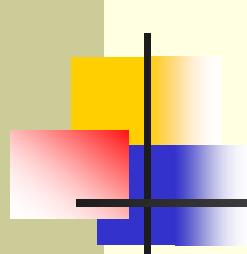


# TECNOLOGIA DE VÁCUO : MET

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## INTRODUÇÃO



# TECNOLOGIA DE VÁCUO : MET



**Vácuo** é uma palavra de origem grega que significa **vazio**

**Vácuo** é qualquer ambiente com pressão **inferior à atmosférica**

## Unidades de Pressão

**1atm** = 760 mm Hg = 760 Torr = 1,01325 bar = 101.325 Pa

1 atm = 10,33 m H<sub>2</sub>O

**Bar** é um múltiplo da Bária: 1 bar =  $10^6$  bárias

Bária: unidade de pressão no C.G.S (1 bária = dyn/cm<sup>2</sup>)

# TECNOLOGIA DE VÁCUO : MET



Por que não há vácuo absoluto?

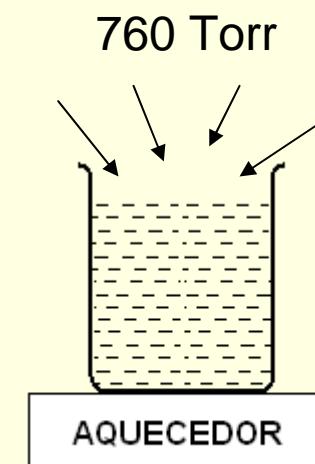
## PRESSÃO DE VAPOR

**Pressão de Vapor** ( $p^*$ ) é a pressão exercida por um vapor quando este está em equilíbrio com o líquido ou sólido que lhe deu origem a uma dada temperatura.

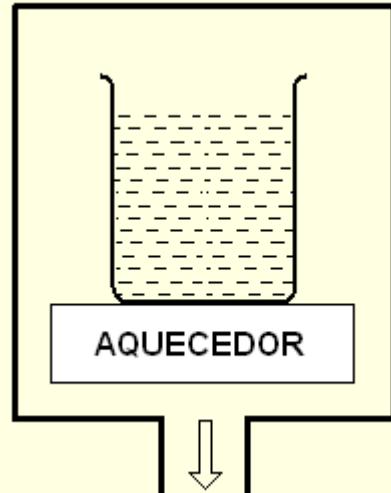
Água a 20 °C  $\Rightarrow$   $p^* = 17,5 \text{ mm Hg} = 17,5 \text{ Torr}$

Água a 60 °C  $\Rightarrow$   $p^* = 150,4 \text{ mm Hg} = 150,4 \text{ Torr}$

Água a 100 °C  $\Rightarrow$   $p^* = 1 \text{ atm} = 760 \text{ Torr}$



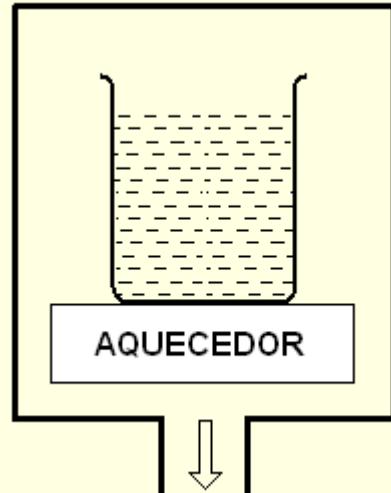
# TECNOLOGIA DE VÁCUO : MET



Água a 20 °C

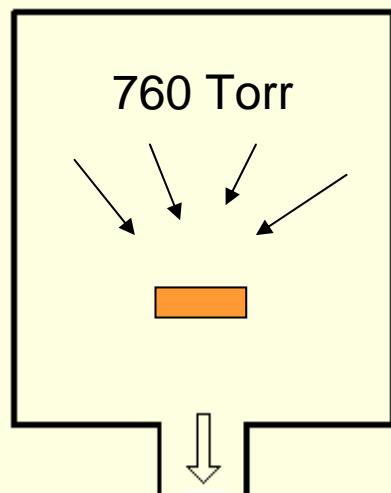
$p^* = 17,5 \text{ mm Hg} = 17,5 \text{ Torr}$

# TECNOLOGIA DE VÁCUO : MET



Água a 20 °C

$$p^* = 17,5 \text{ mm Hg} = 17,5 \text{ Torr}$$



Zinco a 20 °C

$$p^* = 9,76 \times 10^{-13} \text{ mm Hg} = 9,76 \times 10^{-13} \text{ Torr}$$

Alumínio a 20 °C

$$p^* = 5,37 \times 10^{-29} \text{ mm Hg} = 5,37 \times 10^{-29} \text{ Torr}$$

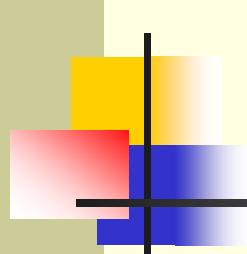
# TECNOLOGIA DE VÁCUO : MET



Por que não há vácuo absoluto?

Temperatura (°C) para Pressões de Vapor (Torr)

Elemento	$10^{-8}$	$10^{-7}$	$10^{-6}$	$10^{-5}$	$10^{-4}$	$10^{-3}$	$10^{-2}$	$10^{-1}$	$10^0$
Ag	574	626	685	752	832	922	1027	1162	1322
Al	685	742	812	887	972	1082	1217	1367	1557
Au	807	877	947	1032	1132	1252	1397	1567	1767
Cu	722	787	852	937	1027	1132	1257	1417	1617
Mo	1592	1702	1822	1957	2117	2307	2527	2787	3117
Ta	1957	2097	2237	2407	2587	2807	3057	3357	3707
Ti	1062	1137	1227	1327	1442	1577	1737	1937	2177
W	2117	2247	2407	2567	2757	2977	3227	3537	3917
Zn	123	147	177	209	247	292	344	408	487



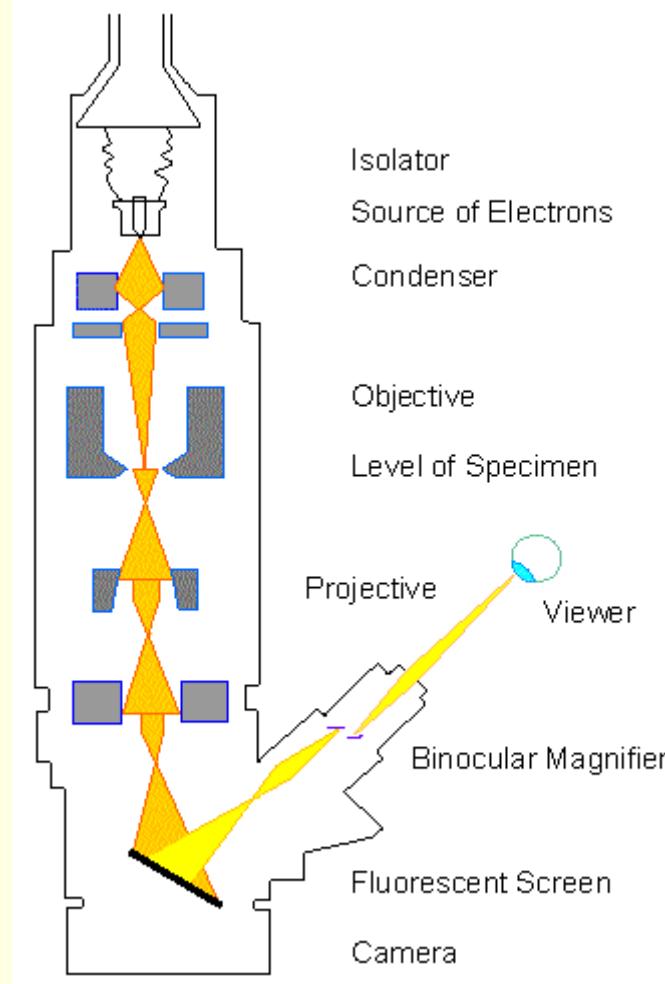
# TECNOLOGIA DE VÁCUO : MET

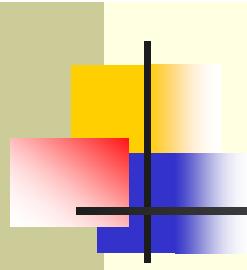


## Faixas de Vácuo

Descrição	Faixa
Baixo vácuo	760 a 25 Torr
Médio vácuo	25 a $10^{-3}$ Torr
Alto vácuo	$10^{-3}$ Torr a $10^{-6}$ Torr
Altíssimo vácuo	$10^{-6}$ Torr a $10^{-9}$ Torr
Ultra alto vácuo	$10^{-9}$ Torr a $10^{-12}$ Torr
Extremo ultra alto vácuo	$p < 10^{-12}$ Torr

# TECNOLOGIA DE VÁCUO : MET





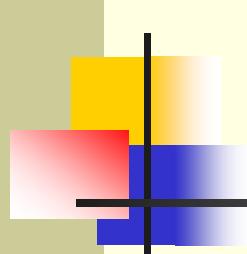
# TECNOLOGIA DE VÁCUO : MET



Por que as colunas em um MET estão em vácuo?

$$\lambda \text{ (cm)} = \frac{5 \times 10^{-3}}{p \text{ (Torr)}}$$

$$\begin{cases} p = 10^{-3} \text{ Torr} \Rightarrow \lambda = 5 \text{ cm} \\ p = 10^{-4} \text{ Torr} \Rightarrow \lambda = 50 \text{ cm} \\ p = 10^{-5} \text{ Torr} \Rightarrow \lambda = 500 \text{ cm} \\ p = 10^{-6} \text{ Torr} \Rightarrow \lambda = 5000 \text{ cm} \end{cases}$$



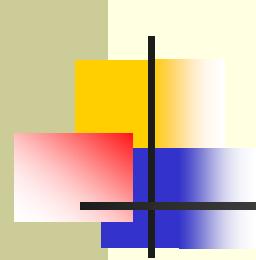
# TECNOLOGIA DE VÁCUO : MET



O nível de vácuo é determinado pelo **tipo de filamento** utilizado:

- Tungstênio  $\Rightarrow 10^{-3}$  Pa ( $7,5 \times 10^{-6}$  Torr)
- Cristal de LaB<sub>6</sub>  $\Rightarrow 10^{-5}$  Pa ( $7,5 \times 10^{-8}$  Torr)
- FEG  $\Rightarrow 10^{-7}$  e  $10^{-8}$  Pa ( $7,5 \times 10^{-10}$  a  $7,5 \times 10^{-11}$  Torr)

**Qualidade do vácuo !**



# TECNOLOGIA DE VÁCUO : MET



## BOMBAS DE VÁCUO

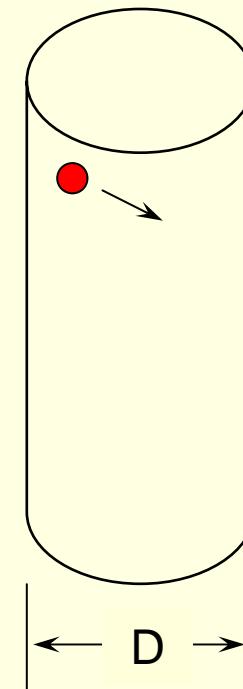


## REGIMES DE ESCOAMENTO

Escoamento Viscoso  $\Rightarrow \lambda \ll D$

Escoamento Intermediário  $\Rightarrow \lambda \approx D$

Escoamento Molecular  $\Rightarrow \lambda \gg D$



# FAIXA DE PRESSÃO DAS BOMBAS DE VÁCUO



BOMBAS DE JATO



BOMBAS MECÂNICAS



BOMBAS ROOTS



BOMBAS DE SORÇÃO



BOMBAS TURBOMOLECULARES



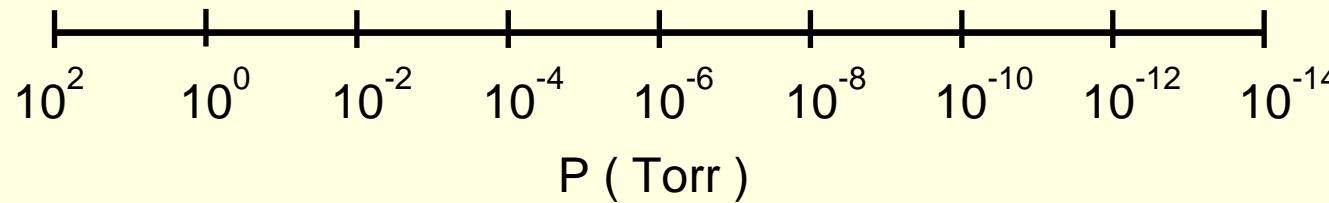
BOMBAS DE DIFUSÃO



BOMBAS IÔNICAS



BOMBAS CRIOGÊNICAS





# MECÂNICAS SELADAS A ÓLEO



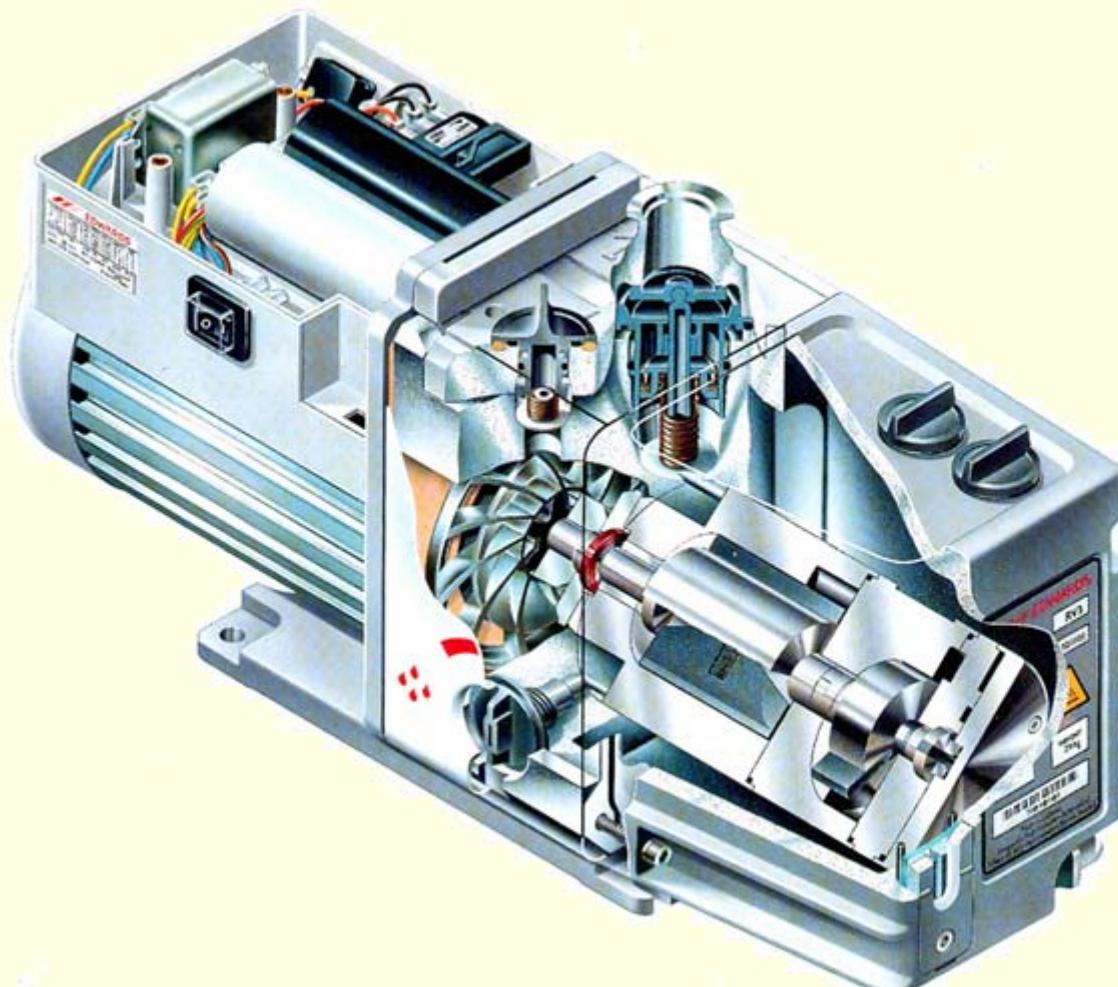


# MECÂNICAS SELADAS A ÓLEO



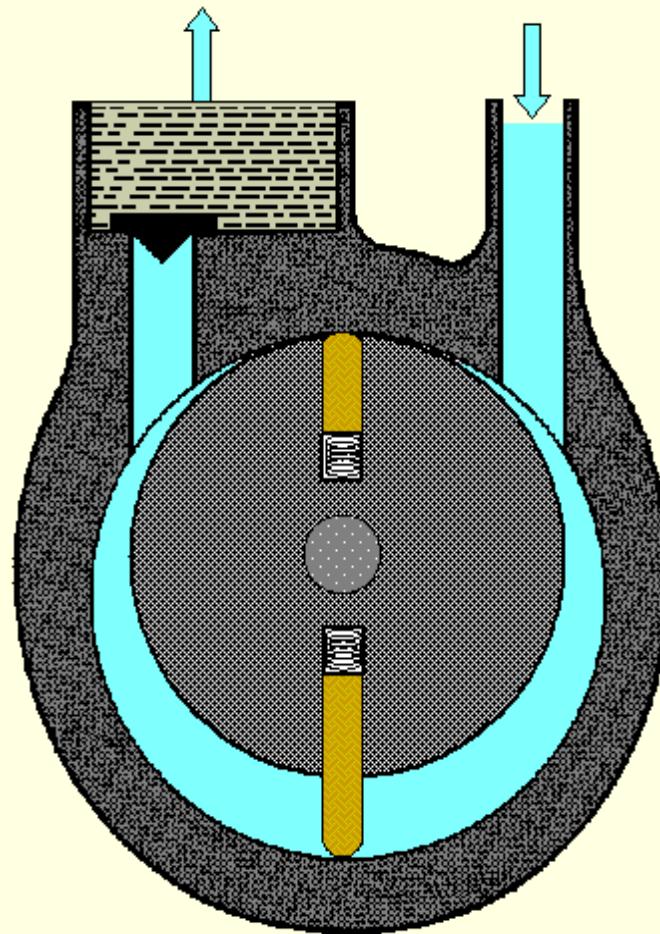


# MECÂNICA SELADA A ÓLEO



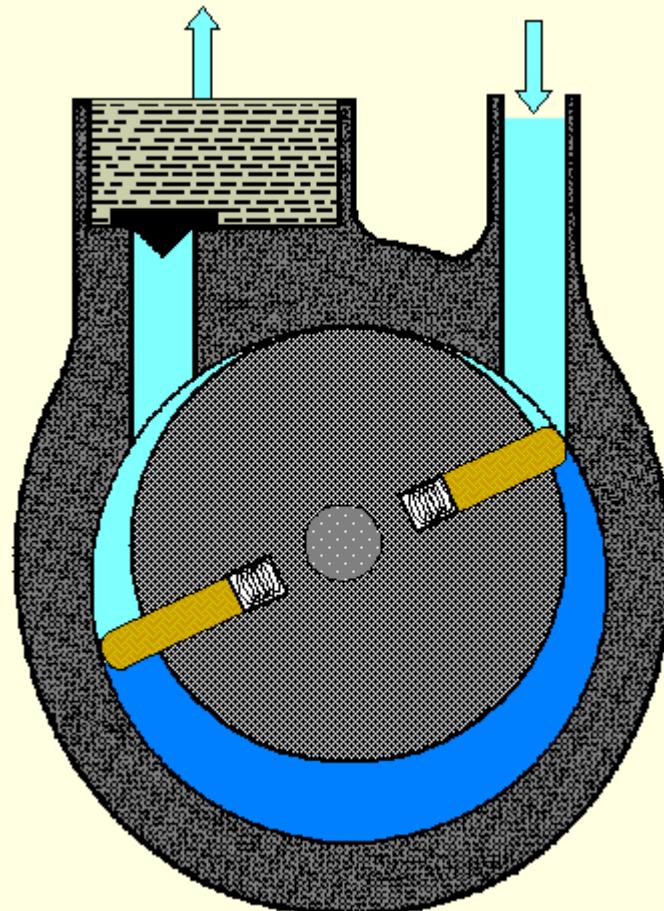


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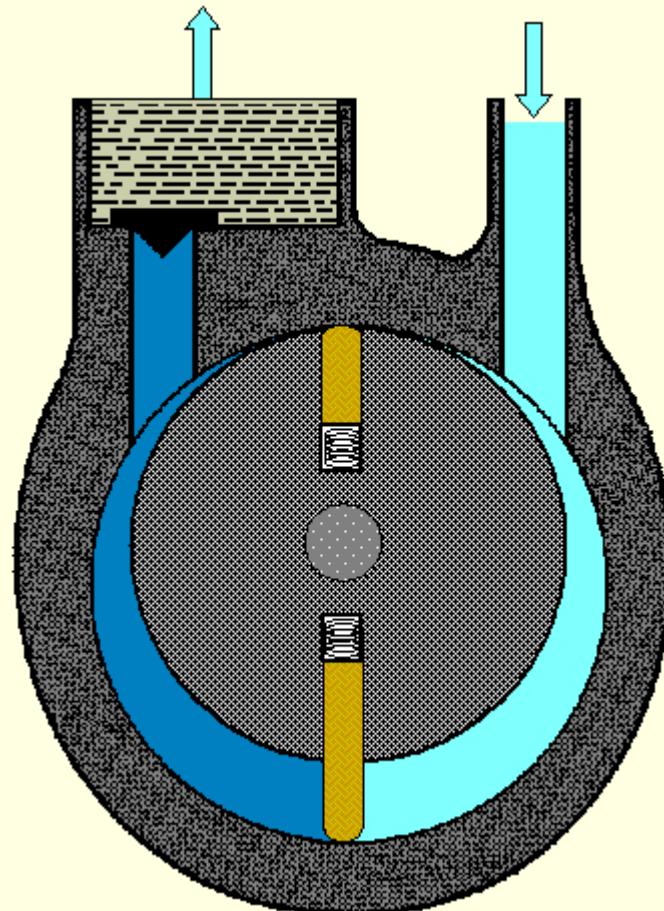


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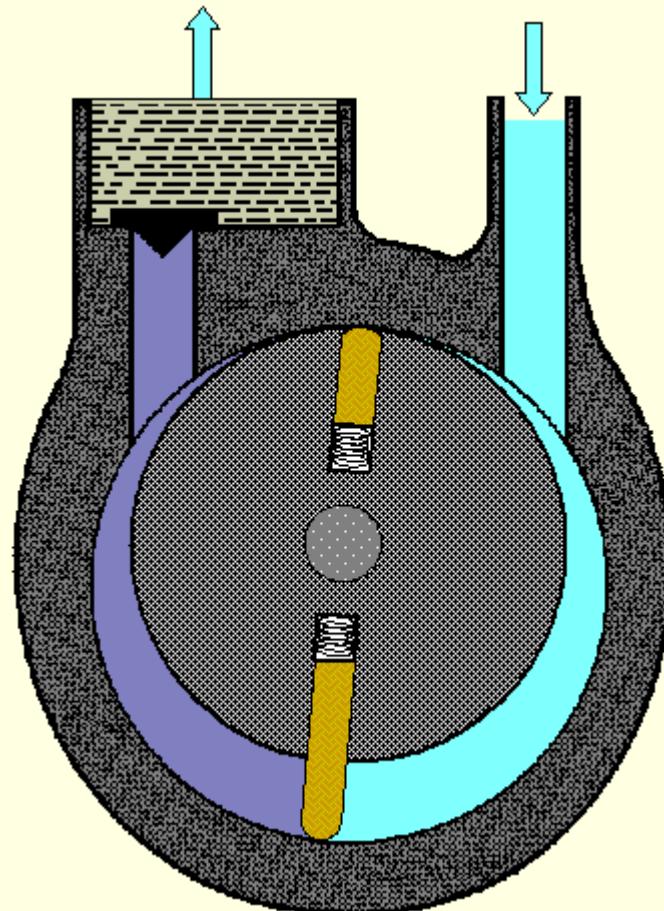


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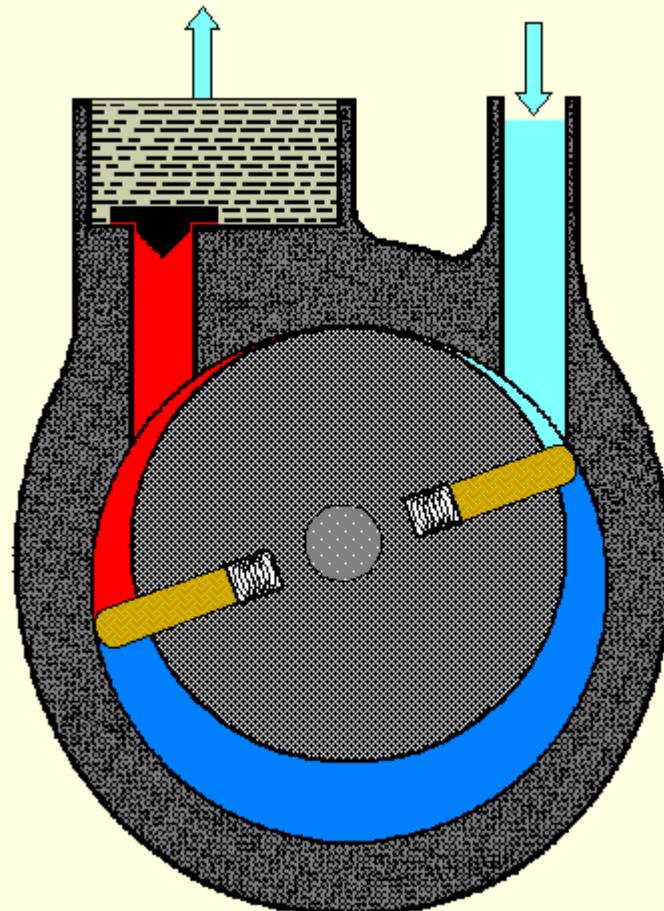


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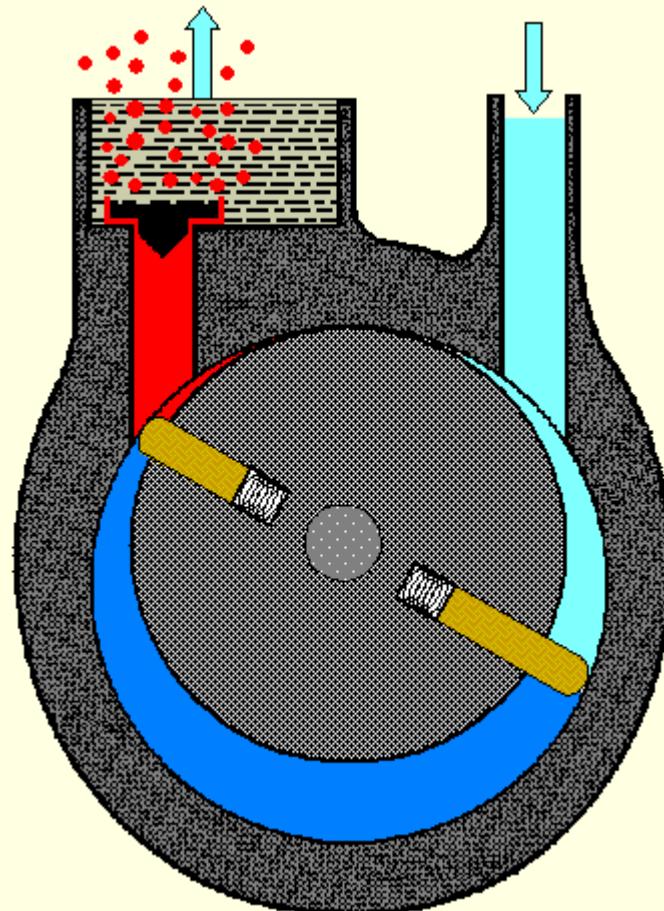


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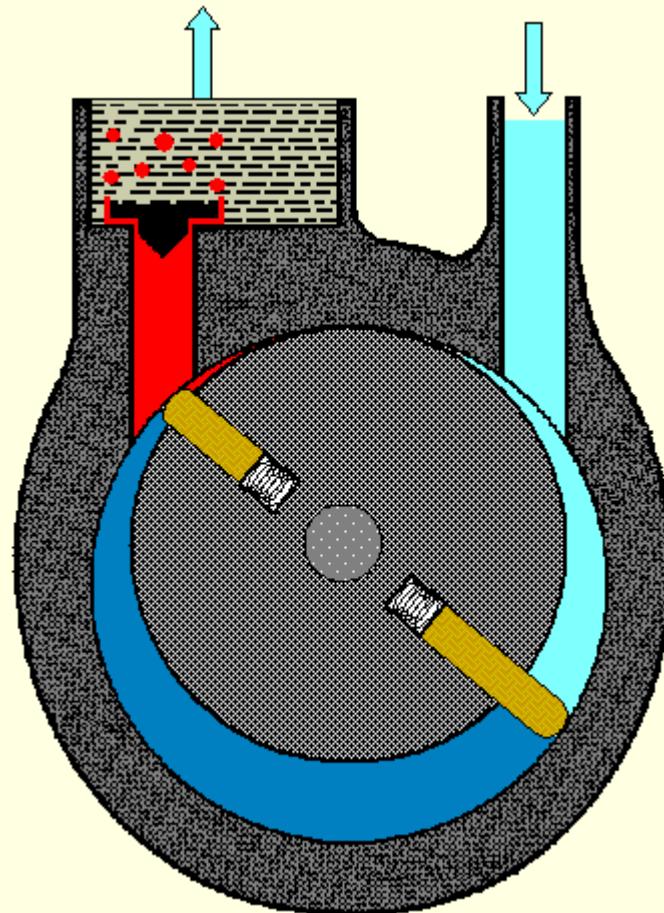


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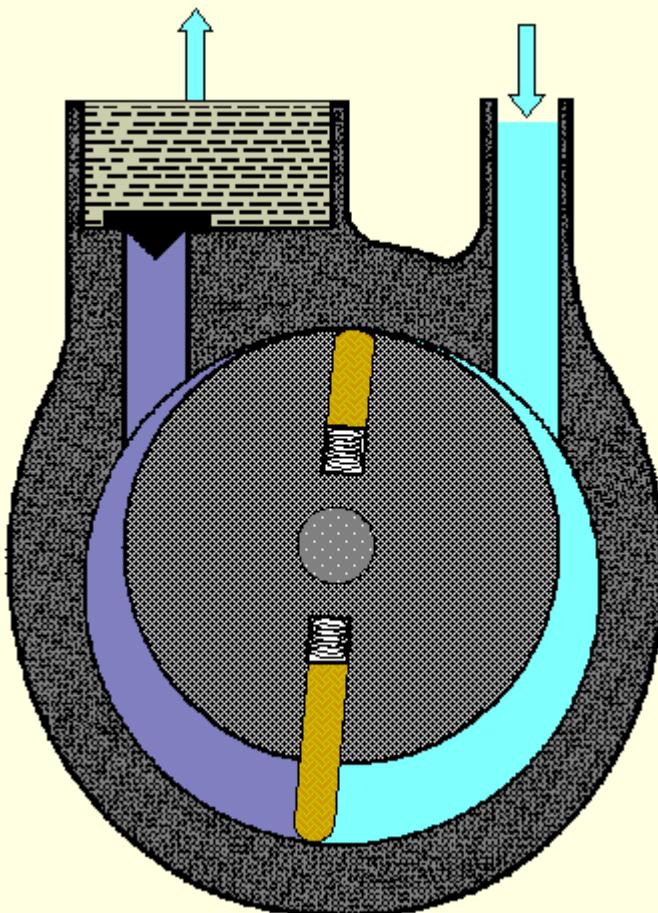


# MECÂNICA SELADA A ÓLEO





# MECÂNICA SELADA A ÓLEO

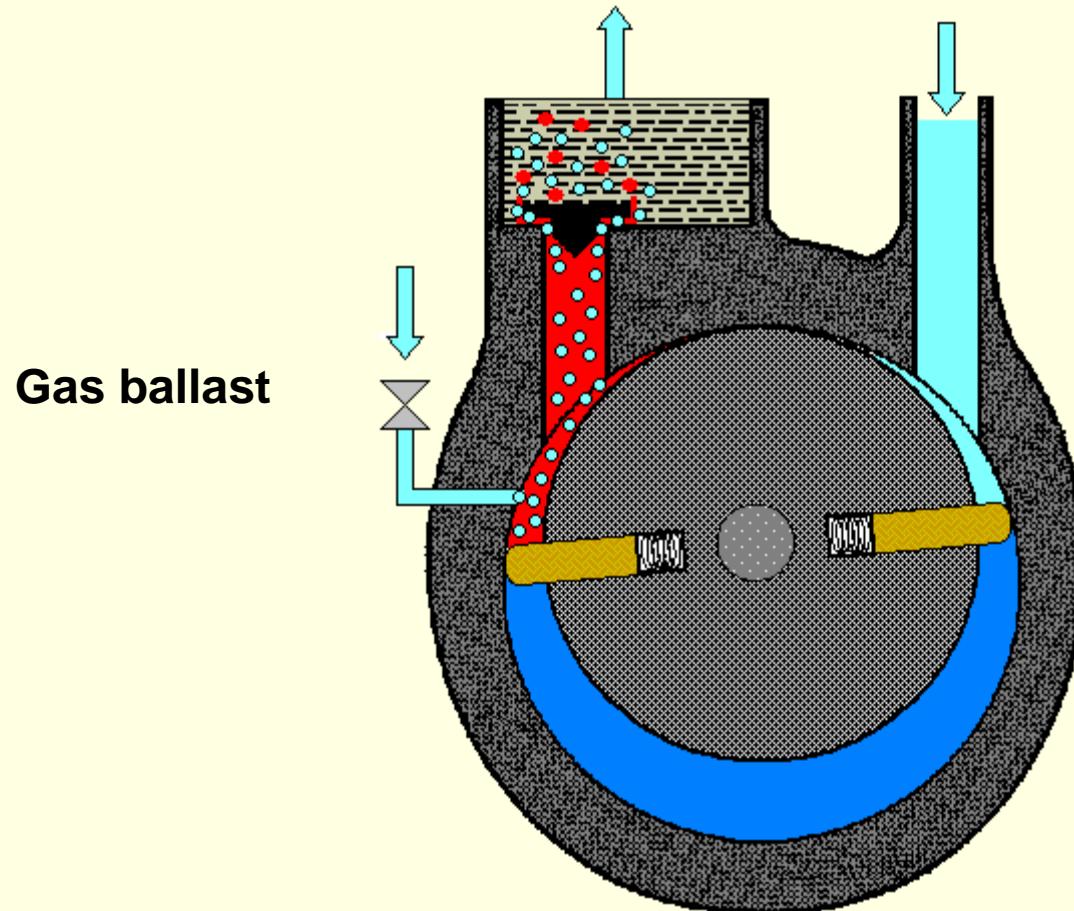


$$p_{\text{H}_2\text{O}}^* (20^\circ\text{C}) = 23,3 \text{ mbar}$$

$$p_{\text{H}_2\text{O}}^* (60^\circ\text{C}) = 200,0 \text{ mbar}$$

$$\frac{200,0 \text{ mbar}}{23,3 \text{ mbar}} = 8,6$$

# MECÂNICA SELADA A ÓLEO



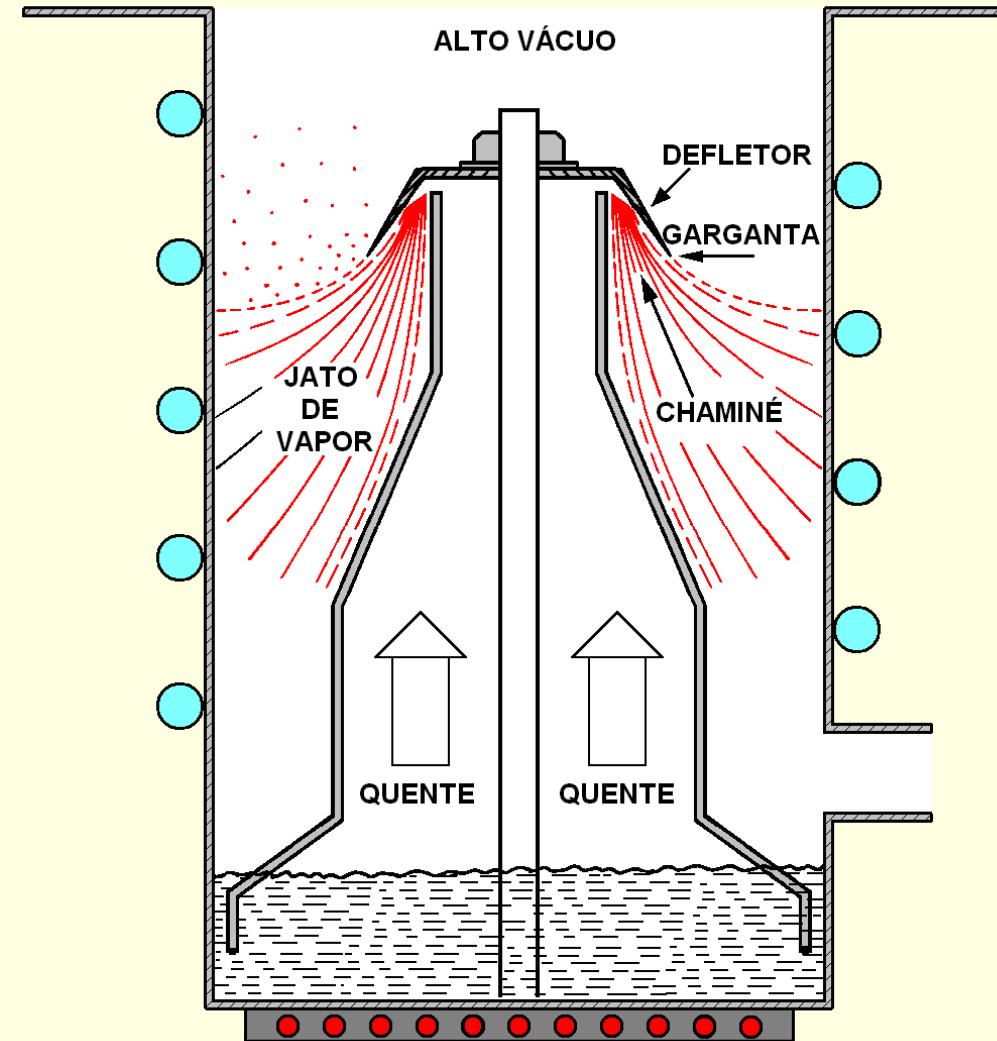


# BOMBAS DE DIFUSÃO



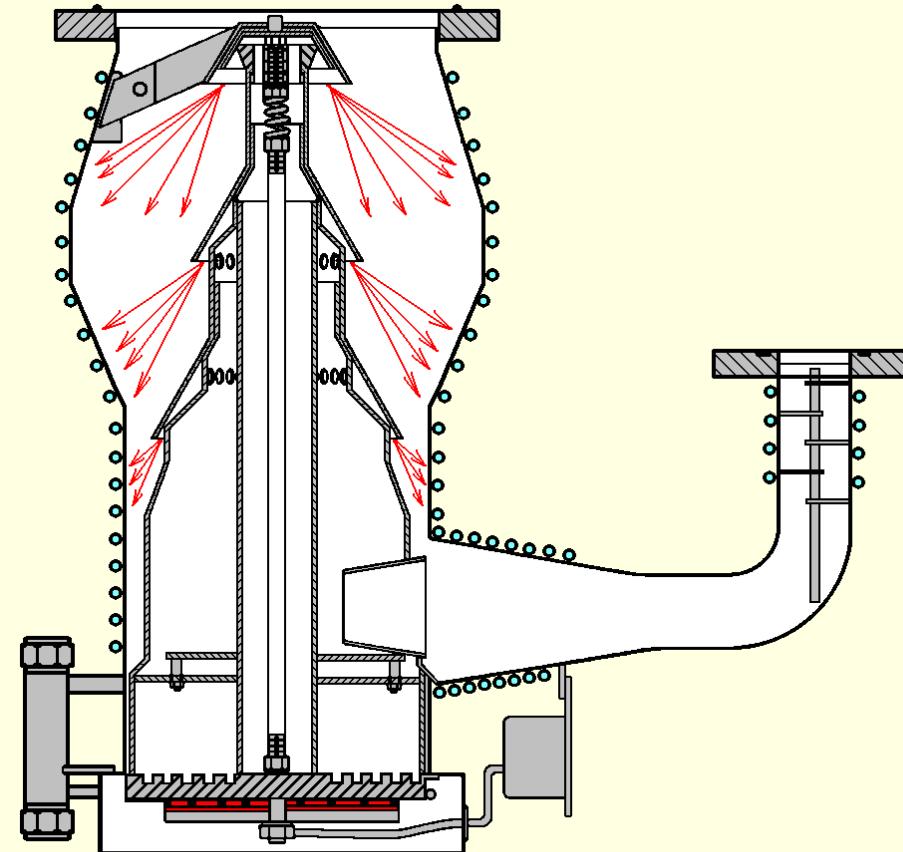
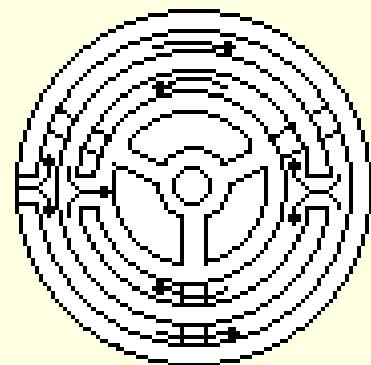


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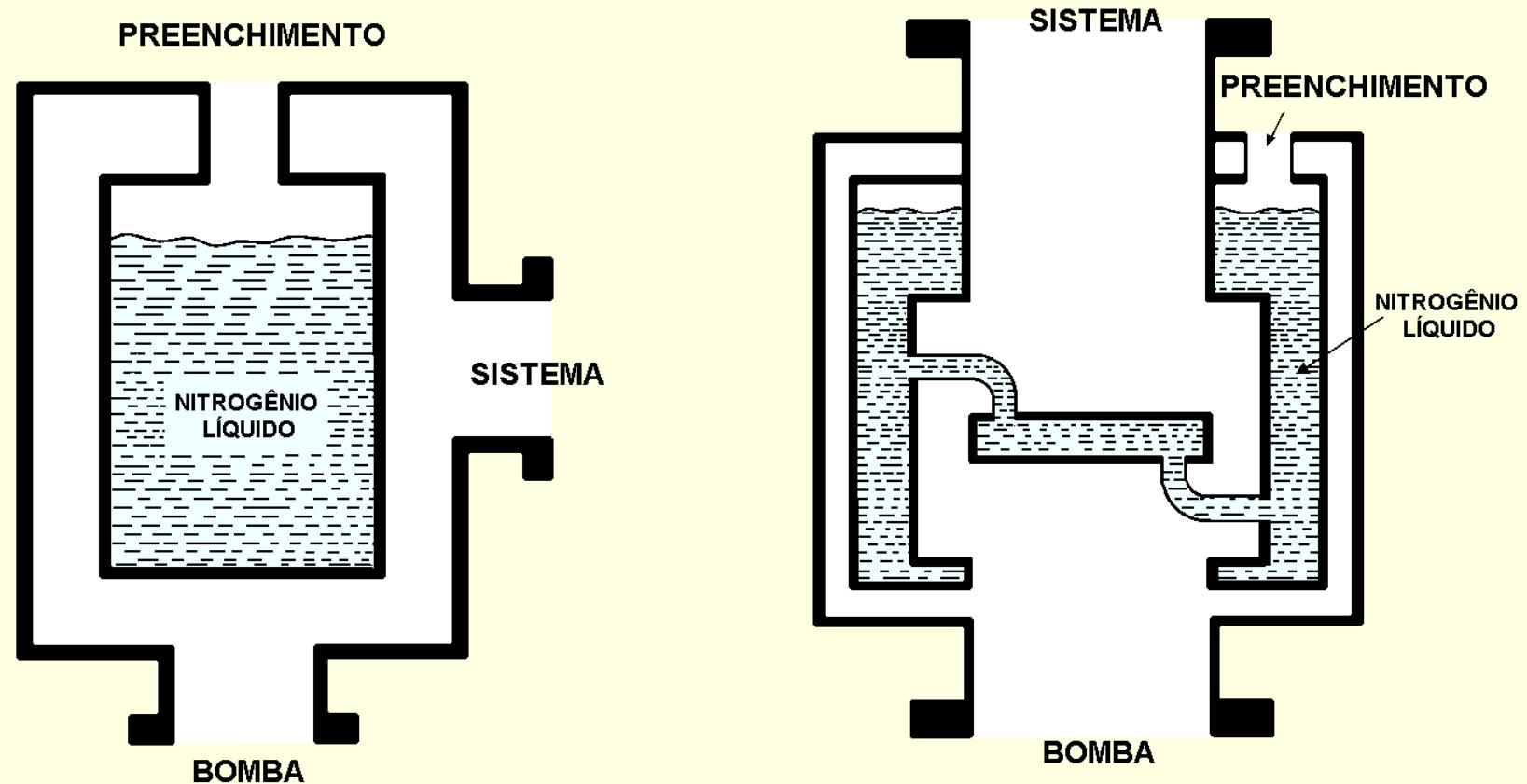


# BOMBAS DE DIFUSÃO





# BOMBAS DE DIFUSÃO





# BOMBAS DE DIFUSÃO

$p_{final} \sim 10^{-9}$  Torr

## Óleos

**Santovac**  $\Rightarrow p^* = 4 \times 10^{-10}$  Torr

**Fomblim**  $\Rightarrow p^* = 10^{-9}$  Torr

**Silicone**  $\Rightarrow p^* = 10^{-9}$  Torr

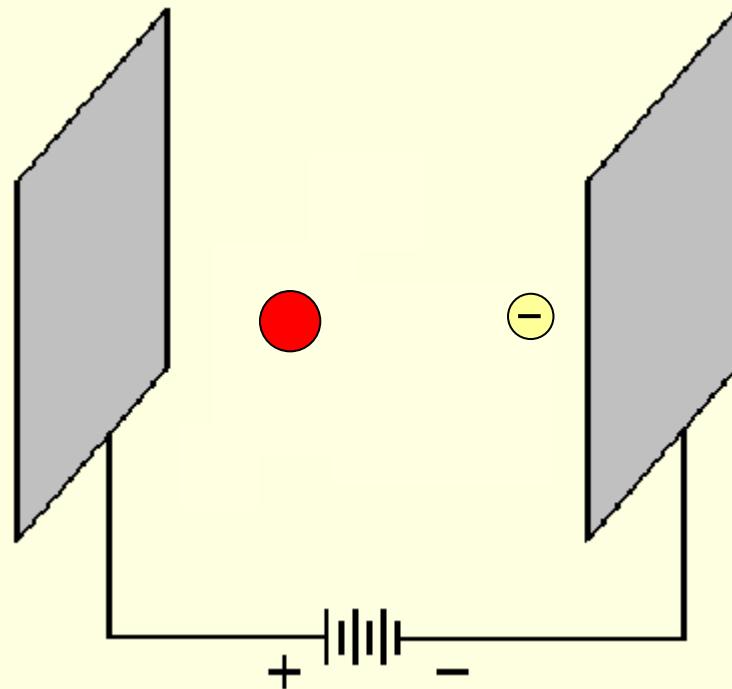


# BOMBAS IÔNICAS



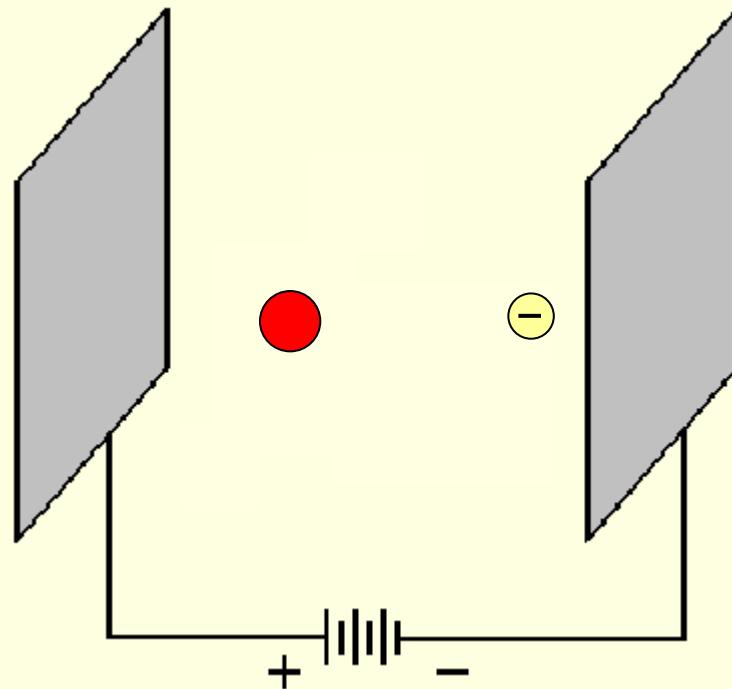


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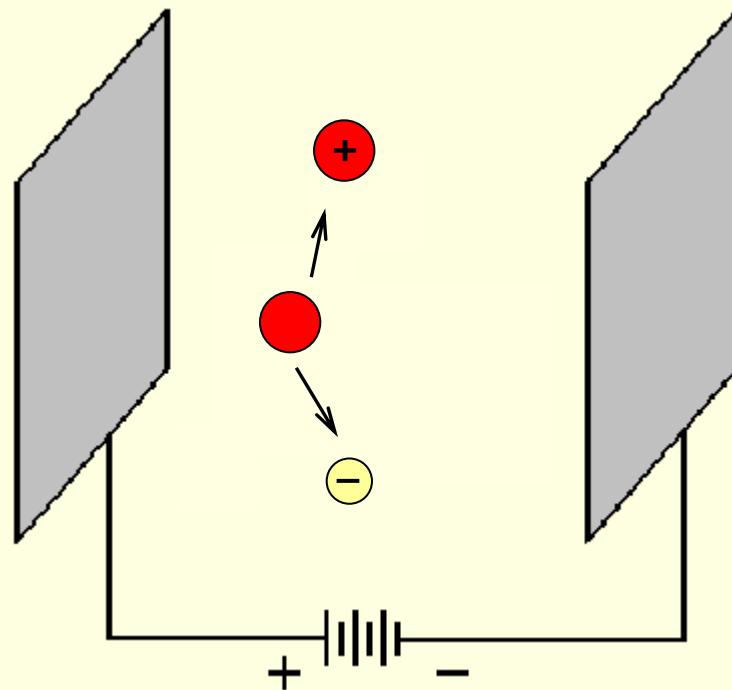




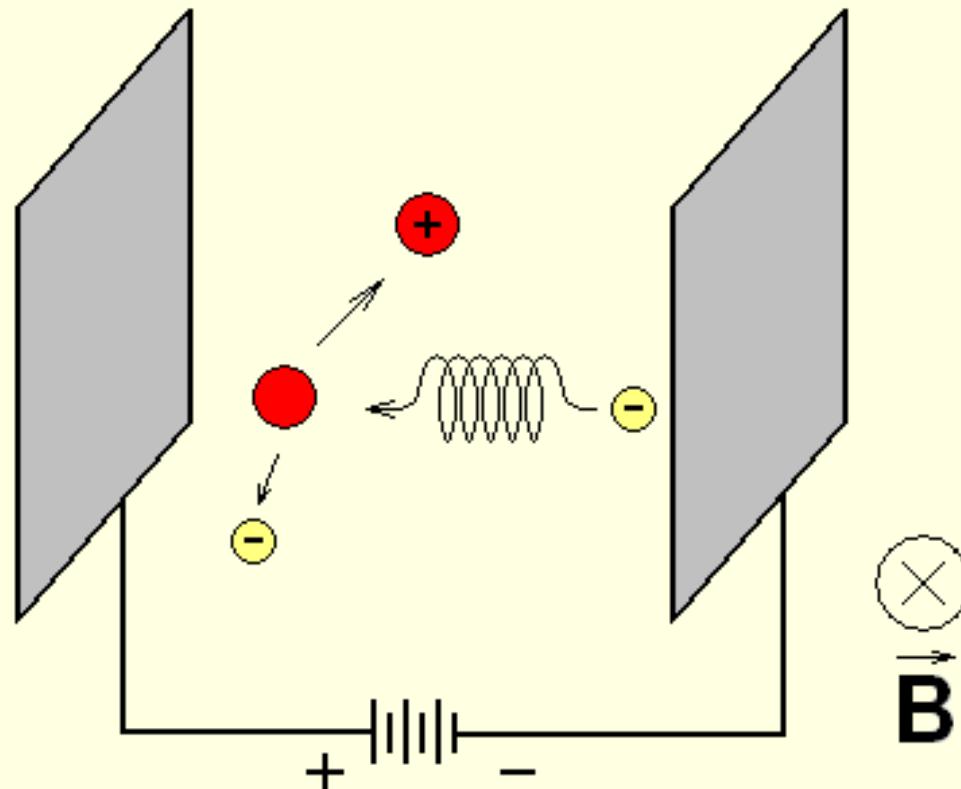
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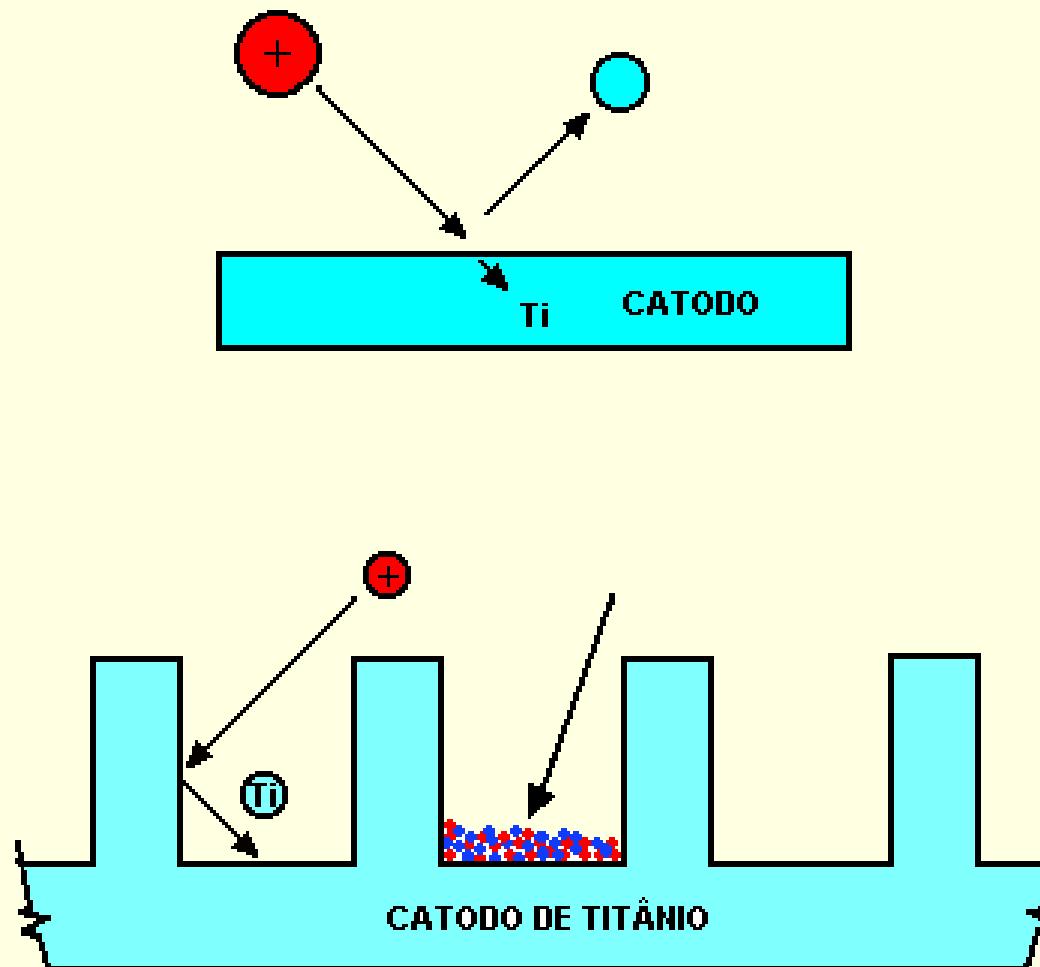
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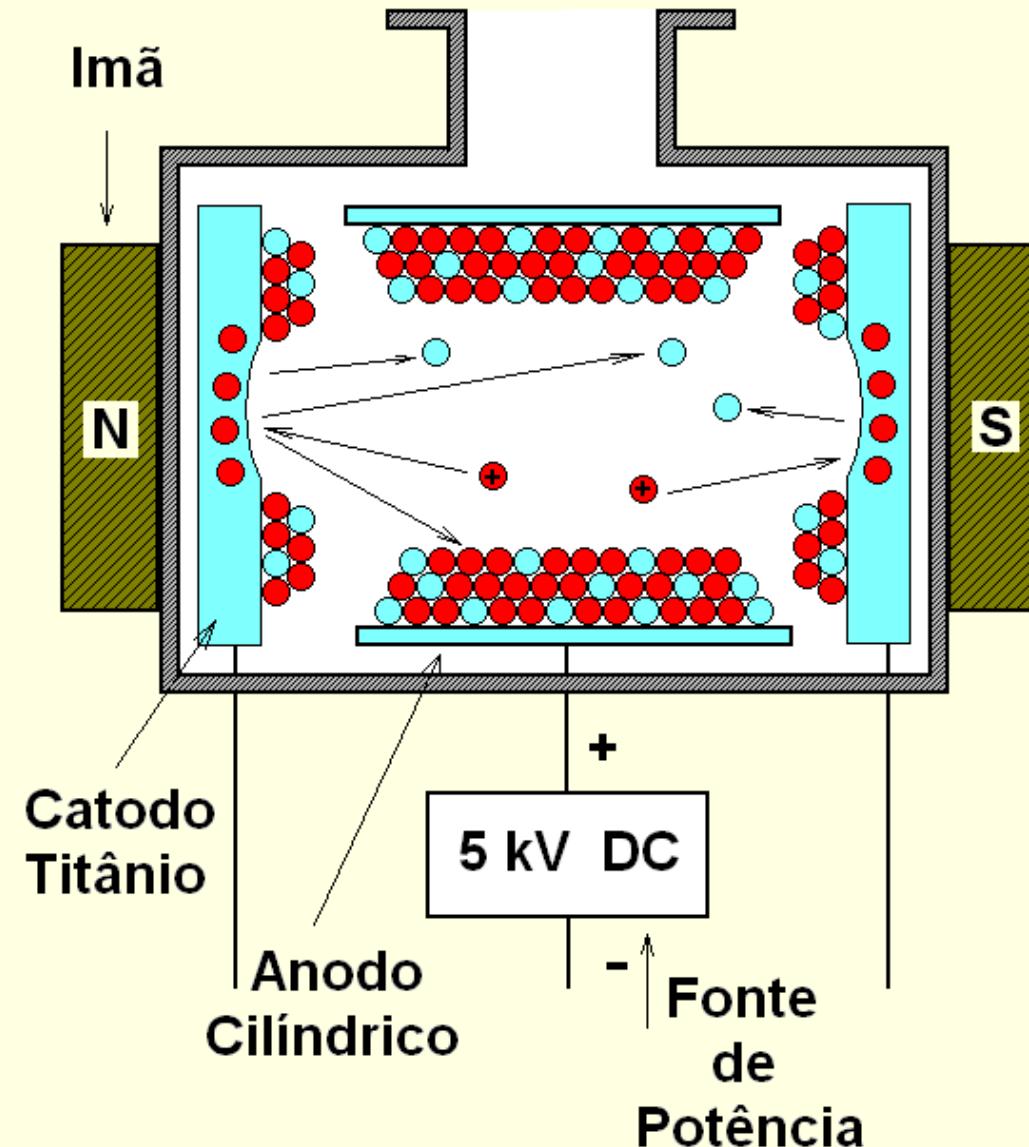
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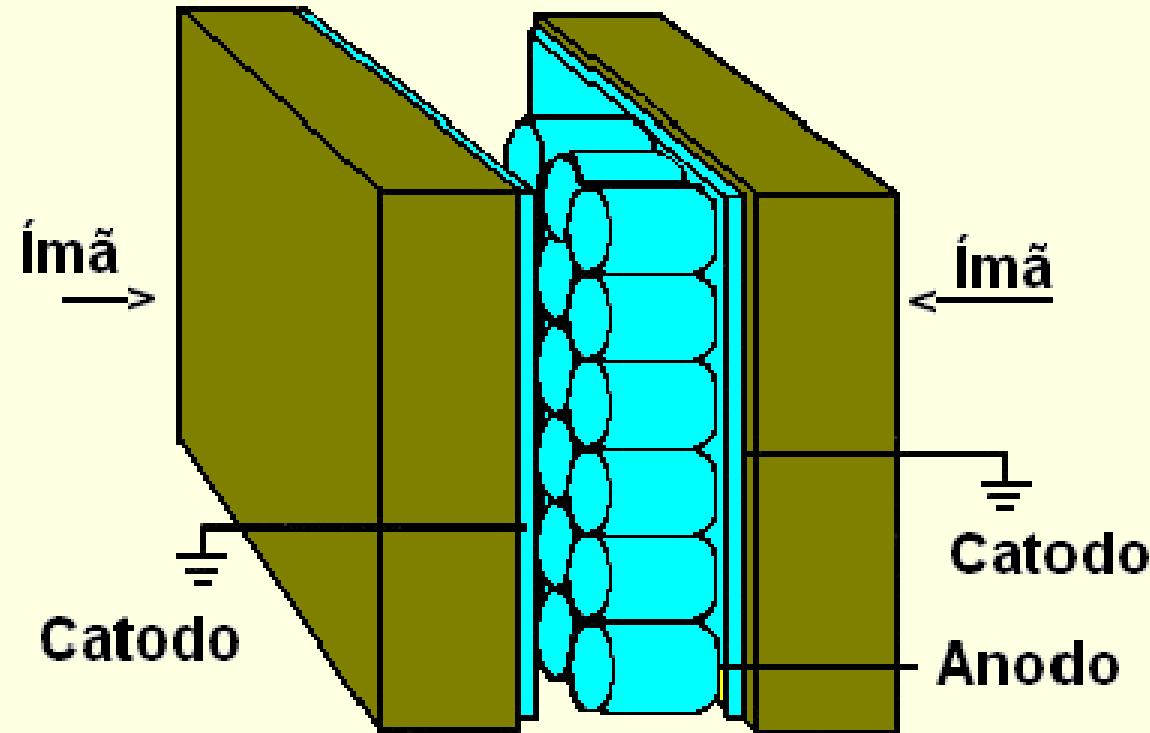
# BOMBAS IÔNICAS



# BOMBAS IÔNICAS



# BOMBAS IÔNICAS



$$p_{\text{final}} \sim 10^{-11} \text{ Torr}$$

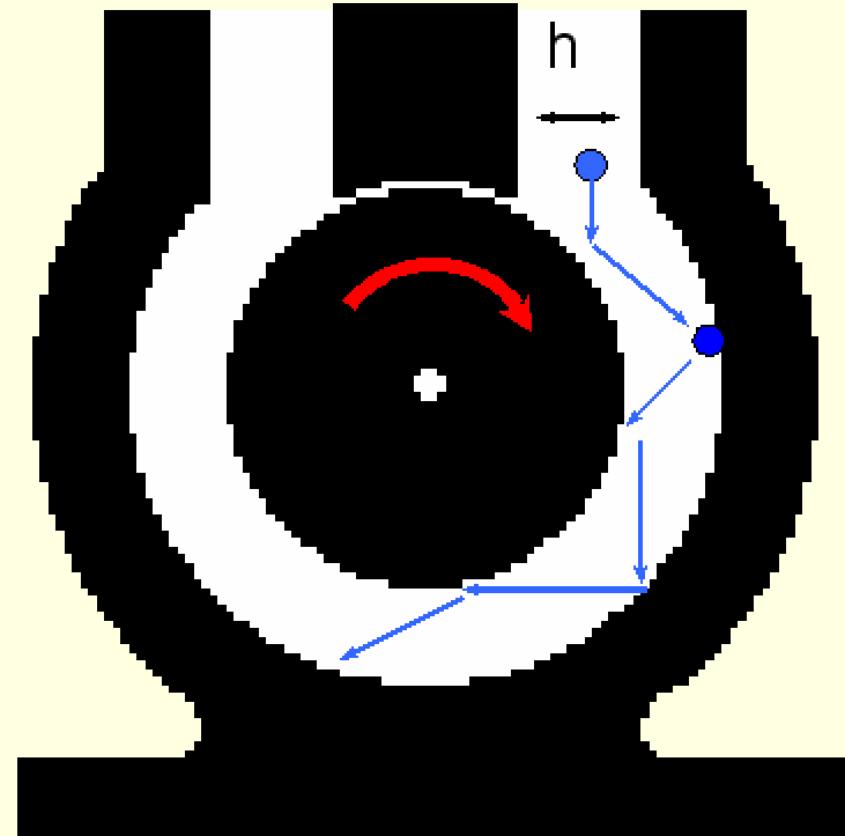


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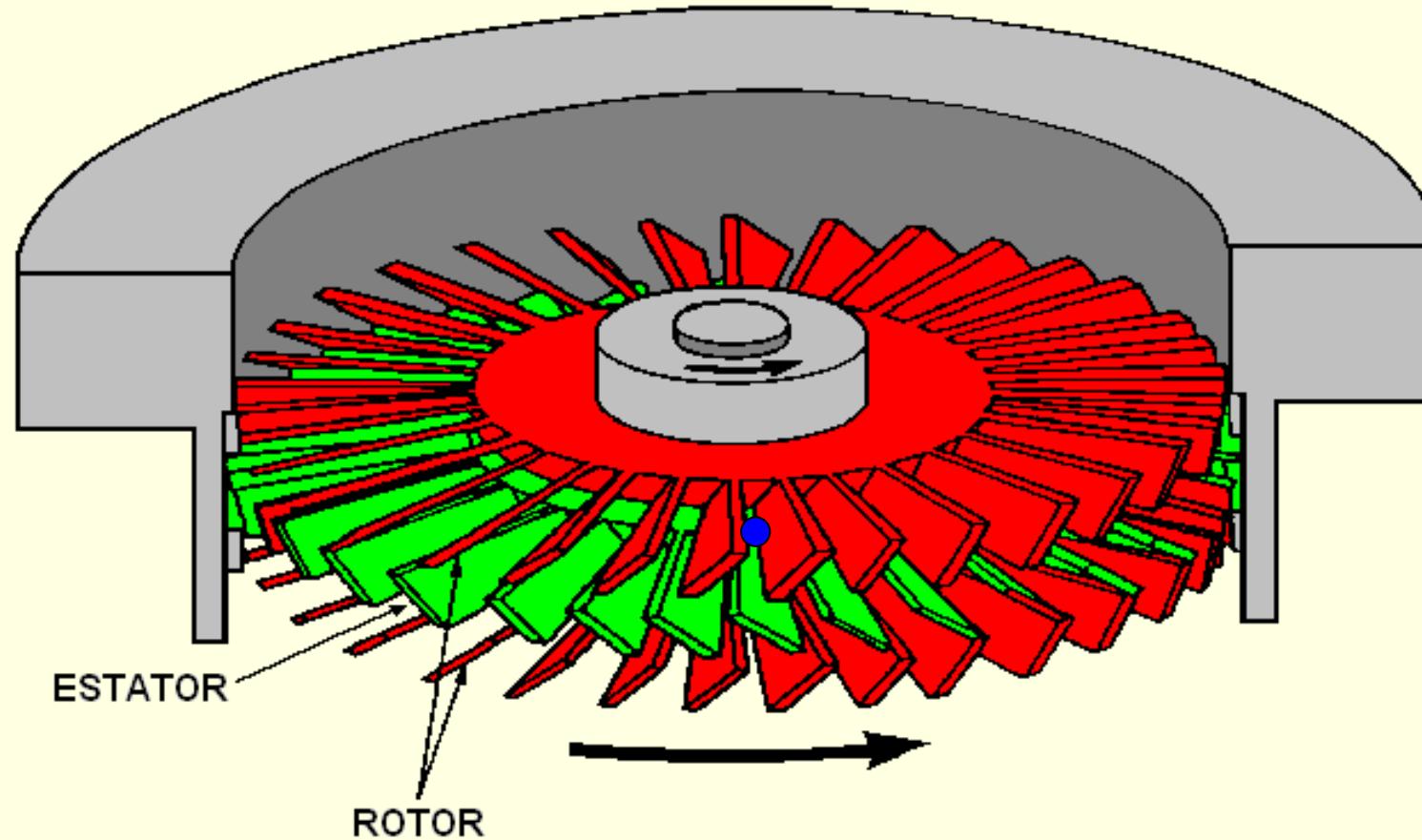




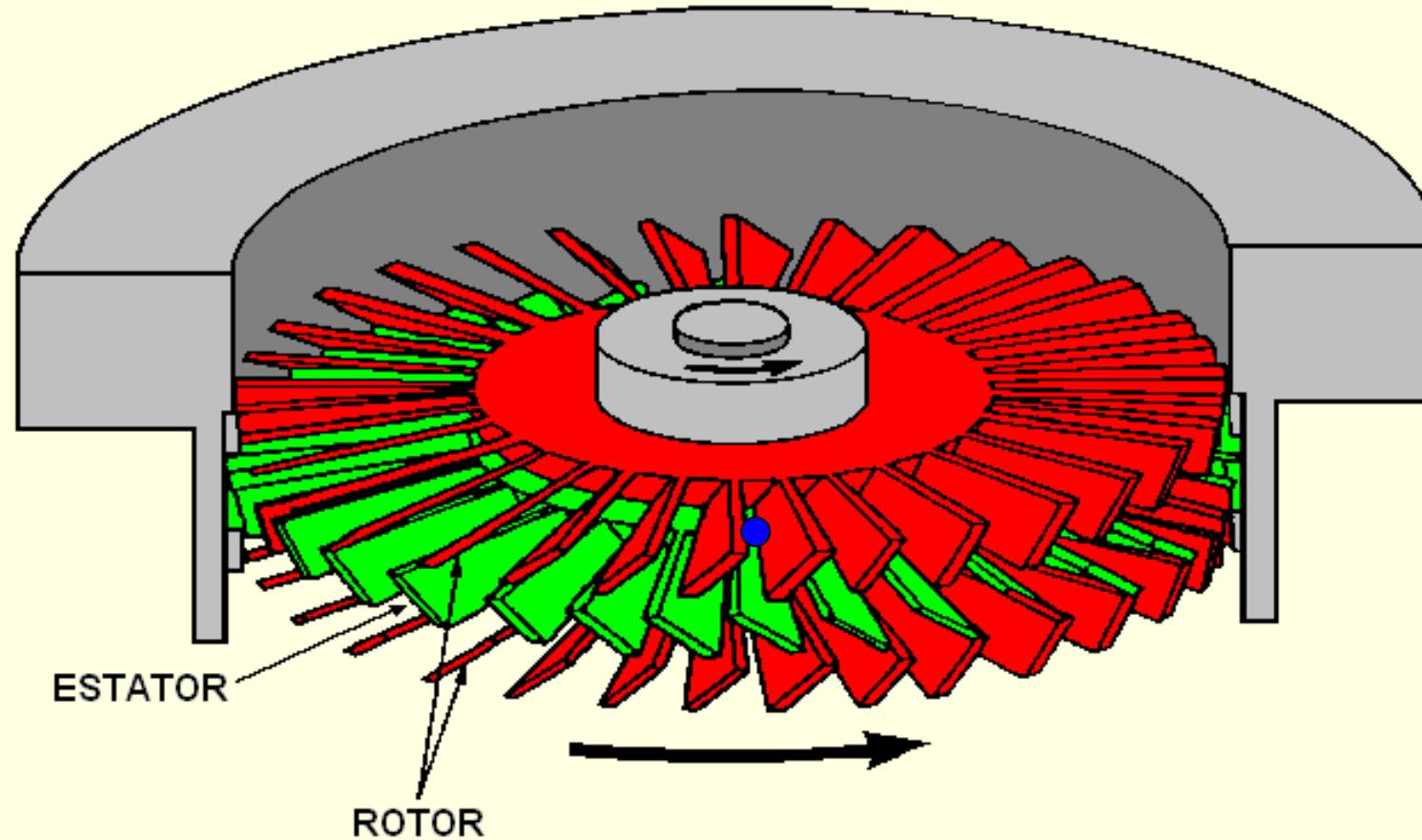
# BOMBAS TURBOMOLECULARES



# BOMBAS TURBOMOLECULARES

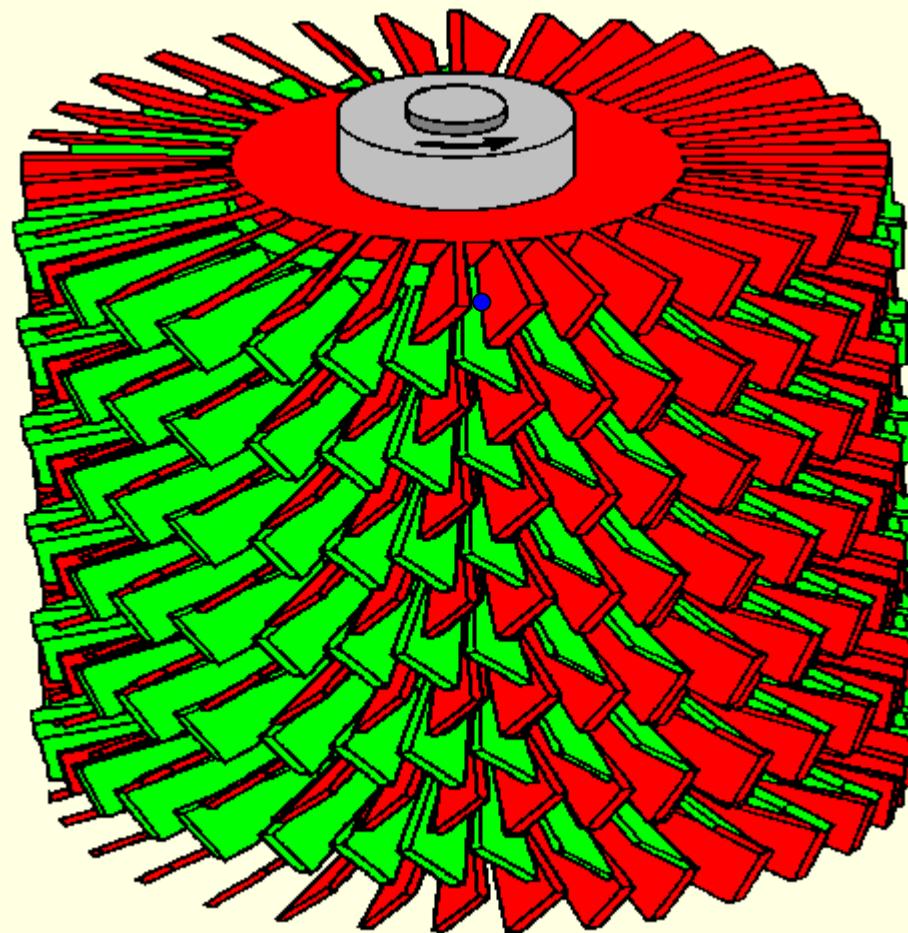


# BOMBAS TURBOMOLECULARES





# BOMBAS TURBOMOLECULARES





# BOMBAS TURBOMOLECULARES





# BOMBAS TURBOMOLECULARES





# BOMBAS TURBOMOLECULARES





# MEDIDORES DE PRESSÃO



# MEDIDOR PIRANI



# MEDIDOR PIRANI

## TROCA DE CALOR GÁS - SUPERFÍCIE ( COEFICIENTE DE ACOMODAÇÃO )

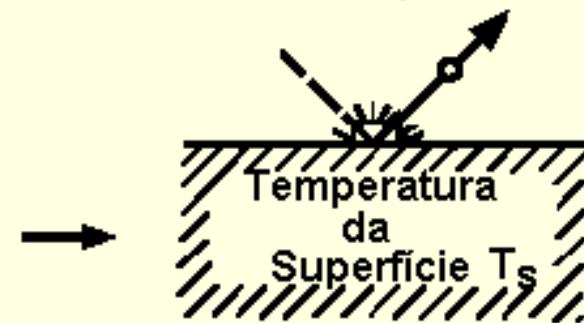
Átomo Incidente

$$E_i = \frac{3}{2} kT_i$$



Átomo retroespalhado

$$E_r = \frac{3}{2} kT_r$$

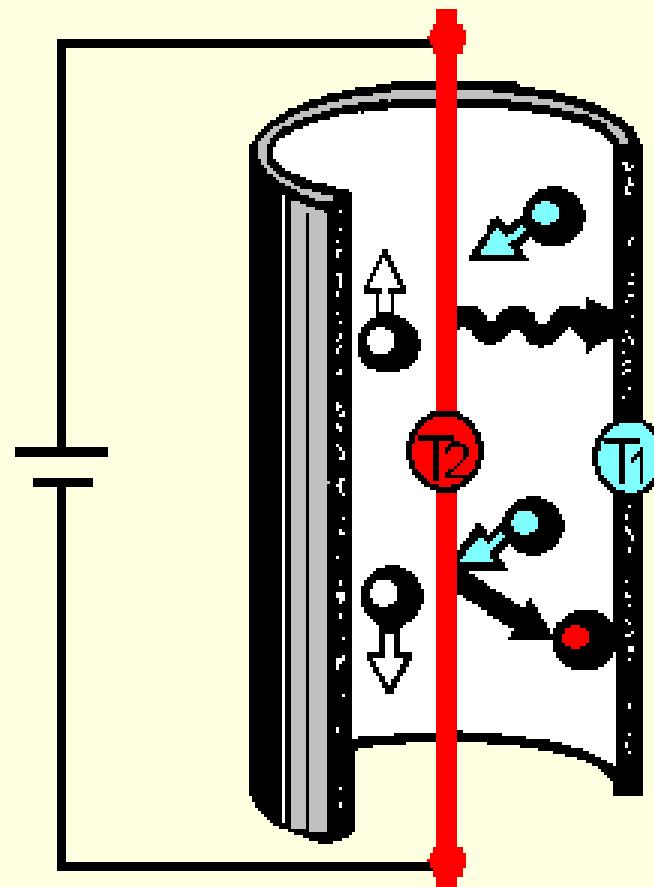


$$\text{Energia cinética do átomo} = \frac{3}{2} kT \text{ (média)}$$

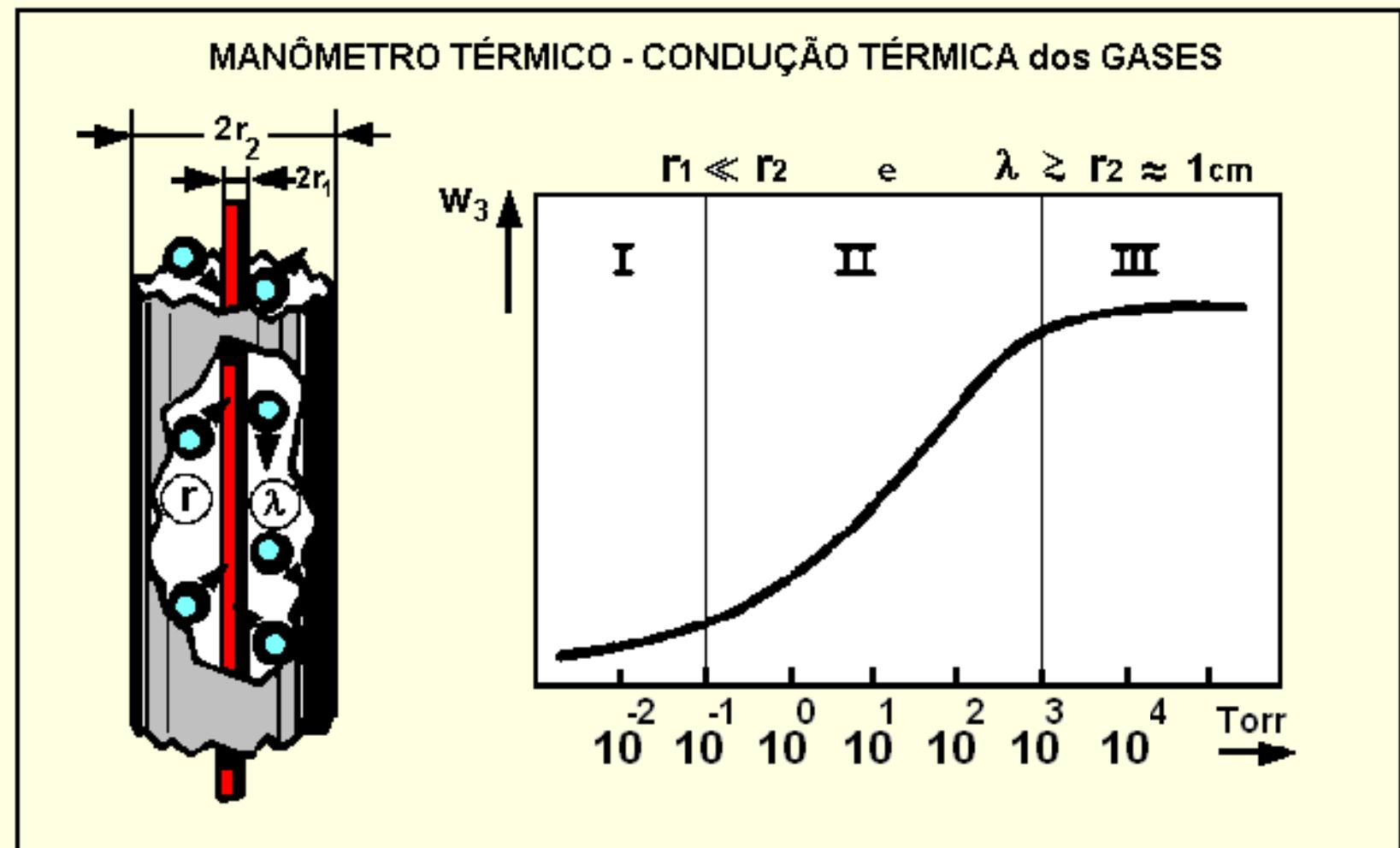
$$\text{Coeficiente de acomodação : } \alpha = \frac{T_r - T_i}{T_s - T_i}$$



# MEDIDOR PIRANI



# MEDIDOR PIRANI





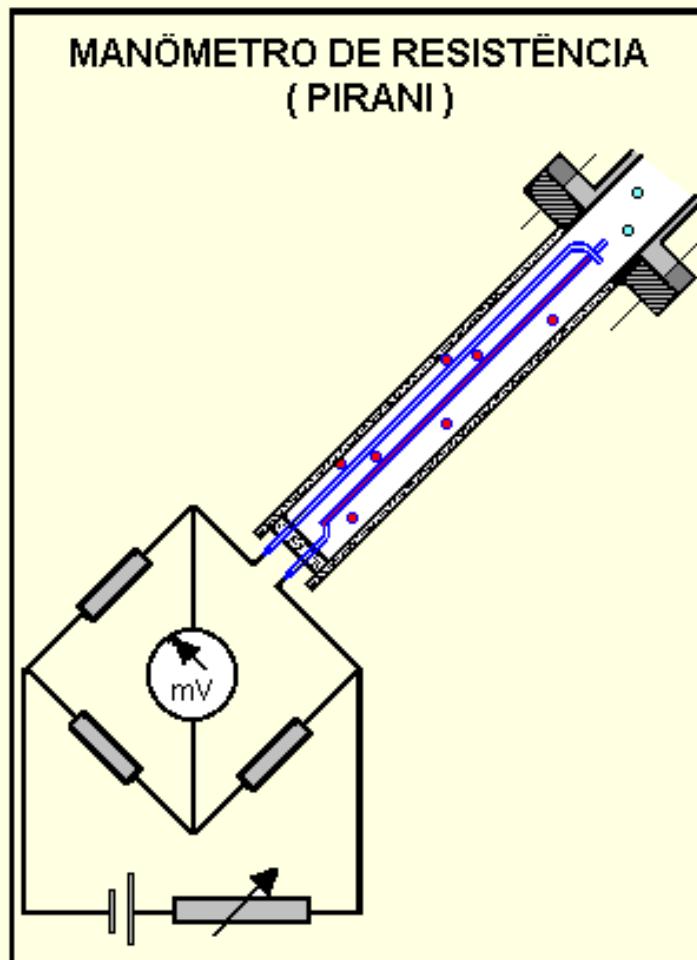
# MEDIDOR PIRANI

## COEFICIENTE DE ACOMODAÇÃO

GÁS	W	SUPERFÍCIE			Ni	Fe		
		Pt		Normal				
		Pt	Preta					
He	0.016	--	--	--	--	--		
Ne	--	--	--	--	0.82	0.40		
Ar	0.85	0.89	--	--	0.93	--		
Kr	--	0.69	--	--	--	--		
H <sub>2</sub>	0.36	0.28	0.71	--	0.29	--		
N <sub>2</sub>	0.87	0.81	--	--	0.82	--		
O <sub>2</sub>	0.90	0.85	0.95	--	0.86	--		
CO <sub>2</sub>	--	--	0.97	--	--	--		
Hg	0.95	--	--	--	--	--		



# MEDIDOR PIRANI

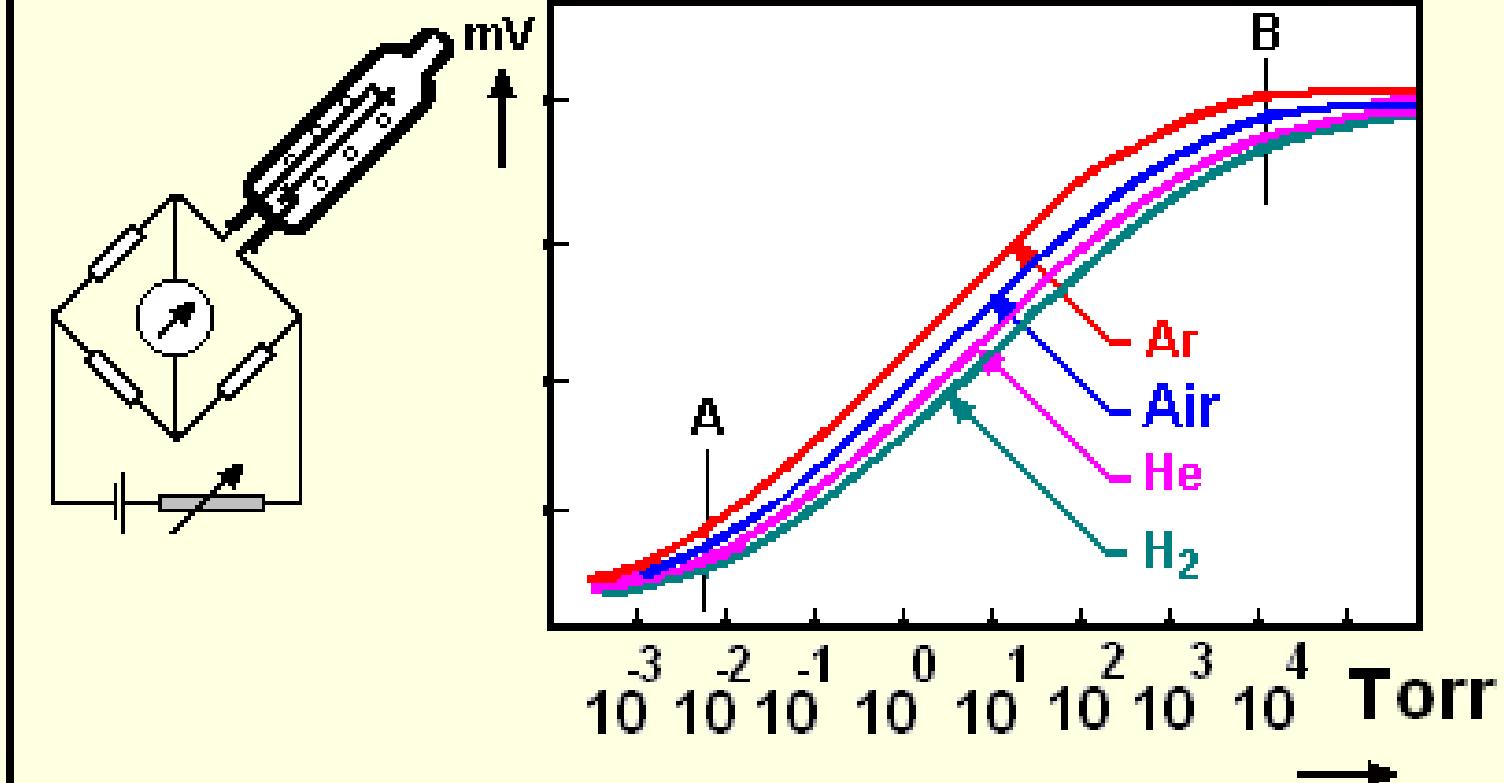




# MEDIDOR PIRANI

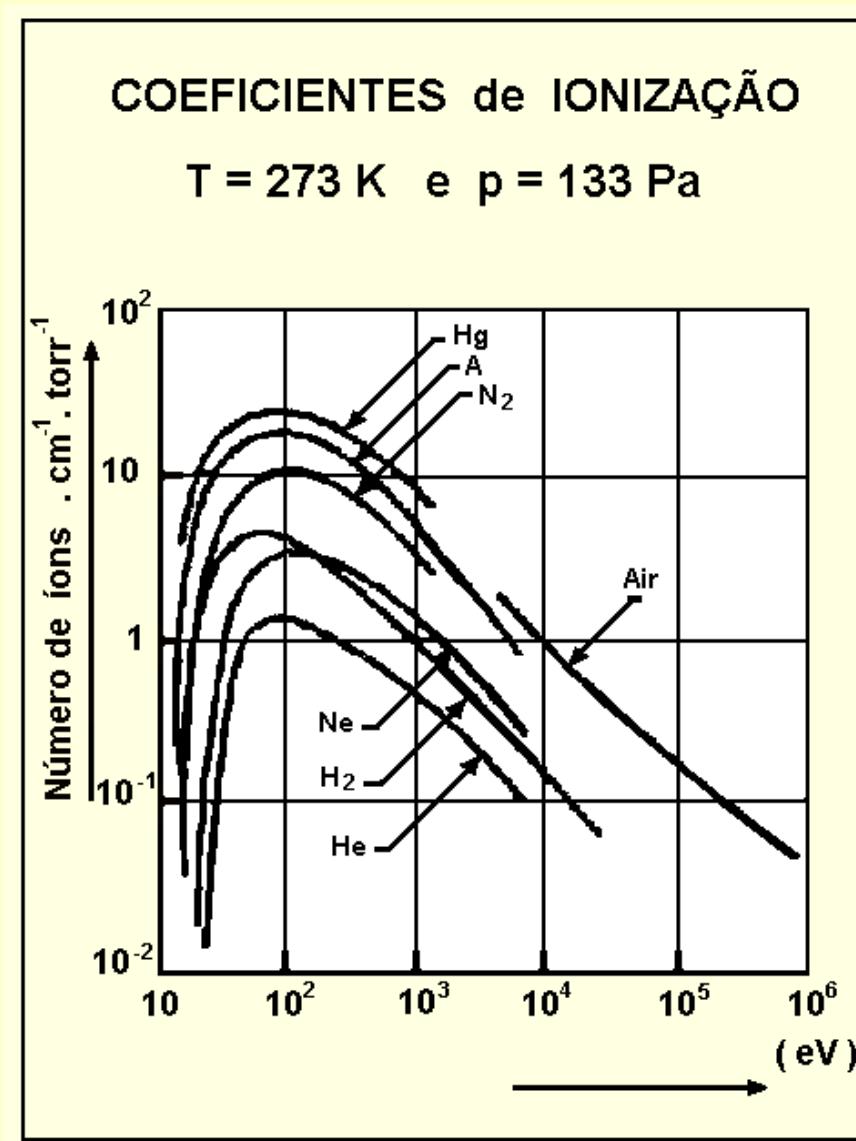
## MANÔMETRO DE RESISTÊNCIA ( PIRANI )

Curva de Calibração





# MEDIDOR DE IONIZAÇÃO



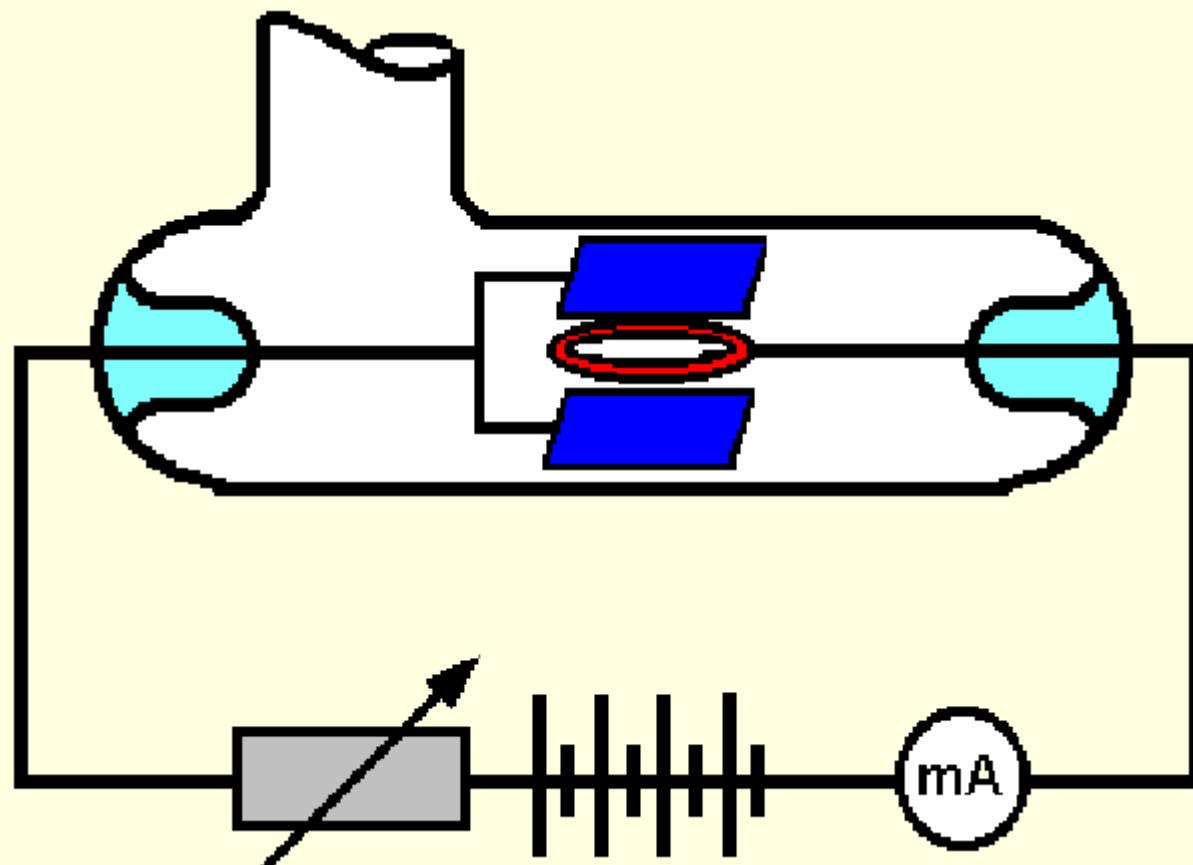


# MEDIDOR PENNING



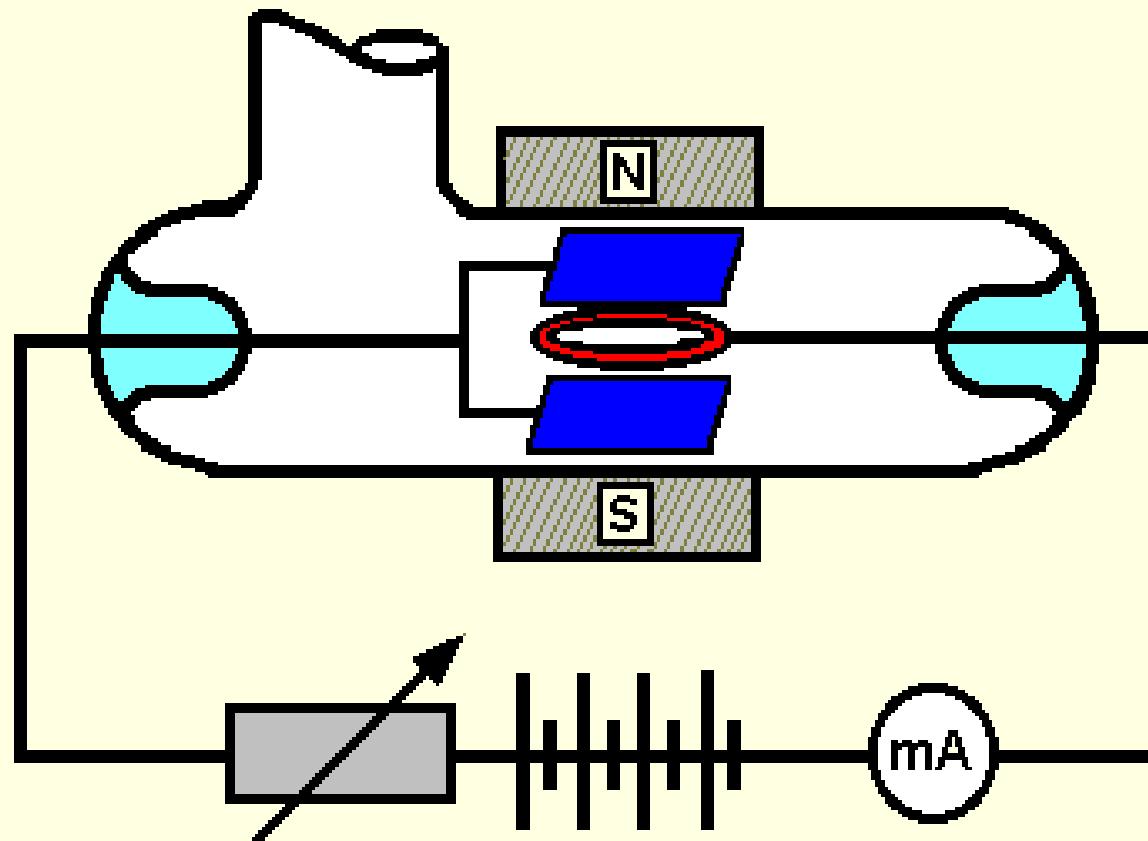


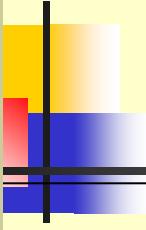
# MEDIDOR PENNING





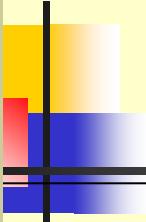
# MEDIDOR PENNING





# MEDIDOR DE IONIZAÇÃO





# MEDIDOR DE IONIZAÇÃO



MEDIDOR BAYARD - ALPERT

