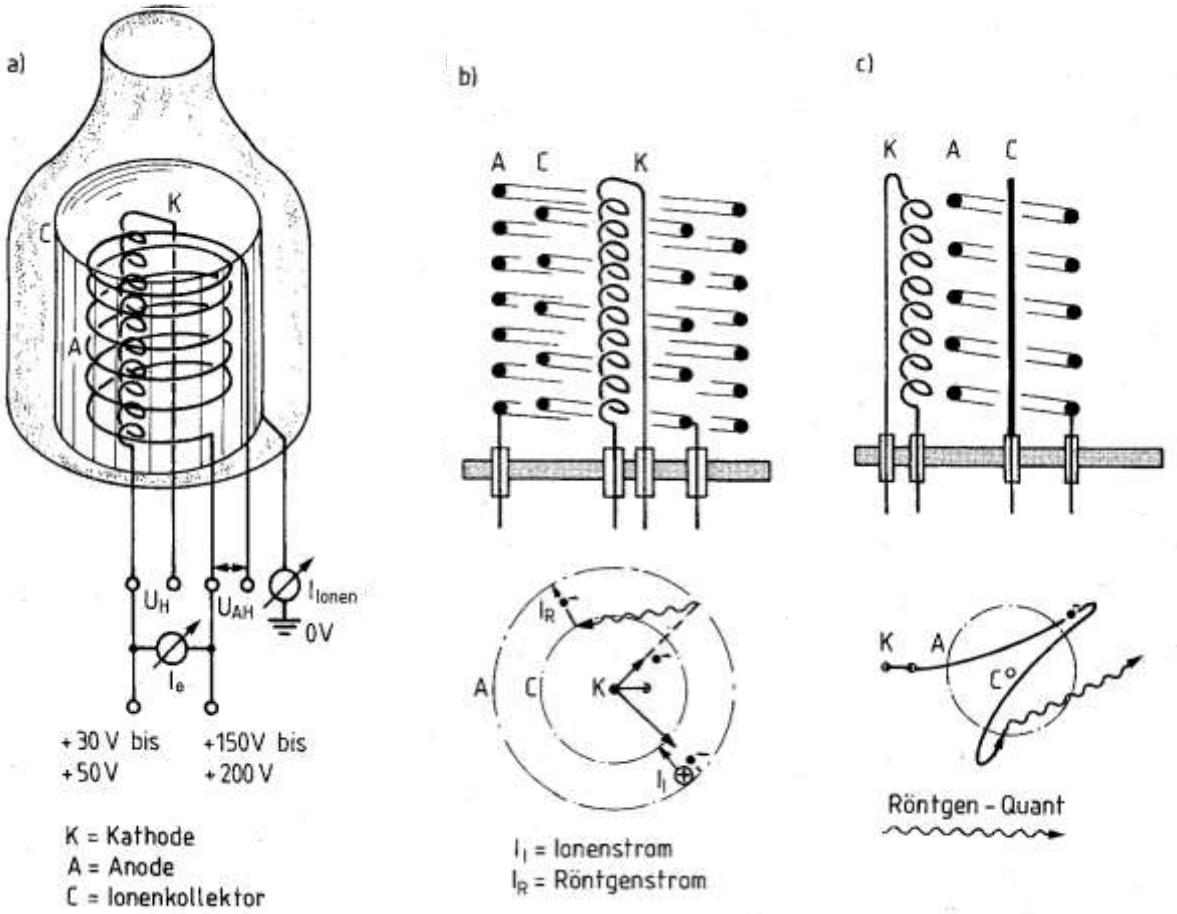


**Abb. 12.8** Glühkathoden-Vakuummeter
a) Einfache Meßröhre (Glas)
b) Hoch- und Feinvakuum-Meßröhre (Eintauchsystem)
c) Bayard-Alpert Meßröhre (HV u. UHV) (Eintauchsystem)

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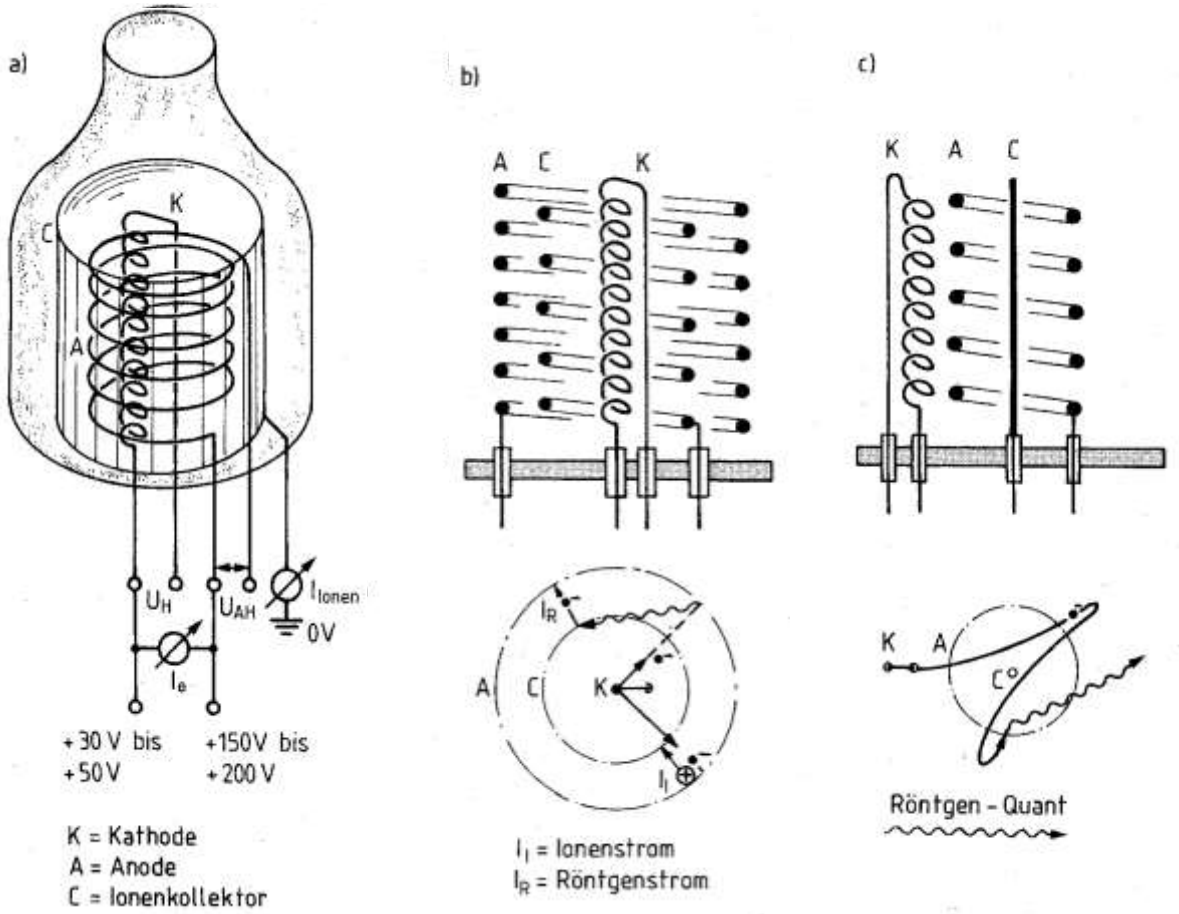


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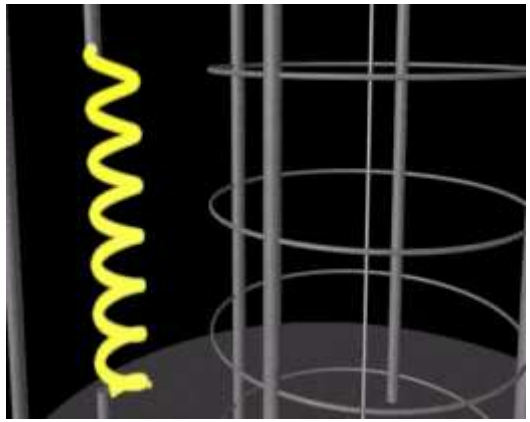

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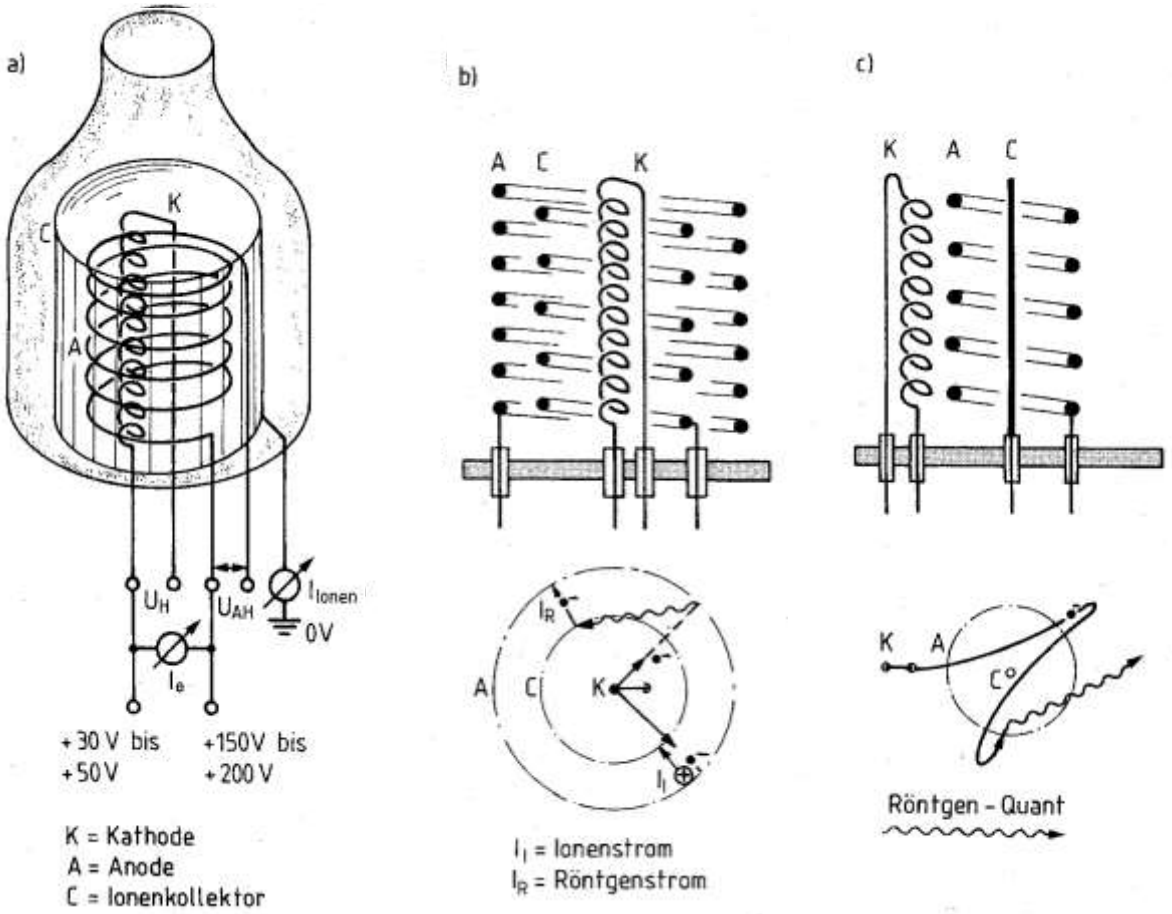


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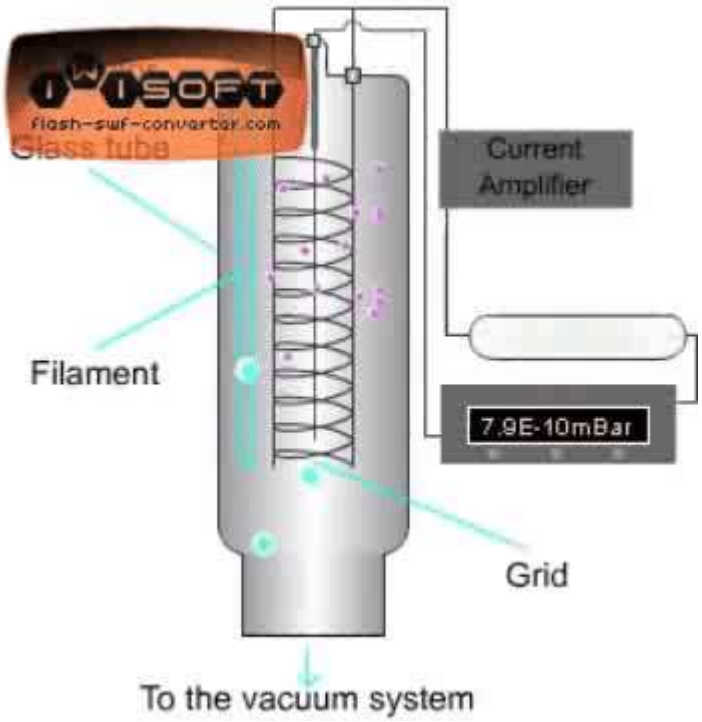


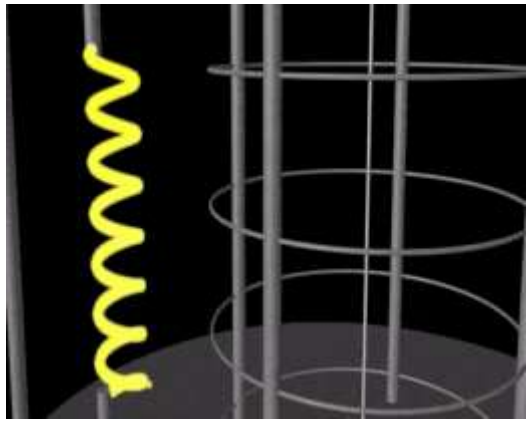

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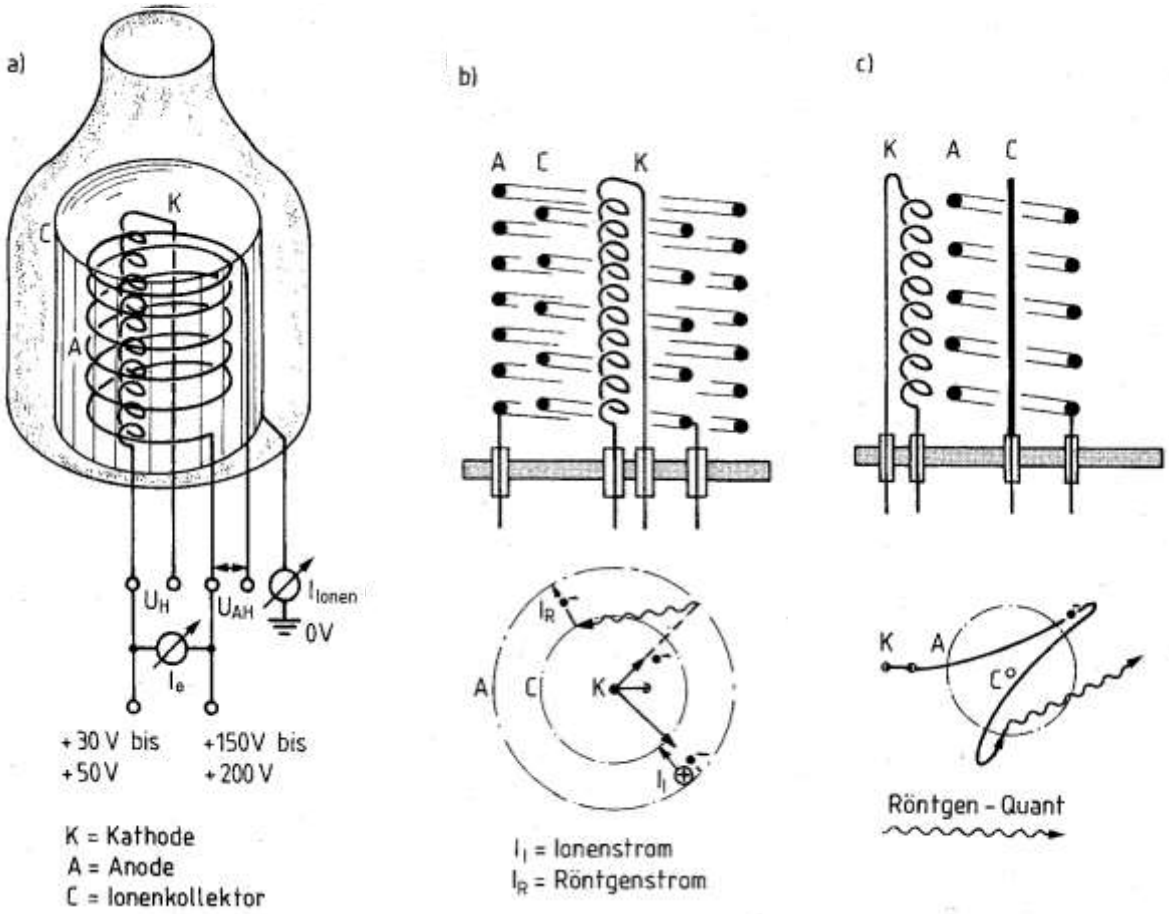


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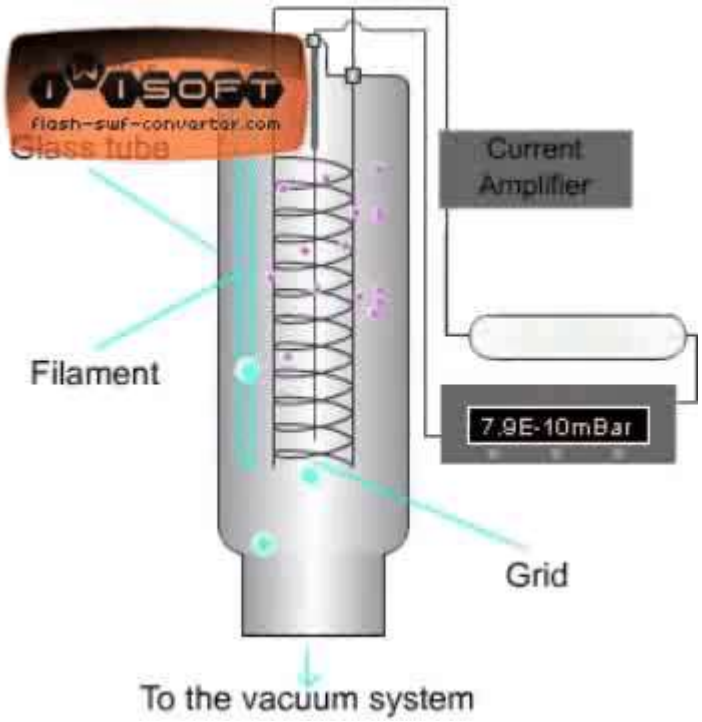


Covers
$10^{-3}$ – $10^{-8}$ mBar
using Bayard-Alpert setup
$10^{-3}$ – $10^{-12}$ mBar

https://www.youtube.com/watch?v=ls6kfQLQWPk
https://www.youtube.com/watch?v=IKKuWeEShM4
https://www.youtube.com/watch?v=RiwCD1TqIIA
https://www.youtube.com/watch?v=6zv_Y0_vwsg

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# B: Control unit


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# 5. Vacuum measurement



## 5.1. Pressure measurement

A: Direct or absolute pressure measurement
= Force / Surface area

!! Independent of the specific gas

- Mechanical: Bending device
- Electrical: Baratron

B: Indirect pressure measurement
= Utilization of density dependent properties
-Heat conductivity
-Ionization probability
-Conductivity

- Pirani
- Penning
- Hot cathode

# 5. Vacuum measurement

"VT L013 ^e 10:43

5.2 Gas flow

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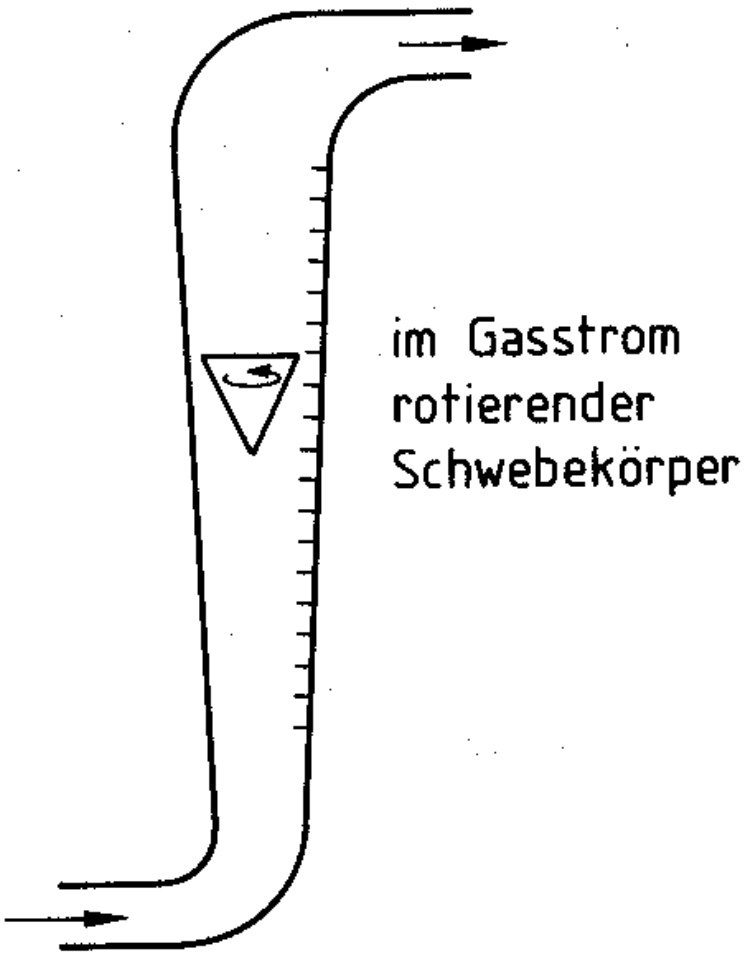
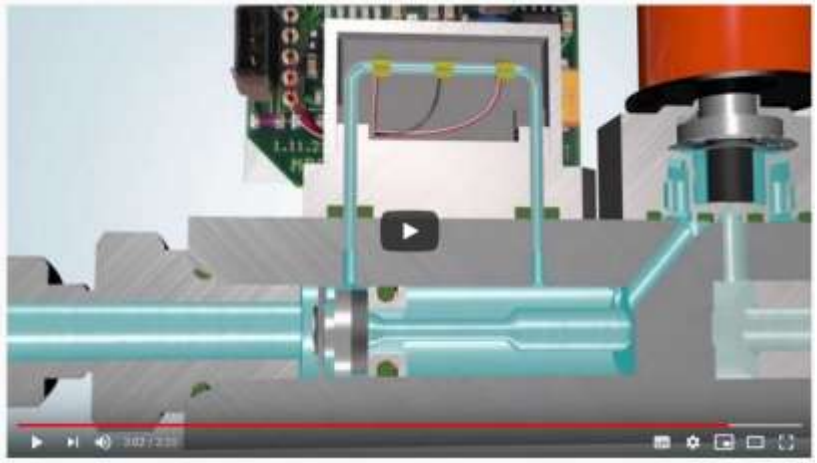
# Gas flow measurement (mechanical)





https://www.youtube.com/watch?v=Pz-Mvdc6nf4

# Gas flow measurement (electronical)



https://www.youtube.com/watch?v=G62ma2IFh9o
https://www.youtube.com/watch?v=nPOzuGIblcc

# Gas flow measurement (electronical)

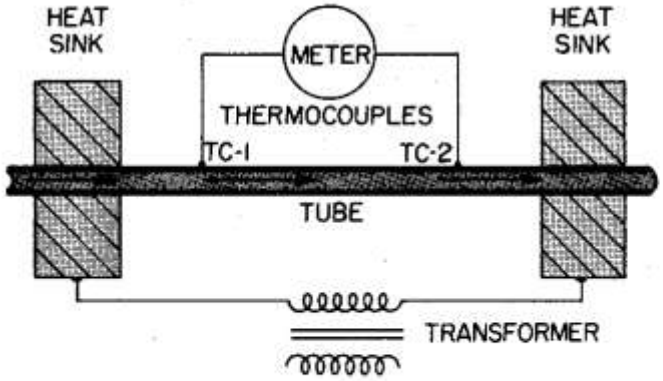
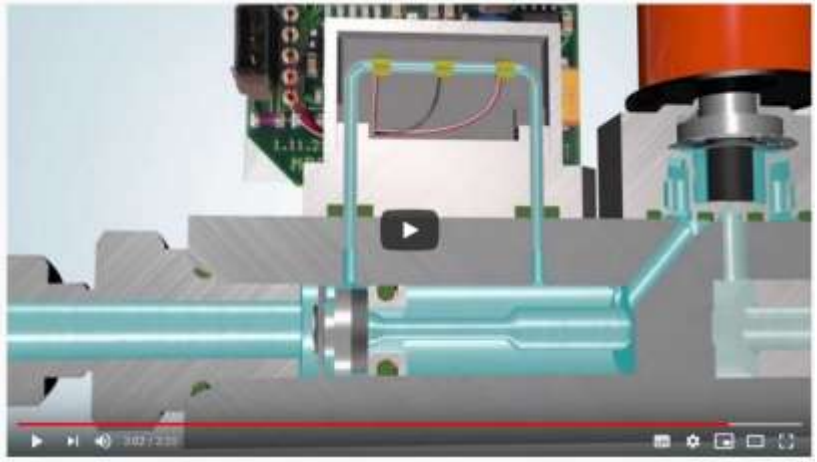



Fig. 9.15. Schematic of a heated tube thermal flowmeter: principle.



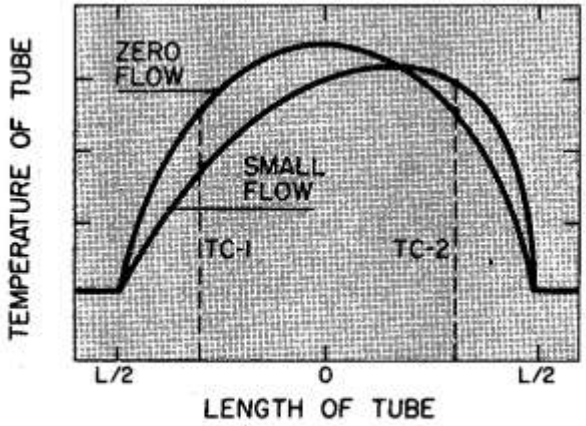



Fig. 9.16. Temperature equilibrium in a thermal flowmeter: principle.

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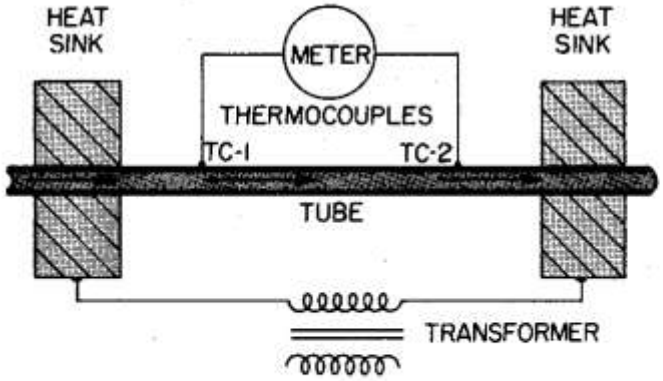


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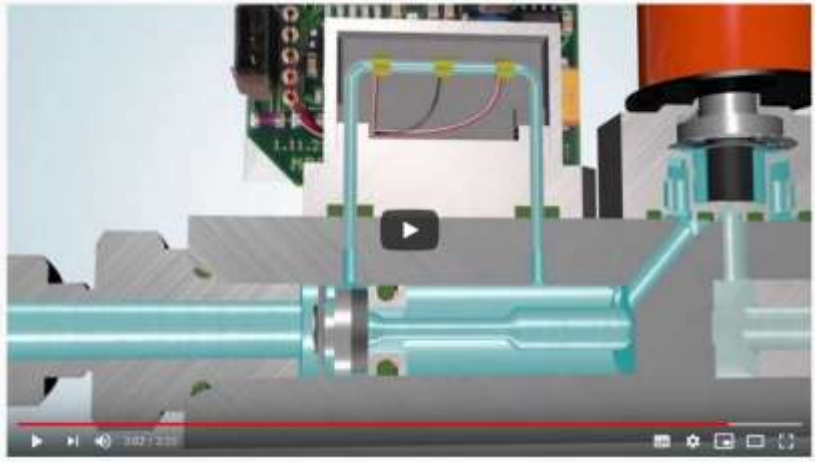

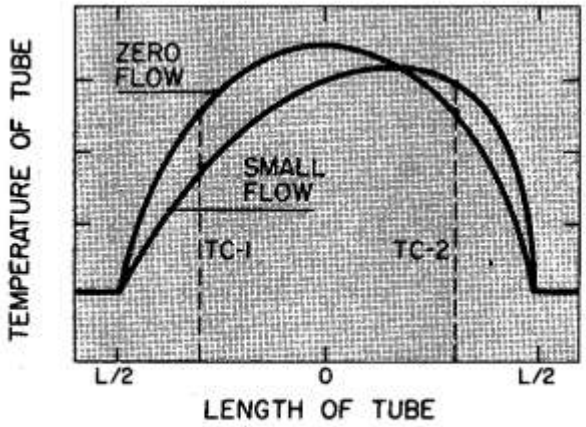


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# 5. Vacuum measurement

5.2 Gas flow

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- Pirani
- Penning
- Hot cathode

# 5. Vacuum measurement

5.2 Gas flow

5.1. Pressure measurement

5.3 Partial pressure

A: Direct or absolute pressure measurement
= Force / Surface area

!! Independent of the specific gas

Mechanical:
Bending device

Electrical:
Baratron

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= Utilization of density dependent properties
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»Wissen schafft Brücken.«