IMNVT

Institute of Mechatronic, Nanotechnology and Vacuum Techniqe

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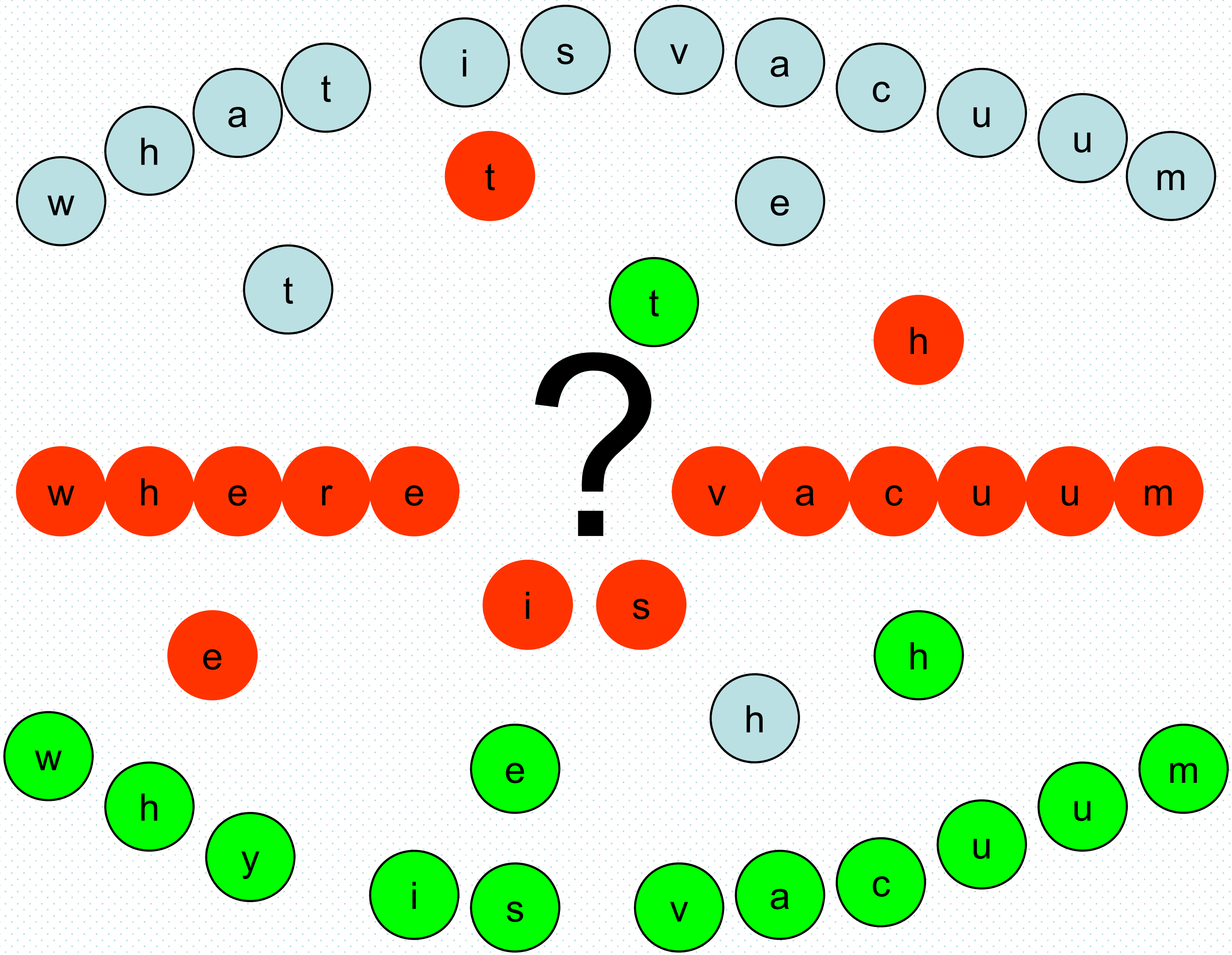
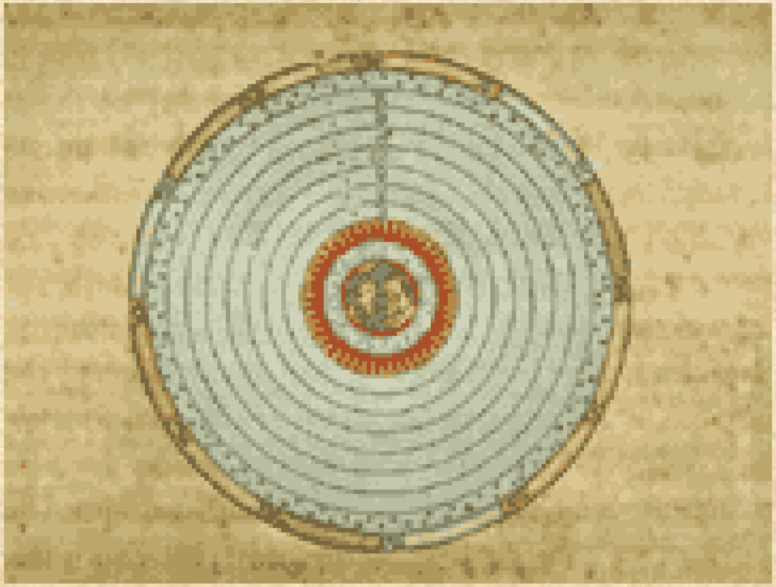

what is vacuum
where ? vacuum
is
why is vacuum

Aristotle 384 – 322 BC

The theory of nature's *abhorrence of the void*.



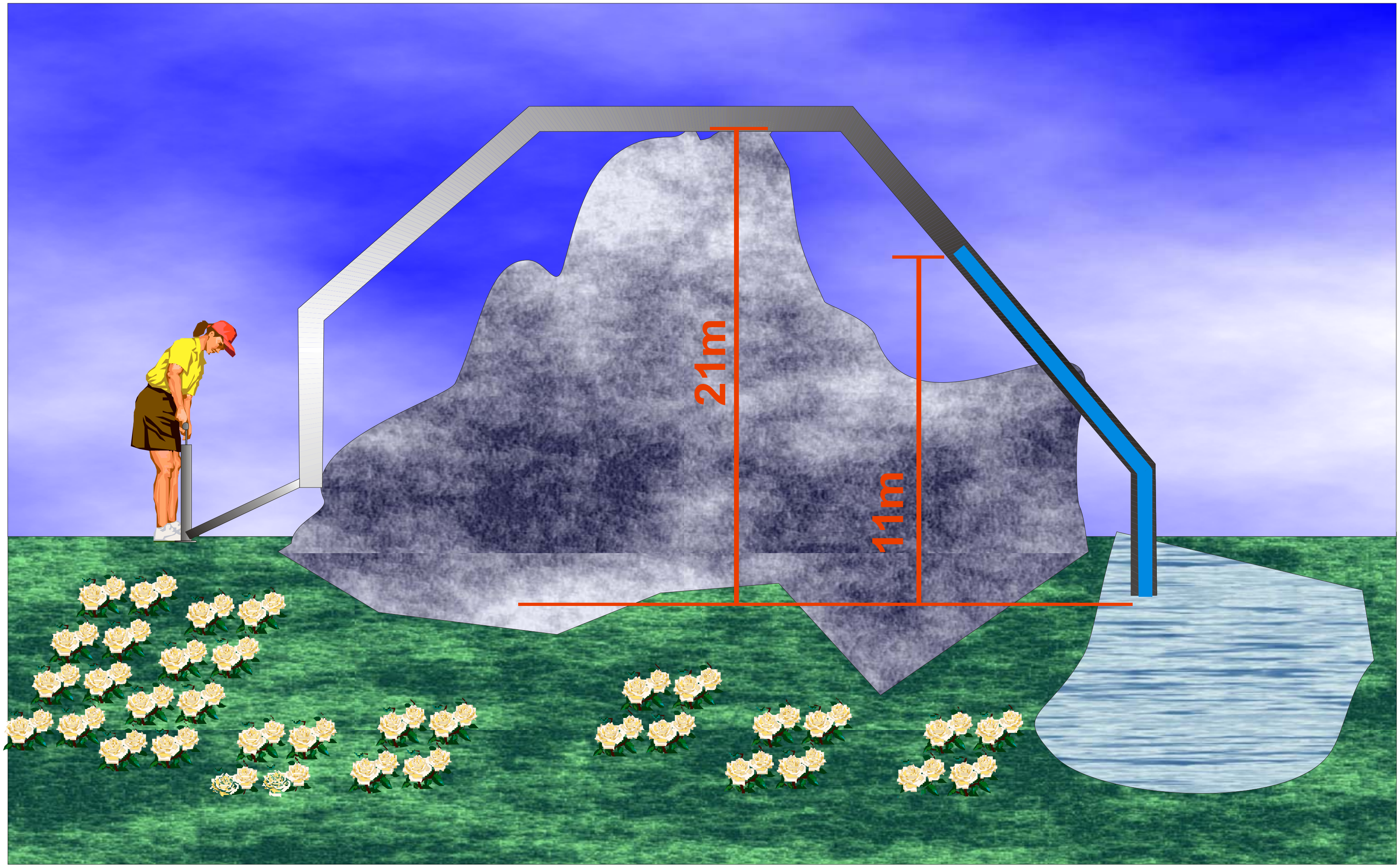
For Aristotle, a space without objects (that means, void), is not in fact the same as nothing, but has its own permanent existence

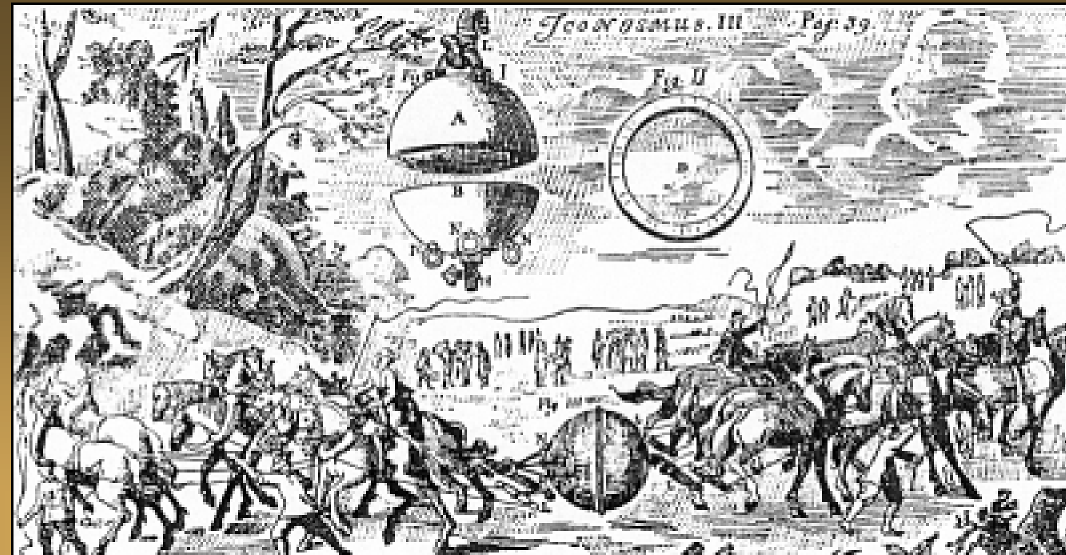
1630, Giovan Battista Baliani a patrician from Genoa

Born in Genoa, he studied law, he worked from 1611 as Prefect of the fortress of Savona. He was nominated Governor of Sarzana in 1623 and became a member of the Genovese Senate the following year. In 1647 he returned to Savona as Governor.

His theories of dynamics had been long debated with Galileo with whom he was in frequent correspondence. It is in a letter to Galileo where he shows his interest in the problems linked to pneumatics. Baliani asked for advice on the reasons for the failure of his syphon, which had to carry water to a height of about 21 metres. Galileo's reply determined the working limits of a suction pump, highlighting the impossibility of raising a column of water any higher than 18 *braccia* (11 meters).

1630, Giovan Battista Baliani ,one of the first historical experiment with vacuum





Magdeburg (1657), Berlin, Vienna

Ottona von Guericke 1602 - 1686

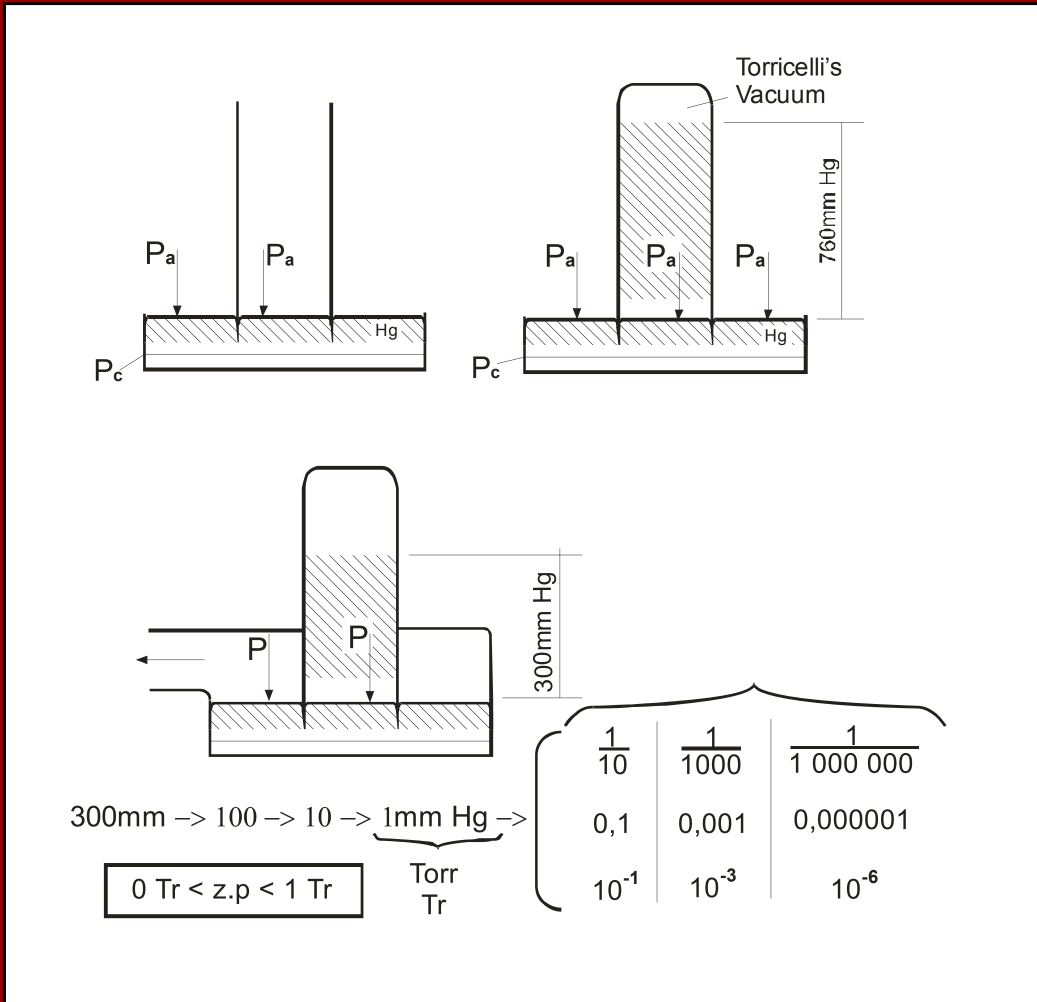
Wrocław, 2007

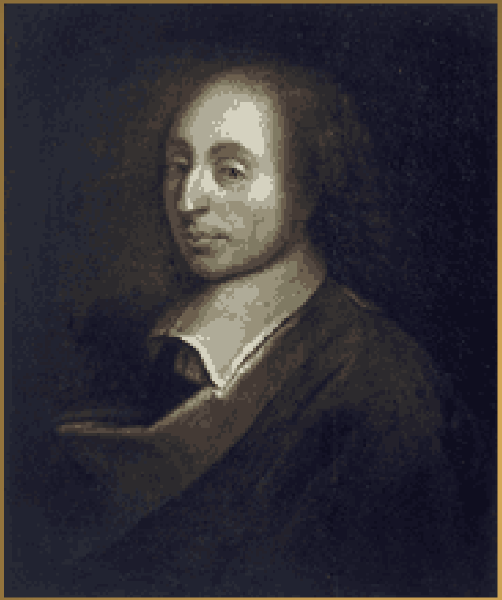
6

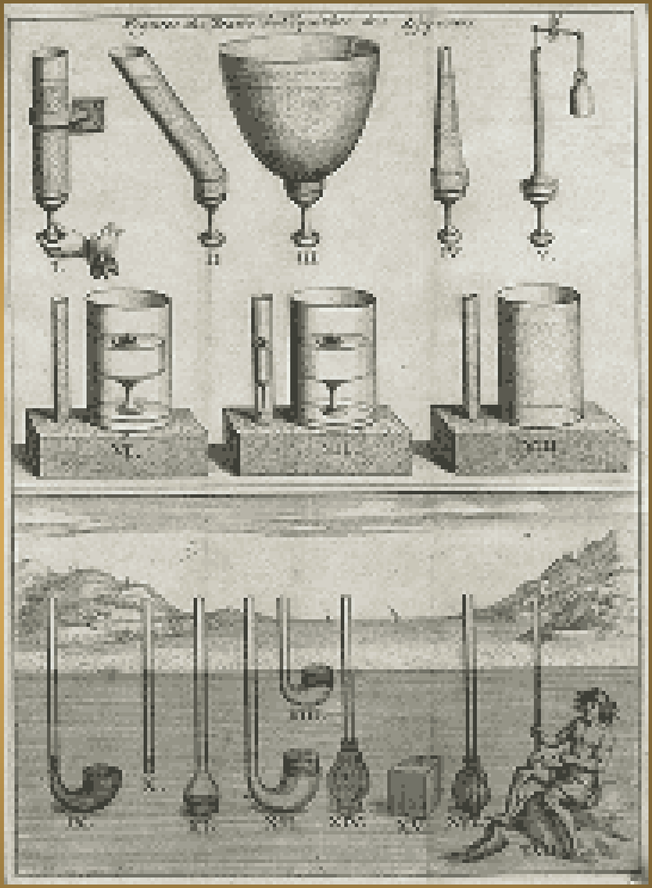
***Evangelista Torricelli*, 1644**

…filled up pipes with Hg and odher fluids and showed that they are able to keep up the lewel over the pot…

Phases of the position of Hg depending on pressure existing over the tank space







Blaise Pascal 1623 - 1662

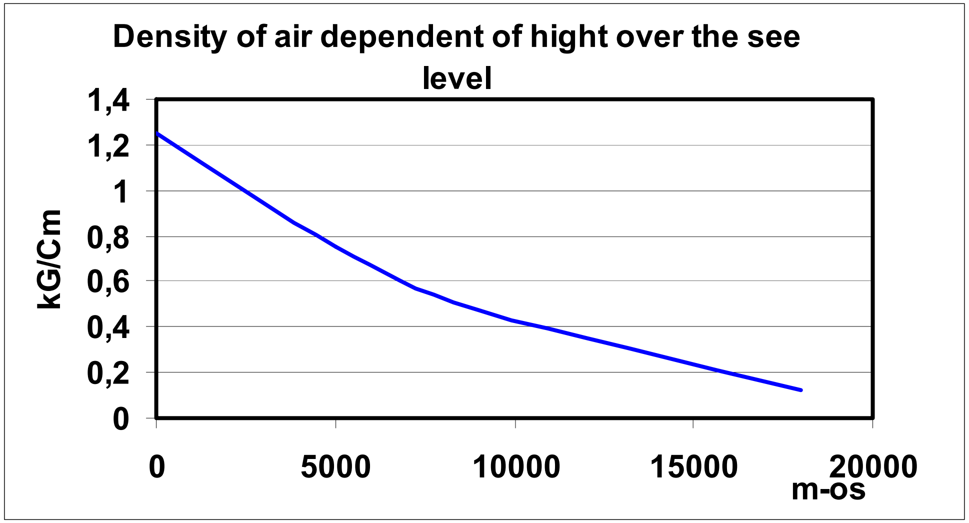
Vacuum is a space and is in the space where pressure is lower even much lower than atmospherical pressure

Generally speaking vacuum means-

the conditions existing in the space filled by gases and vapors which the pressure is lower than the atmospheric one, as well as when the concentration of gases is lower than normal.

$$p = n\,k\,T$$

k = 1,38x 10-23 J/T



(18000m) 0,123

Concord

(9000m) 0,47

Mt. Everest

(5000m) 0,75

Mt. Blanc

(0 m) 1,25

Sea

At sea-level, each cubic metre of air contains a mass of around 1.25 Kg.

At 5,000 metres (around the height of Mont Blanc), this mass goes down to 0.75Kg/ m^3

At 9,000 metres (roughly the height of Everest), it's down at 0.47Kg/ m^3.

At 18,000 metres (the cruising height of Concorde), it is already 10 times less dense than at sea-level, at 0.123Kg/m^3.

1Pa = 1×10^{-2} mba
= $7{,}5 \times 10^{-3}$ Torr
= $1{,}45 \times 10^{-4}$ psi
= $1{,}02 \times 10^{-5}$ at
= $9{,}87 \times 10^{-6}$ atm

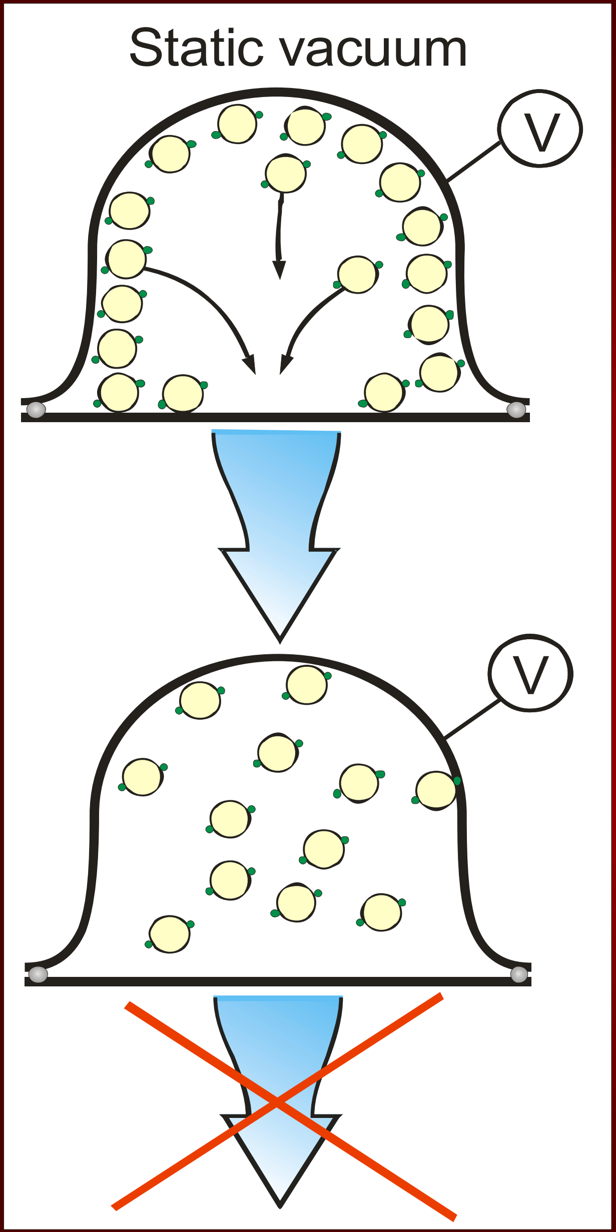
Pressure range		If the pressure is the criterion of classification , vacuum can be classified to:
Pascal (absolute mode)	Pascal (absolute mode)	
1×10^{5} to 3×10^{3}	100 000 to 3 000	low vacuum
3×10^{3} to 1×10^{-1}	3 000 to 0.1	medium vacuum
1×10^{-1} to 1×10^{-4}	0.1 to 0.000 1	high vacuum
1×10^{-4} to 1×10^{-7}	0.000 1 to 0.000 000 1	very high vacuum
1×10^{-7} to 1×10^{-10}	0.000 000 1 to 0.000 000 000 1	ultra-high vacuum (UHV)
$<1 \times 10^{-10}$	<0.000 000 000 1	extreme-ultrahigh vacuum (EHV or XHV)

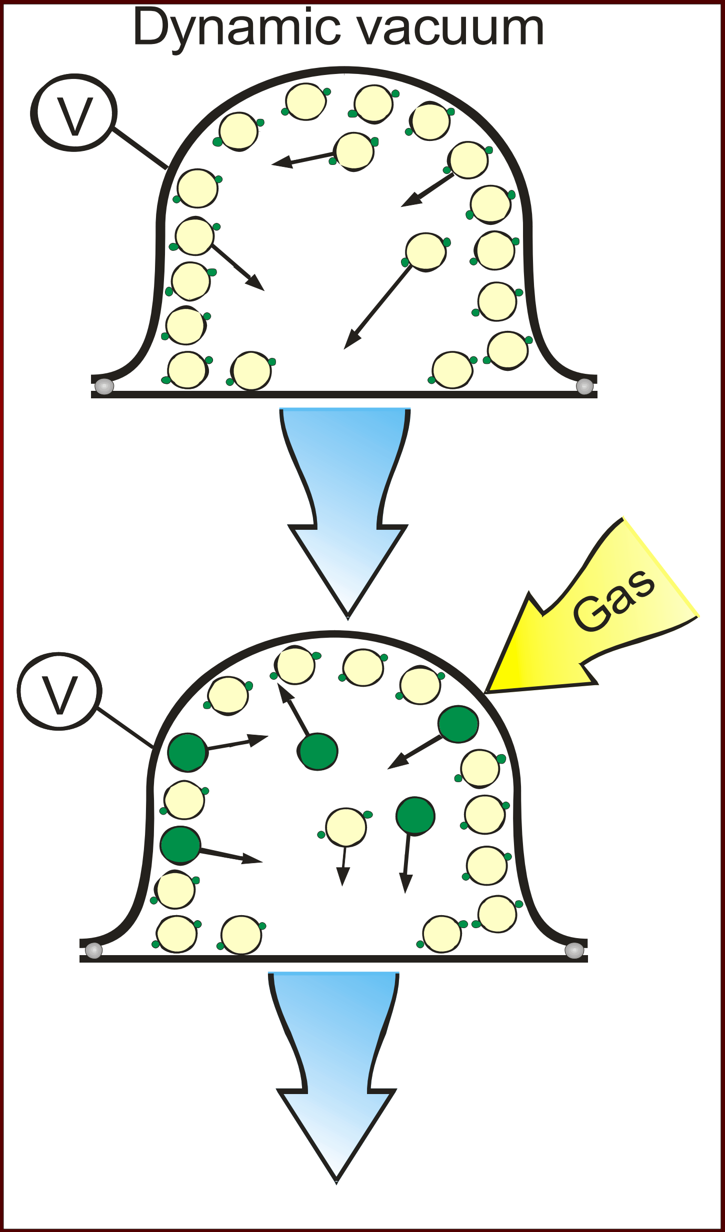
Criterion of classification the vacuum

A) Pressure

B) Having vestigian quantities of oil (water) commonly called wet and without the pumping medium, called dry

C) Relatively to kinetics of flow gas as well as sorption and desorption gases on the surface, called static and dynamic vacuum


Static vacuum
V
V


Dynamic vacuum
V
V
Gas

We can say that in case when desorption processes don't influence the value of pressure, we speak about the dynamic vacuum, but when they do, we speak about the static vacuum.

The gas sorption and desorption is in relation with the cleaness of a surface and has an implication on the technological processes.

It is obvious, that when the other particles (solid and gaseous) deposite on the plate, separates the particles which will cover the surface.

The promptness of adsorption

$$\frac{dN_a}{dt} = 8{,}33x10^{23} S \frac{p}{\sqrt{MT}}$$

where:

S= coefficient of adhesion, for most of gases it has value from 0,1 to 1,0

M= molar weight,

T= temperature K deg,

For example, for Ar with

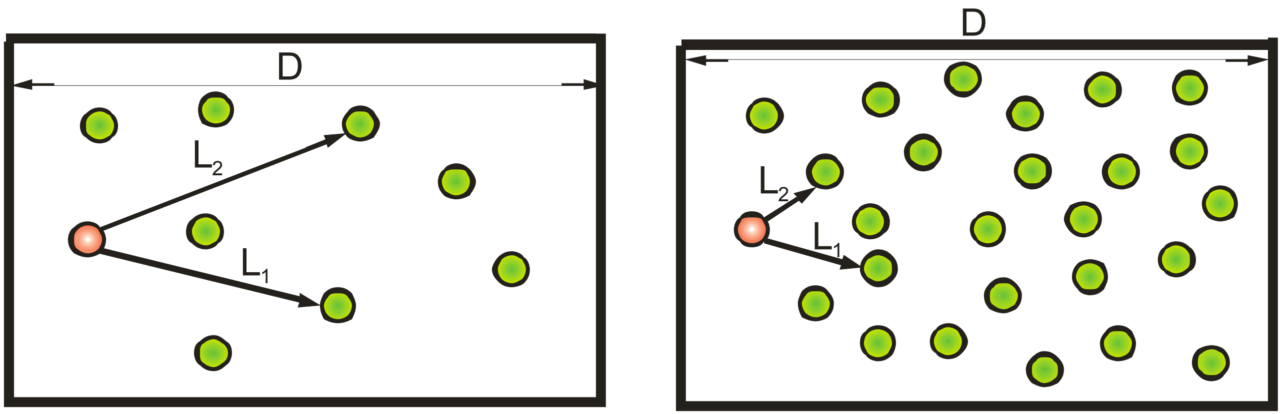
$M = 39{,}94 \times 10^{-3}$, $p = 10^{-4}$ Pa, T = 300K, S=0,5

<u>$dNa/dt = 1{,}2 \times 10^{18}\ m^{-2}\ s^{-1}$</u>

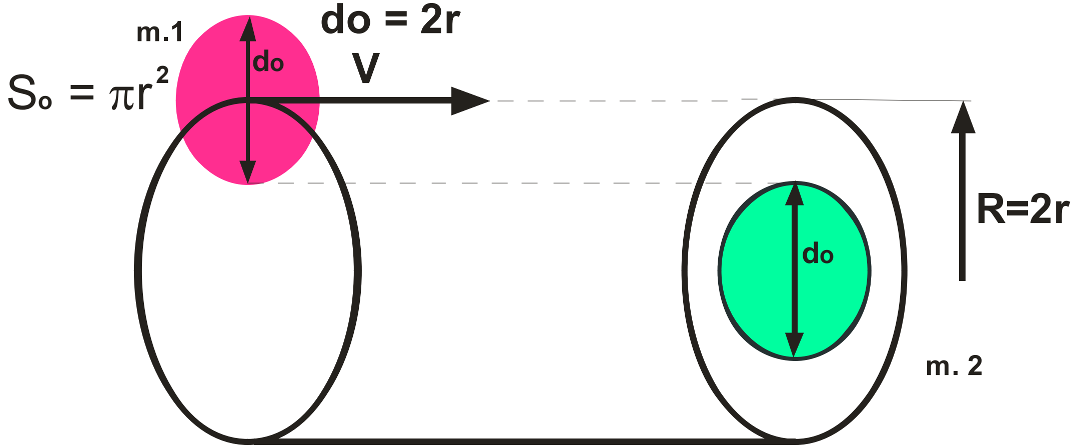
The promptness of desorption

$$\frac{dN_d}{dt} = \frac{N_0}{\tau}\theta$$

where:
N_0 = number of particles in completed monomolecular layer.
θ = coefficient of covering N_a/N_0,
where N_a = number of an adsorptive particles on 1 sm.



$$Sm_{.2\text{-}1} = \pi R^2 \Rightarrow Sm_{.2\text{-}1} = 4\pi r^2 \text{ Or } Sm_{.2\text{-}1} = \pi d_0^2$$



$$L = V \cdot \tau$$

$$\tau = 1 \quad L = V$$

The length free way

$$L_{MB} = 3{,}11x10^{-24}\,\frac{T}{pd_0^2}$$

The frequency of collision

$$Z_{MB} = 14{,}79x10^{23}\,\frac{pd_0^2}{\sqrt{MT}}$$

AIR

$M=29\times10^{-3}kGmol^{-1}$
$T=293K$
$d_0=3,76\times10^{-10}m$
$p=1,013\times10^5Pa$ (atm. press.)

$L_{MB} = 63\times10^{-8}m$

$Z_{MB}= 7,5\times10^9s^{-1}$

$p=10^{-2}Pa$

$L_{MB} = 0,637m$

$Z_{MB}= 737s^{-1}$

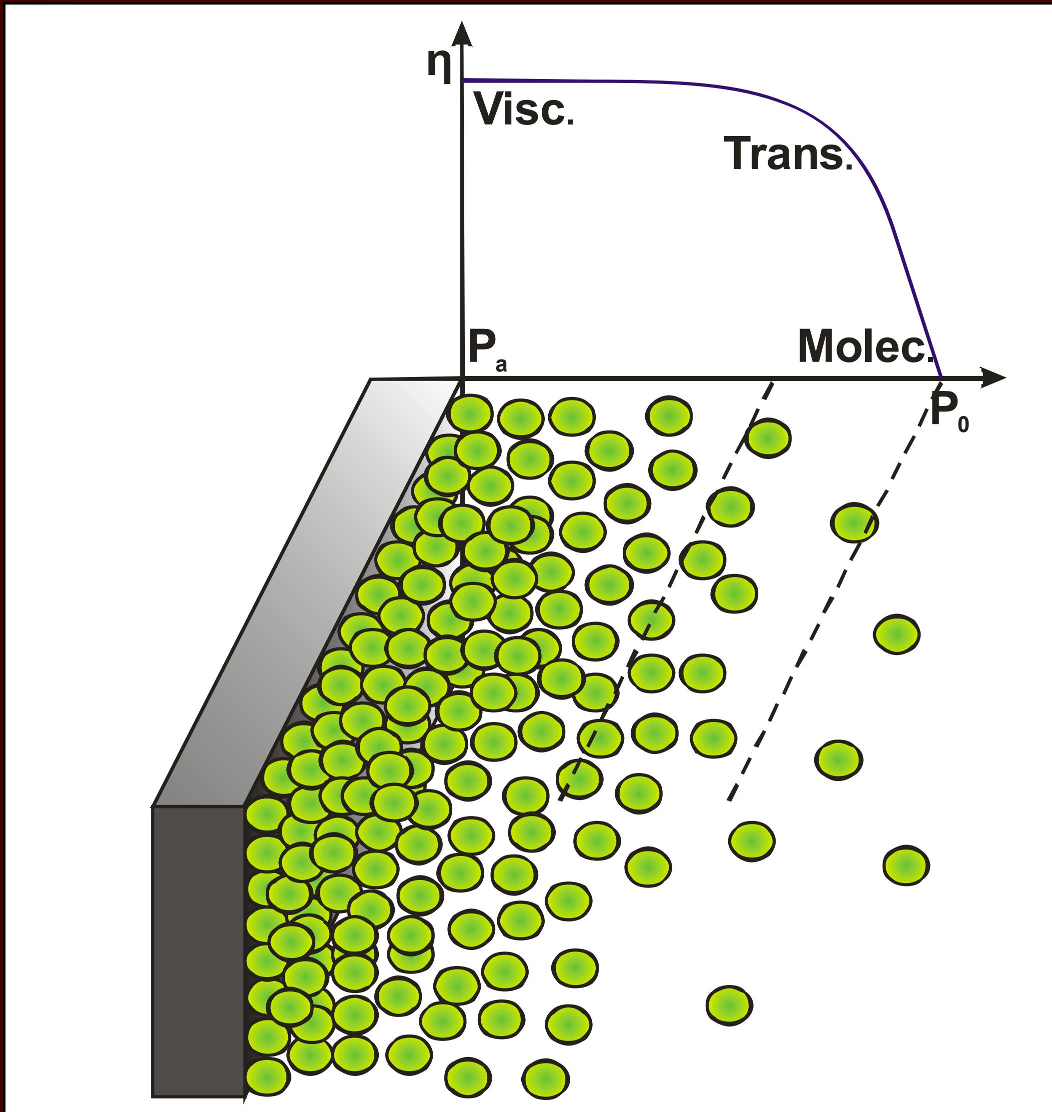
HELIUM

$M=4,003\times10^{-3}kGmol^{-1}$
$T=10^4K$
$d_0=2,22\times10^{-10}m$
$p=10^{-11}Pa$ (near crone)

$L_{MB} = 0,64\times10^{11}m = 64000000km$

$Z_{MB}= 11,32\times10^{-8}s^{-1}= 3,57year^{-1}$

reletionship $\eta = f(p)$



Direct implication: flow in pipes and trough holes

Indirect implication: heat transfer, light and voice transfer

Transfer coefficient of heating for viscous gas

$$\Lambda_c = K \frac{\sqrt{T}}{d_v^2 \sqrt{M_0}}$$

where:
K = gas coefficient
d_v= diameter of gas particle
M_0 = atomic weight of gas molecule
Q = heat

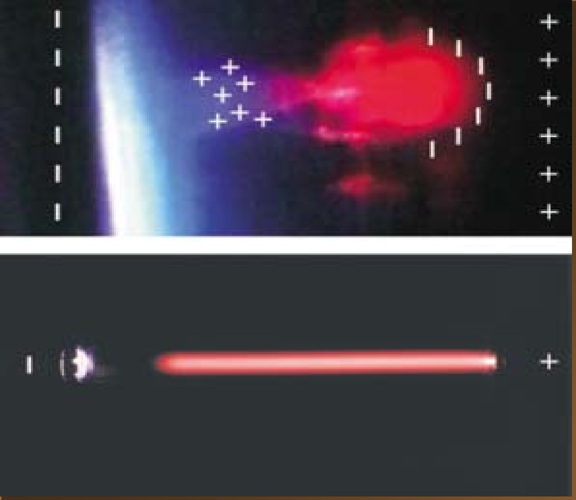
$$\Lambda_c = \frac{Q}{\frac{\partial T}{\partial x}}$$

Transfer coefficient of heating for molecular gas

$$\boxed{\Lambda_c = \Lambda_0 p}$$

where:

Λ_0 = f (avarage coefficient of accomodation α_0, the rate of proper heat γ_c, molecular weight $1/M_0$)

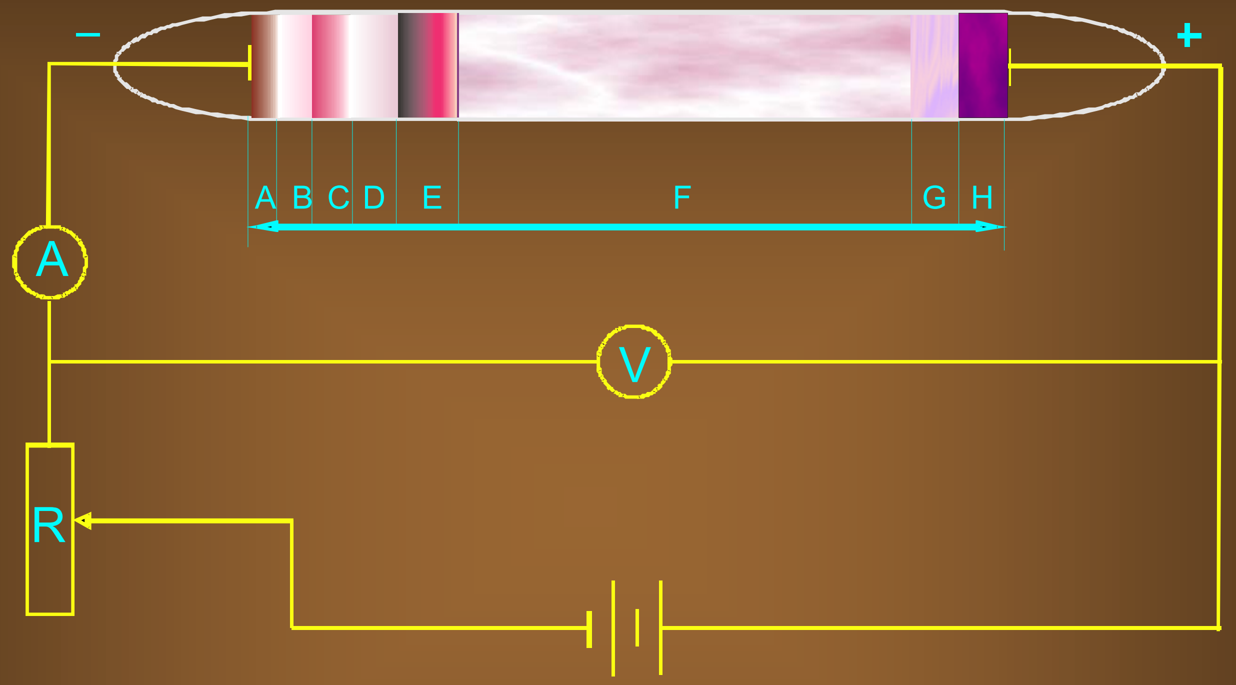


Transportation of electric energy

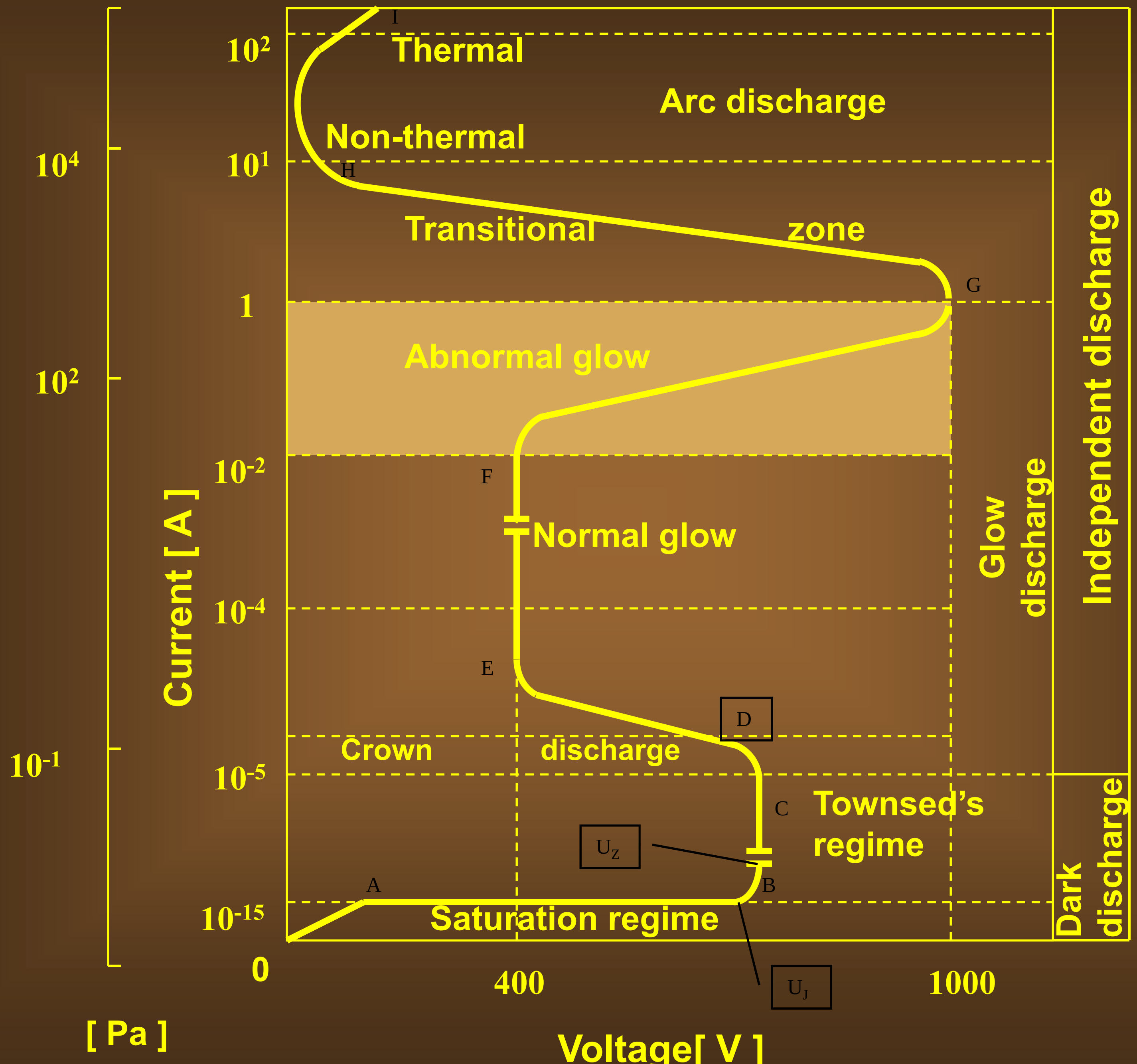
1. Is connected with the motion of energy supports which are electrons and ions, when the motion is not disturbed by vacuum enviroment.
So, the higher the vacuum is, the fewer collision, the lower dissipation of energy and in consequence the smaler losses will occur.

2. Is connected with glow discharge. The presence of gas particles on the proper level of pressure makes it possible to obtain the phenomenon creating electron discharge, which start from exciting and ionization of gas atoms and molecules.

3. Is connected with measurements of vacuum pressure, in which the ions and electrons are used to quantyfying of gas particles.



A- Aston dark space, B- cathodic glow, C- cathode dark space (Crooks, Hittorf), D- negative glow, E- Faraday dark space, F- positive column, G- anodic dark space, H- anodic glow



Thermal
Arc discharge
Non-thermal
Transitional
zone
Abnormal glow
Normal glow
Crown
discharge
Townsed's
regime
Saturation regime
Glow
discharge
Independent discharge
Dark
discharge
Current [A]
Voltage[V]
[Pa]
10^2
10^1
1
10^{-2}
10^{-4}
10^{-5}
10^{-15}
0
400
1000
10^4
10^2
10^{-1}
A
B
C
D
E
F
G
H
I
U_Z
U_J

Comparison the inner energy of agregate states

No.	Kind of state	Energy range	Details about energies of state
1	Solid st.	$U_0 < W_k < 0{,}05$ eV	Between bonding energy at 0K and bonding energy of solid state
2	Liquid st.	$0{,}05 < W_k < 0{,}3$ eV	Between bonding energy of solid state and minimal value necessary to break the Van der Waals forces
3	Gas st.	$0{,}3 < W_k < 20$ eV	Between the minimal energy of Van der Waals forces and lower than ionization energy
4	Plasma st.	$20 < W_k < 2x10^6$ eV	Between the ionization energy and lower then nuclear bonding energy
	Low energy plasma	$20 < W_k < 10^3$ eV	Between ionization energy and arc discharge

To qualify an electron or ion motion, we have to remember, that:

- **in the case of plasma it will depend on the kind and quantity of loads influencing it,**

- **and in the case of vacuum – it depends on free route and initial energy towards the motion.**

Two mechanisms of influences on electric load:

- **deflection of running track of beam load in particular direction in magnetic field,**
- **speeding up of beam load in electric field,**

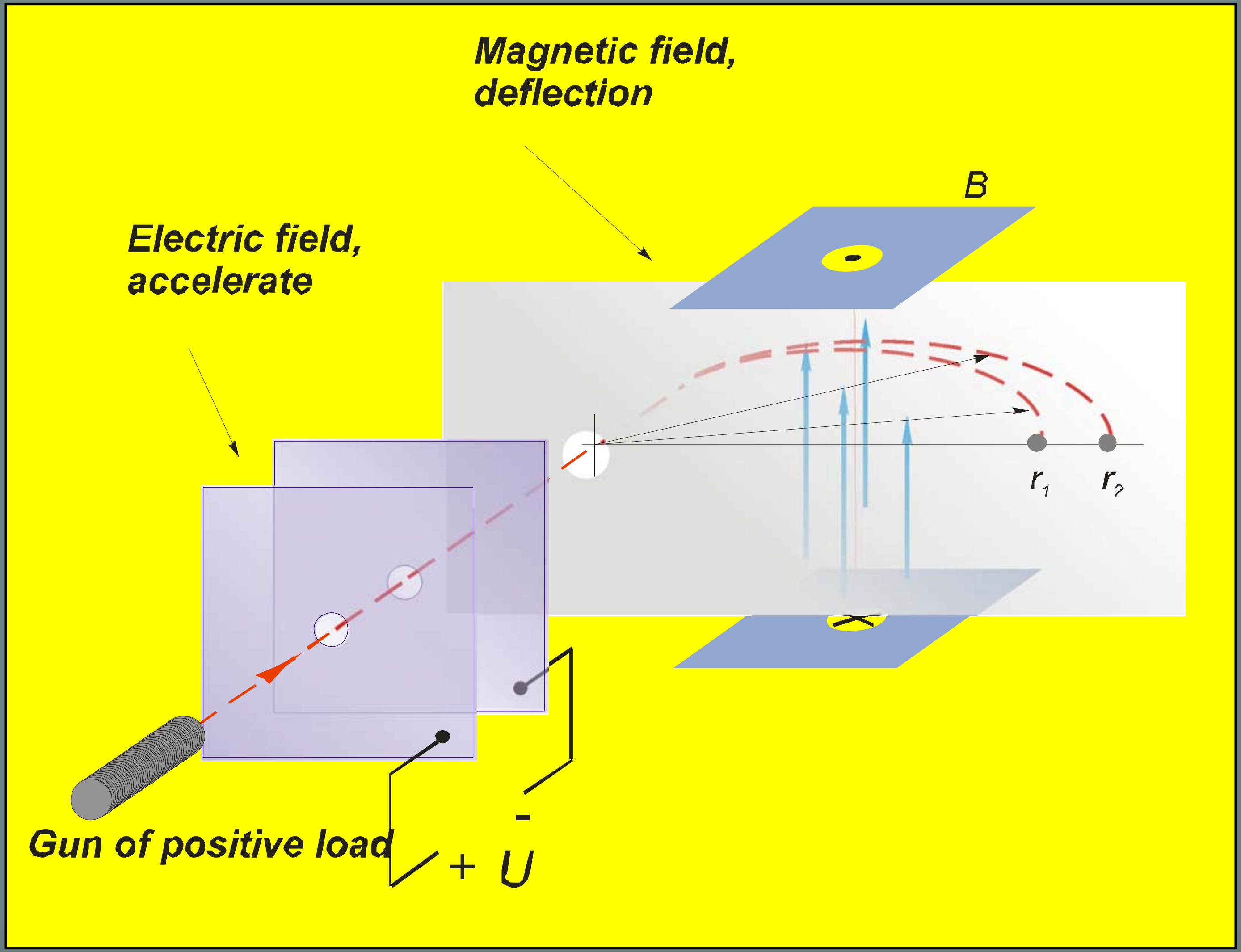
which can be presented by this equation:

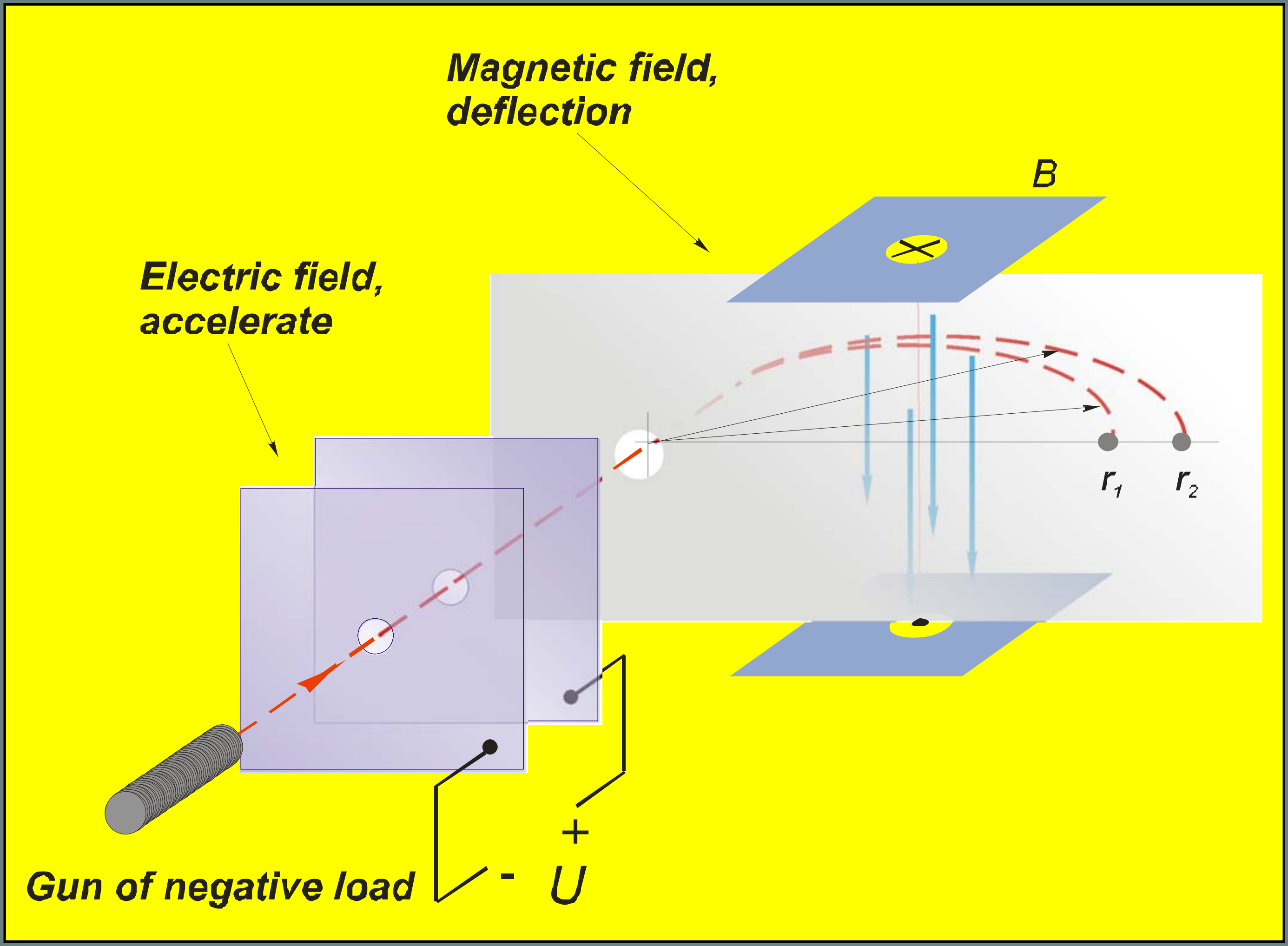
$$\frac{d}{dt}(m_e\vec{V}) = -e[\vec{E} + (\vec{V} x \vec{B})]$$

where: $\vec{V}$ = speed of electron

$\vec{B}$ = magnetic field

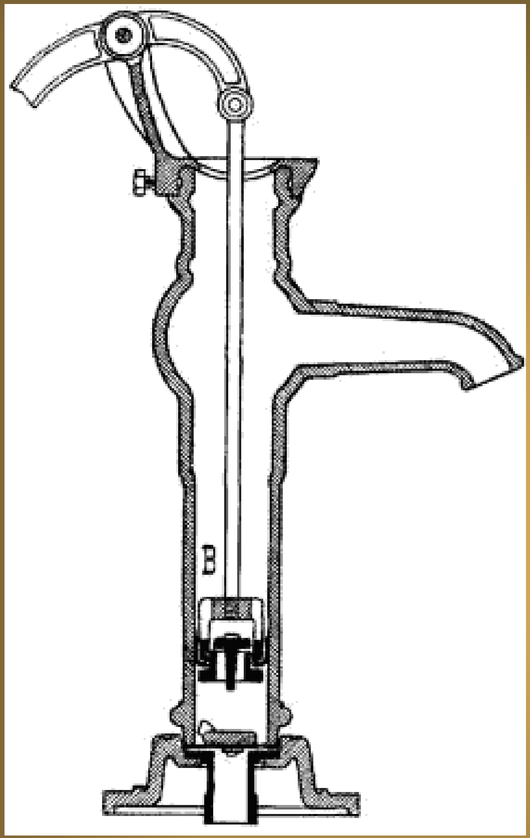
$\vec{E}$ = electric field

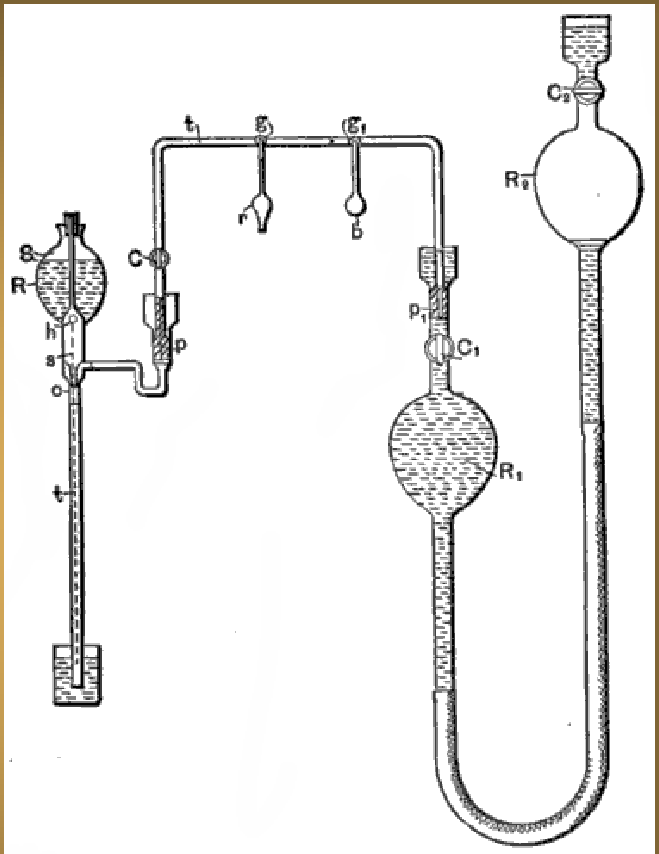

Magnetic field,
deflection
B
Electric field,
accelerate
r_1
r_2
Gun of positive load
-
+ U



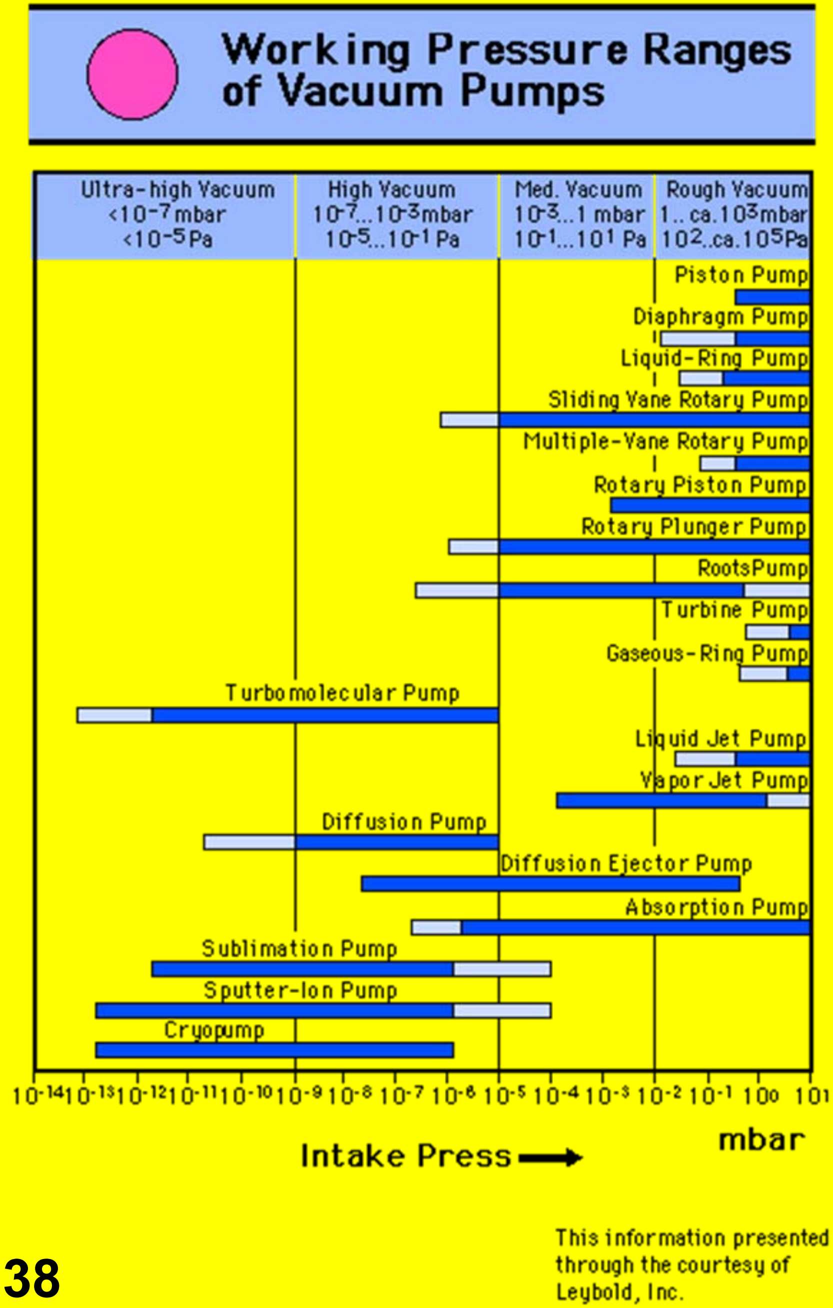
Magnetic field,
deflection
B
Electric field,
accelerate
r_1
r_2
+
-
U
Gun of negative load

PUMPS





Water or Hg pumps

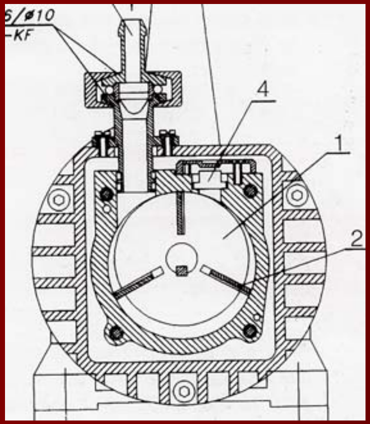


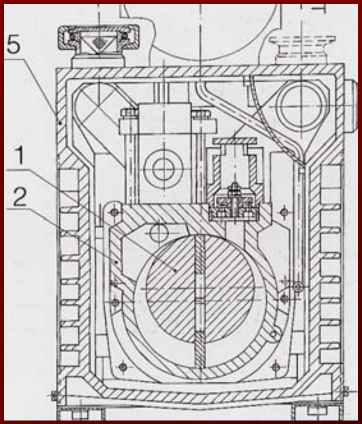
There are as many vacuum pumps as there are uses for them.
However, it is possible to narrow the field down to two broad categories: transfer pumps and trapping, or entrapment, pumps.
Entrapment pumps works by trapping molecules within a confined space.
Transfer pumps (also known as kinetic pumps) transwes gas from the vacuum side to the exhaust side.

Examples are:
the cryopumps, which traps liquified gas molecules in a cold trap, and the ion pumps, which uses ionized gas that is magnetically confined,
as well as the turbomolecular pumps uses momentum to accelerat the gas molecules

Rotary oil pump

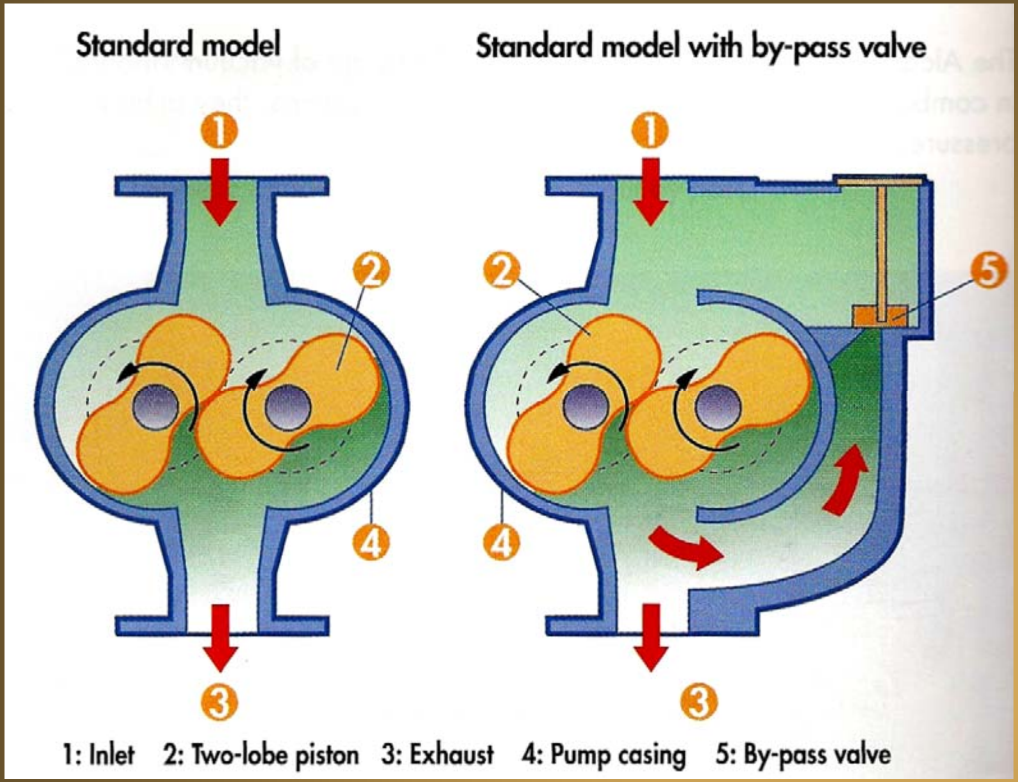
Rotary oil pump





Inside the rotary pump there is rotor with two or three vanes expended by a springs.
The rotor situated eccentric of the chamber divides it into two parts: inlet and outlet. During the rotation in one part gas is sucked, in other gas is compressed and removed outside by a special valve. This valve opens only when the particular pressure of compression is obtained.

All the grinding parts are lubricated with oil inside the chamber as well. Oil is the stuffing medium, that's why the name of the pump is rotating oil (lubricated) pump. When the pump has 2 chambers, than it is called a 2 step pump.



Roots pumps

In the chamber of the pump two special rotors revolve in opposite directions. In order to obtain the pumping effect , rotors have to rotate with the high speed (3000cycle/min). The pump has not lubrication oil, so it is a dray pump.

Since the rotation are so high, the pump has to work with the pressure lower than atmospherical one because with high resistance force of gas molecules - rotators could be overheated.

Their diameter would be changed and the pump could be damaged. That's why the pamp works with reduced pressure, near 1Pa, made by initial rotary –oil pump, for ex. giving the final pressure of 10 $^{-2}$ Pa.

Aggregates

Vacuum groups are systems designed for customers which need to couple single stage or two-stage vane vacuum pumps to Roots pumps.

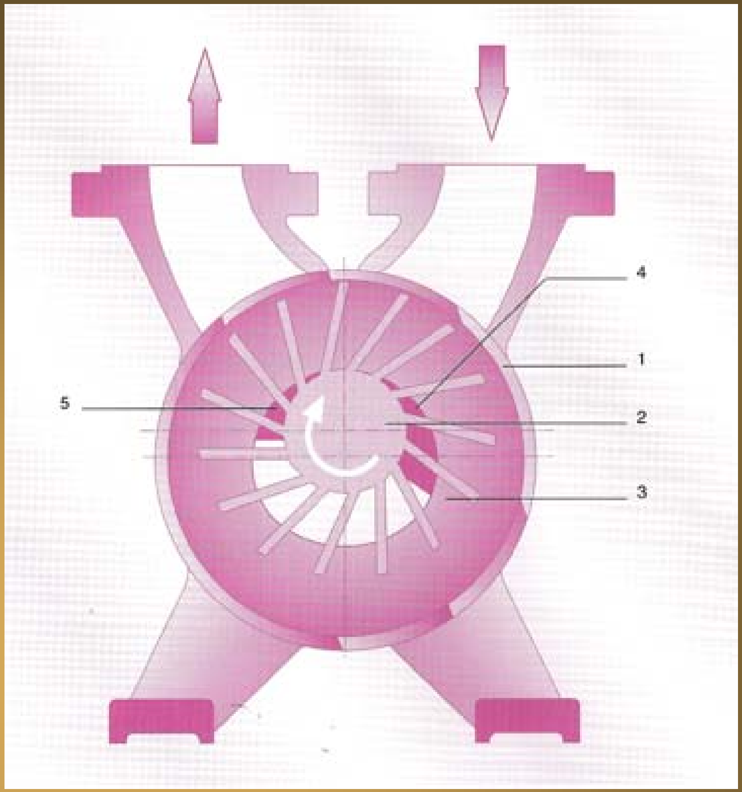
This solution allows to get large capacity related to very high ultimate pressure (up to 10^{-5}hPa) in relatively limited room.

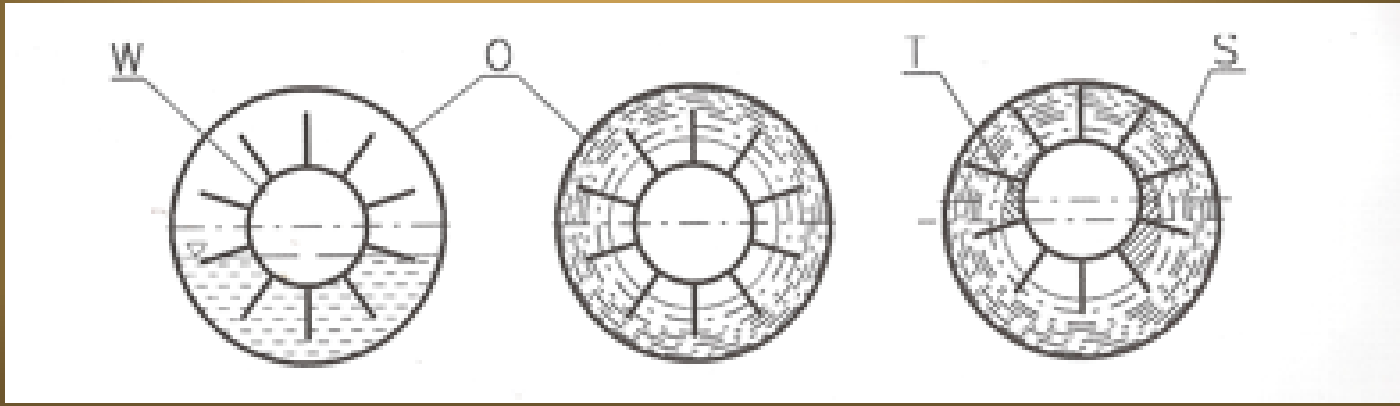
Those sytems are usually used for degassing process, heat treatments, drying systems, freeze-drying process, closed chamber pumping down, etc.

The group characteristics are defined depending on customer requirements.

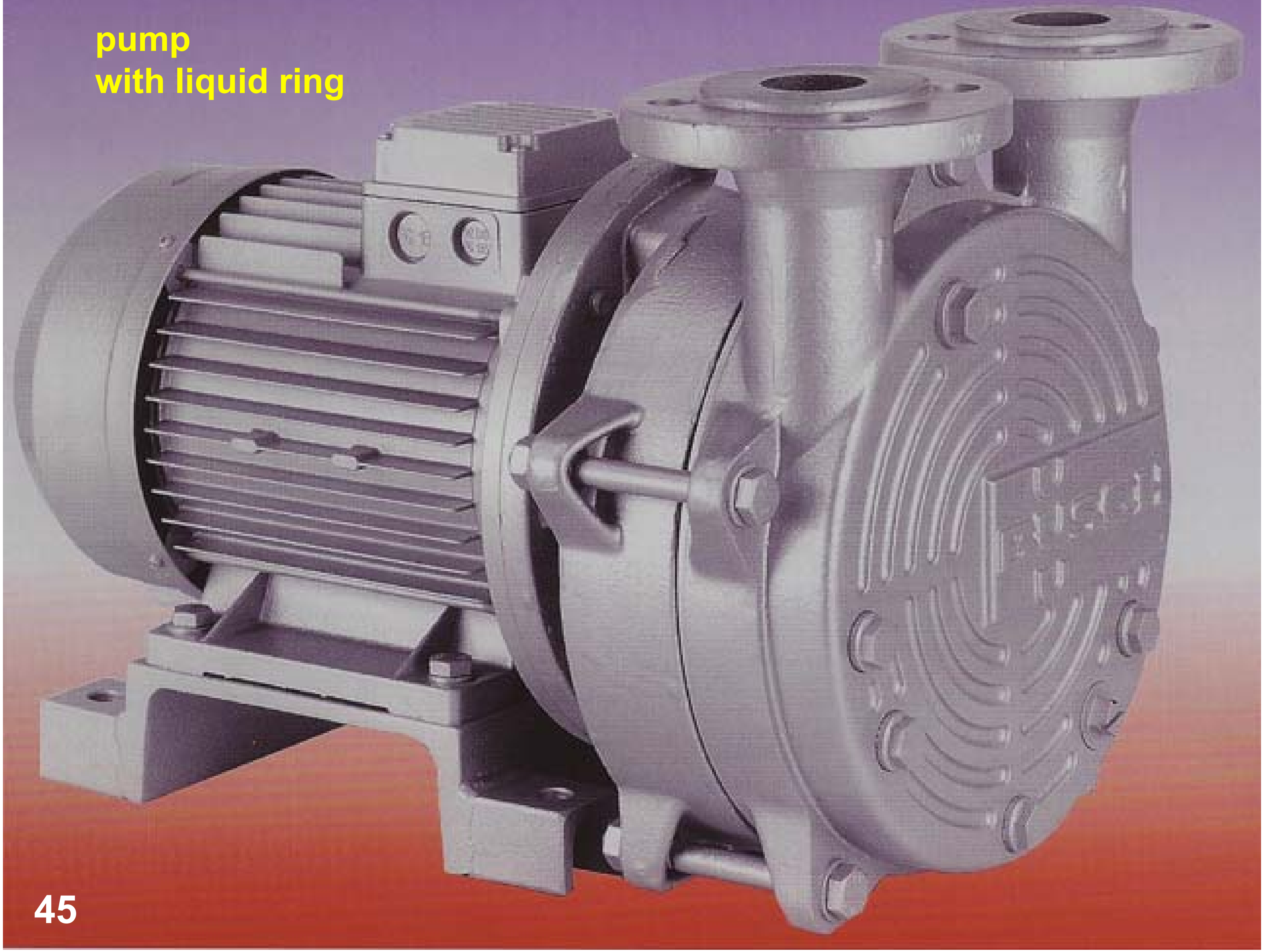
Pump
with liquid ring

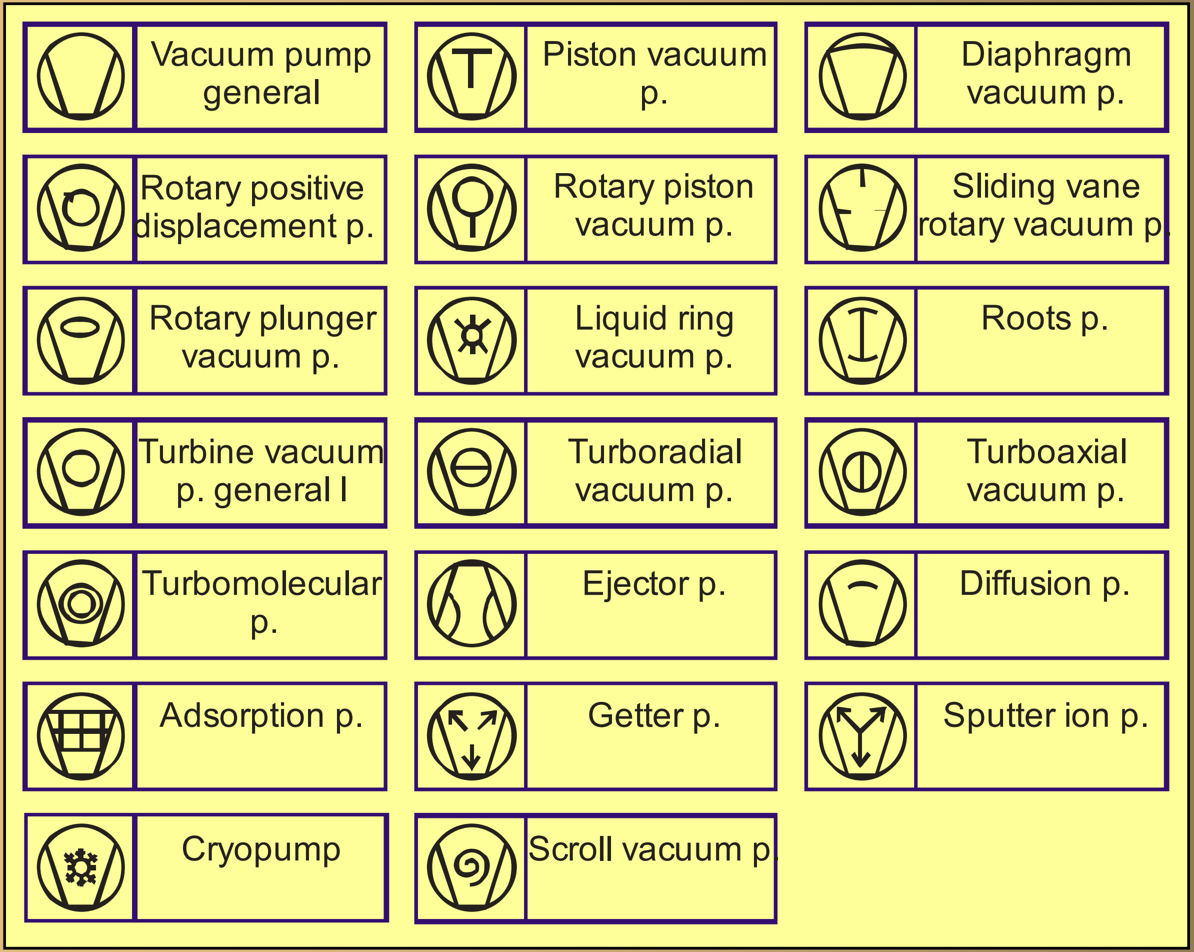
usualy is used there, where a lot of water vapour is blowing up.





pump
with liquid ring





The proposal of application a tremolant coil as a rotor. On the left side are shown the symbols of main types of pumps.

Where does these pumps works?

That are an examples for the various fields of applications:

* Coating technology
* Chemical process technology
* Metallurgy/ construction of melting furnaces
* Packing industry
* Central vacuum systems
* Helium leakage detection units
* Manufacture of lamps
* Drying technology
* Machine construction
* Electronics
* Automotive industry

The most common type of pump for use in high vacuum applications is diffusion pump.
The original diffusion pump fluid used by Irving Langmuir in 1915, was mercury. Because of very high toxic properties of mercury, from a few decades the oil fluid is used.

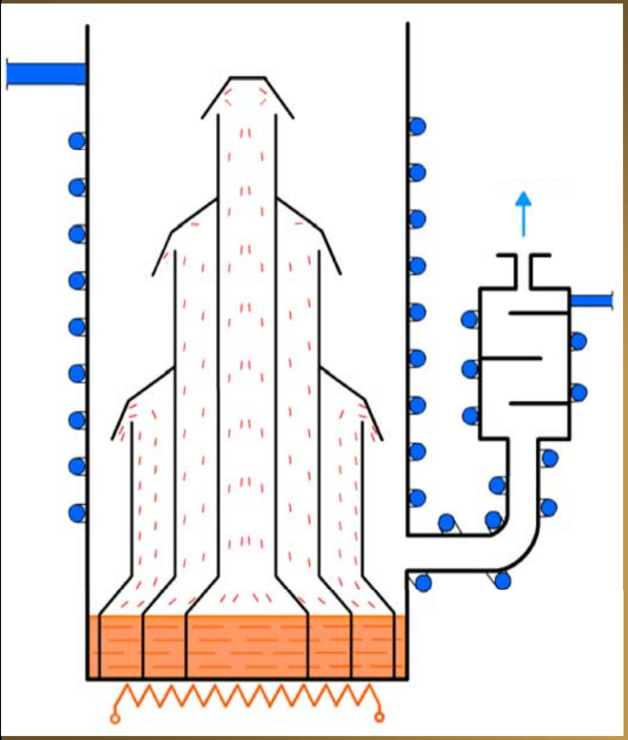
The level at which a vacuum diffusion pump begins to operate i is pressure of 10-3 Torr. The final pressure is 10-9Torr. In spite of that involve the forepumps.

Diffusion pumps are reliable, simple in design, they run without noise or vibration and they are relatively inexpensive to operate and maintain.

Diffusion pumping is still the most economical means of creating high vacuum environments.

These pumps also tolerate operating conditions such as excess particles and reactive gases that would destroy other types of high vacuum pumps.

Diffusion oil pump



$$D \approx \frac{1}{d_0^2 \sqrt{M_0}} \times \frac{T^{3/2}}{p}$$

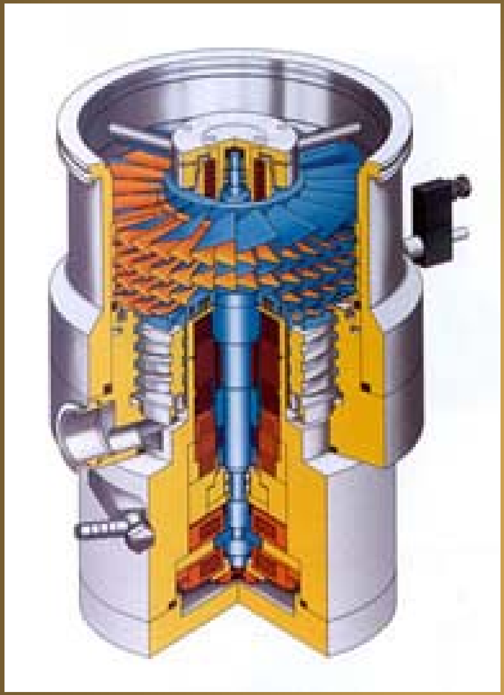
vertically stacked cone-shaped jet assemblies

The vaporized oil moves up and is expelled through the jets. On the boundary of a space with a gas and the jet of oil vapor two processes occurs. There are diffusion of gaseous molecules to the vapor jet of oil and transportation the gas molecules to the cold walls

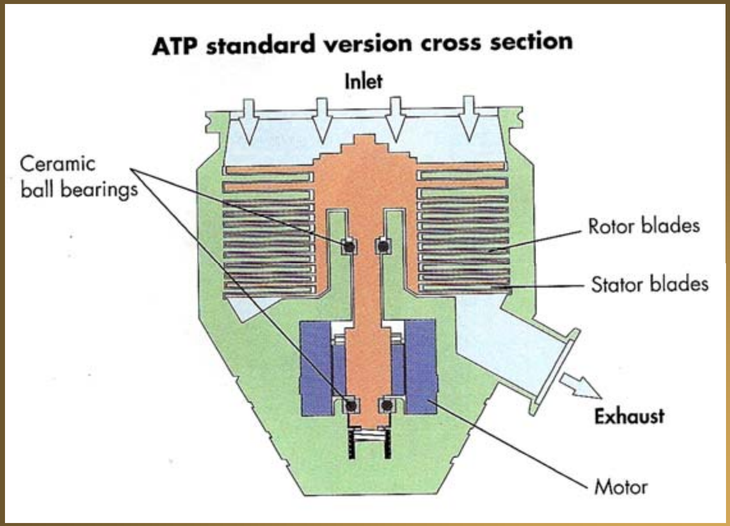
The most often used types of oil :

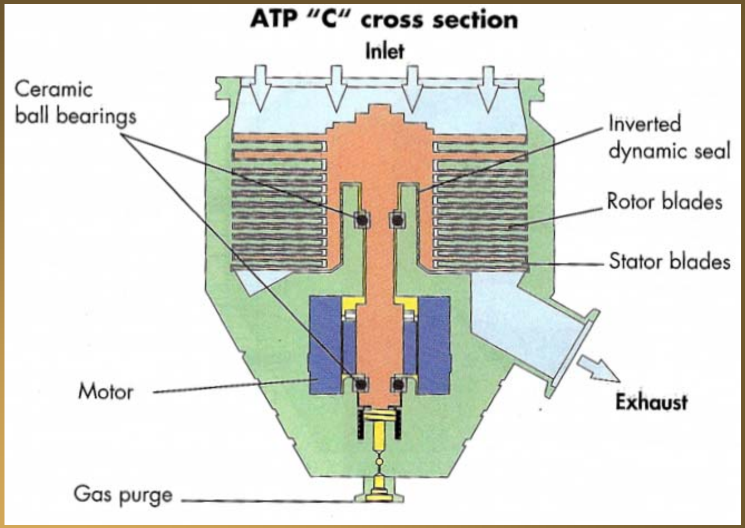
Oils	P (Pa)	M (kg/mol) E -3	Relative price
Mineral	1x10E-5	350-450	1
Silicone (DC-705)	4x10E-8	546	2
Organic (Santowac 5)	1x10E-8	454	15
Perfluoropolyesters (Fomblin, Krytox)	3x10E-7	2000-7000	30

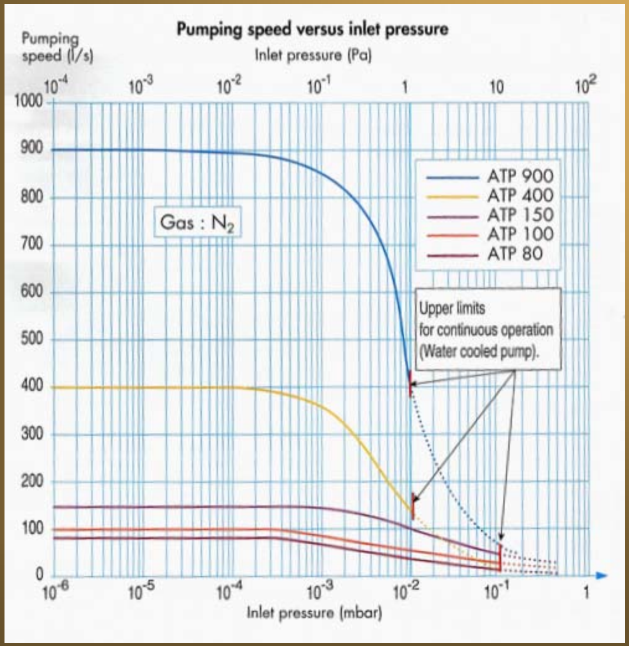
Turbo-molecular pomp



Disks with a variable setting of blades


ATP standard version cross section
Inlet
Ceramic
ball bearings
Rotor blades
Stator blades
Exhaust
Motor


ATP "C" cross section
Inlet
Ceramic
ball bearings
Inverted
dynamic seal
Rotor blades
Stator blades
Motor
Exhaust
Gas purge


Pumping speed versus inlet pressure
Pumping
speed (l/s)
Inlet pressure (Pa)
Gas : N_2
ATP 900
ATP 400
ATP 150
ATP 100
ATP 80
Upper limits
for continuous operation
(Water cooled pump).
Inlet pressure (mbar)

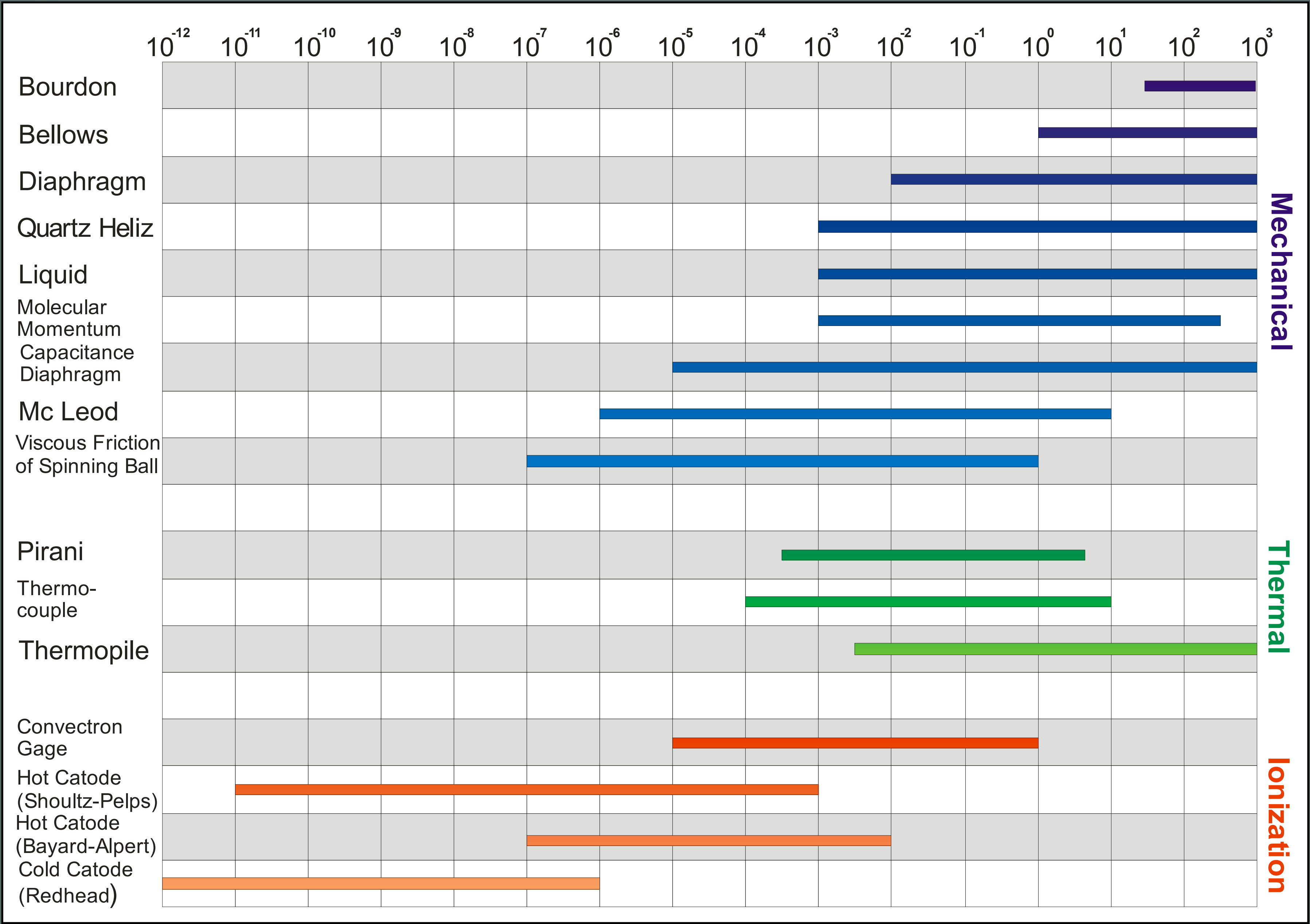
Vacuum measurement and leak detection

Where the vacuum measurement is needed?

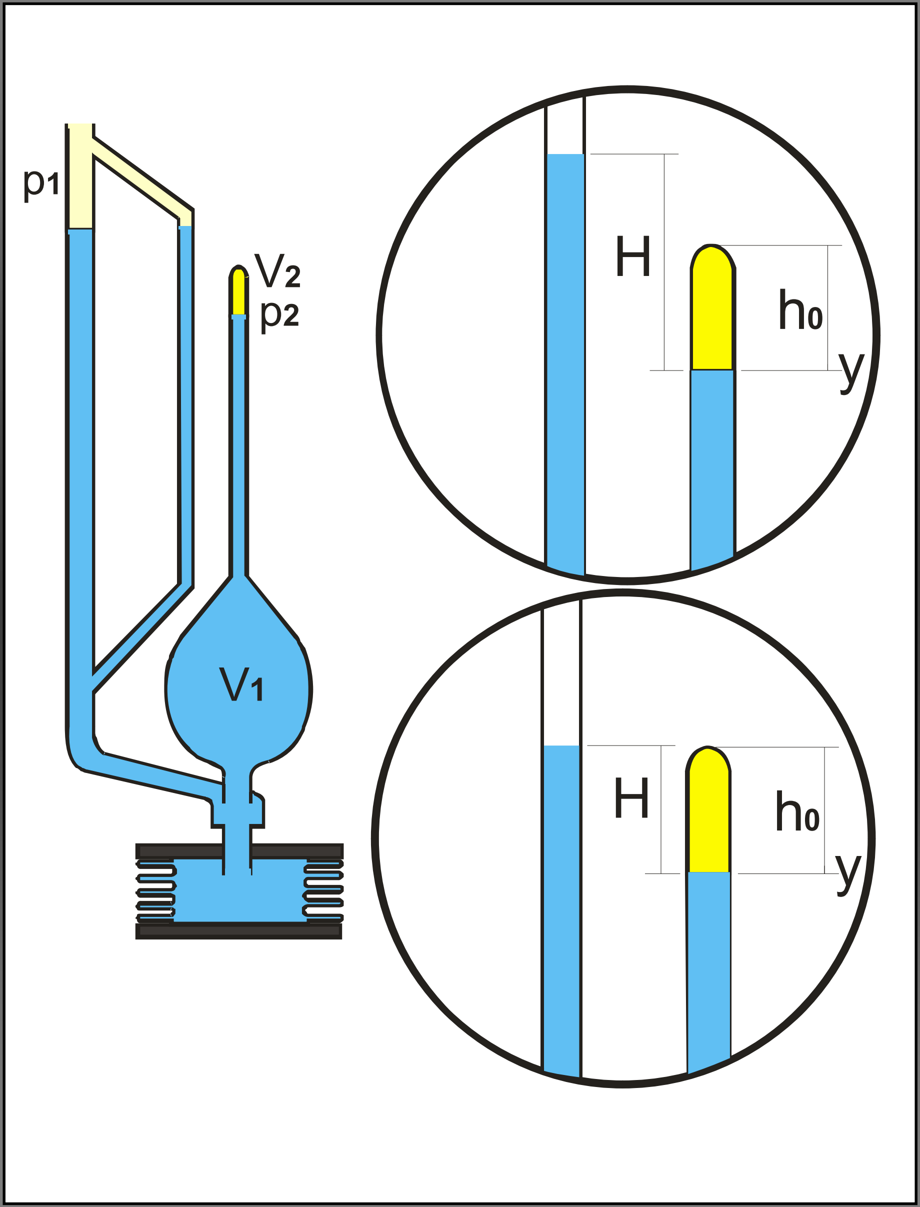
Mechanical engineering
Car industry; filling of brake and air conditioning systems
Vacuum conveying technology
Packaging technology
Isolation vacuum
Chemical processes
Absolute pressure measurements in gas mixtures
Drying and degassing processes
Solvent recovery
Vacuum pressure control in existing central vacuum supply systems
Electrics/electronics/optics
Evaporation and coating systems
Monitoring and controlling of sputter systems
Semiconductor technology (CVD, plasma etching etc.)
Ion implantation
Lamp production
Analytical instruments and surface physics
ESCA, SIMS, AES, XPS
Electron microscopy
Crystal growing
Gas analysis systems, mass spectrometers

Research
Measurement of ultimate pressure in UHV systems
Application in MBE systems
Particle accelerators
Beam guidance systems, cyclotron
Fusion experiments
Space simulation chamber
System control/pressure control
Pressure checks on backing pumps and vacuum systems
Safety circuits in vacuum systems, protection of vacuum gate valves
Control of ionization vacuum gauges
Pressure measurements on HV pump systems, e.g. diffusion, TMP, cryo pump systems
Venting systems
Valve control, pressure dependant systems control
Simple pressure control arrangements
Calibration
Calibration of vacuum gauges and mass spectrometers
Reference instruments for the determination of the physical properties of gases
Precision measurements of low pressures also in the presence of corrosive or reactive gases
Miscellaneous
Vacuum annealing, melting, soldering and hardening furnaces
Cooling and air conditioning technology
Electron beam welding

Classification of vacuumeters



Mc'Leod vacuumeter – the secondary pattern



$p_l = c_1 h_0 H$

The pressure measurement consists in comparing the levels of mercury threads in the reference capillary and the capillary after compression. There are applied linear and square-law measuring methods.

$p_s = c_2 H^2$

Thermoelectric vacuum gauge

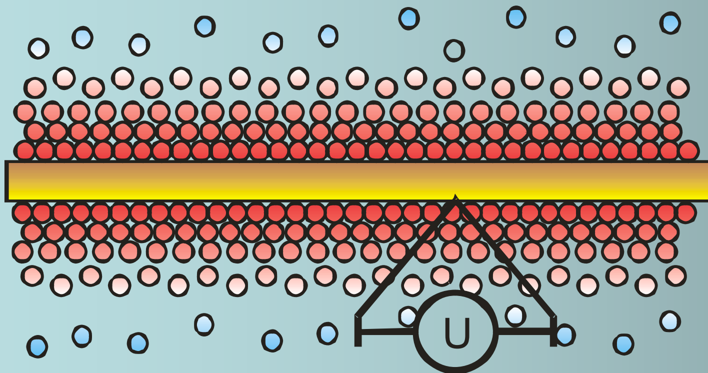
A thermoelectric vacuum sensor is the most popular among the preliminary vacuum gauges. It runs on a gas thermal conduction principle as a function of pressure.

A sensor element consists of a resistance wire, which is heated due to the supply of current. It is in contact with a thermocouple, which is measuring the temperature of a wire.

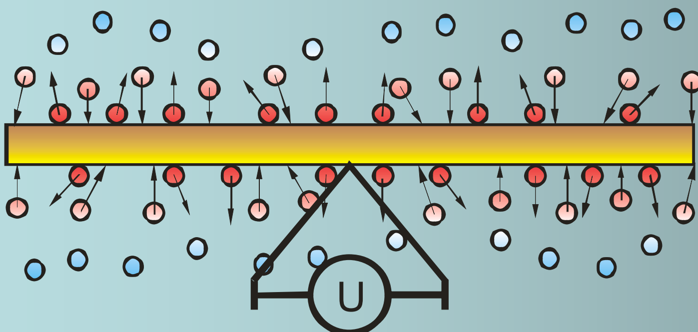
The gas particles being in contact with a wire perform a function of a cooling medium affecting the thermal electromotive force of a thermocouple. It shows that the heat is transferred by low-molecular gases.

The thermal electromotive force of a sensor corresponding to individual pressures is the smallest if the cooling is highest and oposite.

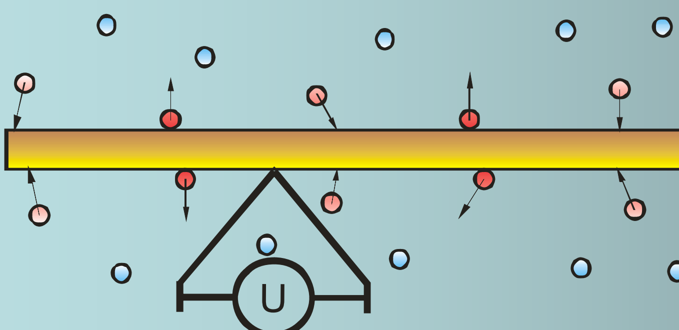
Thermocouple method



$n = n_a \quad p \neq f(U)$



$n < n_a \quad p = f(U)$



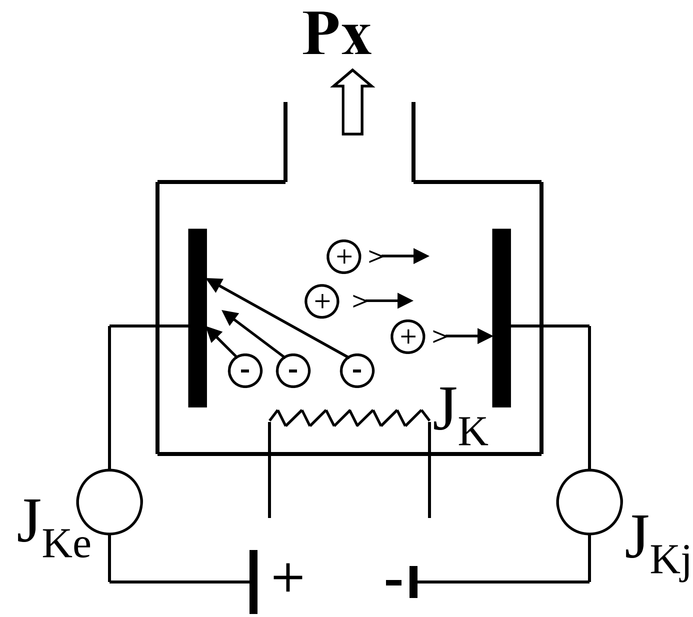
$n <<< n_a \quad p \neq f(U)$

Ionisation vacuum gauge - hot catod

It consists of the cathode, which emits electrons under the influence of high temperature, the anode performing a function of a collector of electrons emitted from the cathode and the electrons generated in the process of gas ionisation and a collector of ions generated as a result of ionisation.

The vacuum measurement consist in measuring the ion current in an ion collector circuit which is proportional to the number of ionised gas particles being present between the cathode and anode at the moment.

$$n_{jśr} \cdot \frac{273}{T} \cdot L = c$$



Conditions of pressure measurement	$J_j >> J_x$
	$J_K >> J_e$

$$J_{Kj} = n_{jśr} \cdot P_x \frac{273}{T} \cdot L \cdot J_{Ke}$$

Ionisation vacuum gauge with a hot cathode.

Vacuum gauges of this type have a limited range of pressure measurement:

From the side of high pressures caused by the large number of gas particles being in contact with the surface and additionally oxidising the cathode which hampers electron emission as well.

From the side of low pressures by the value of so-called noise currents produced by other ionisation media than thermal ones. For ex. there are x-ray and photon radiation.

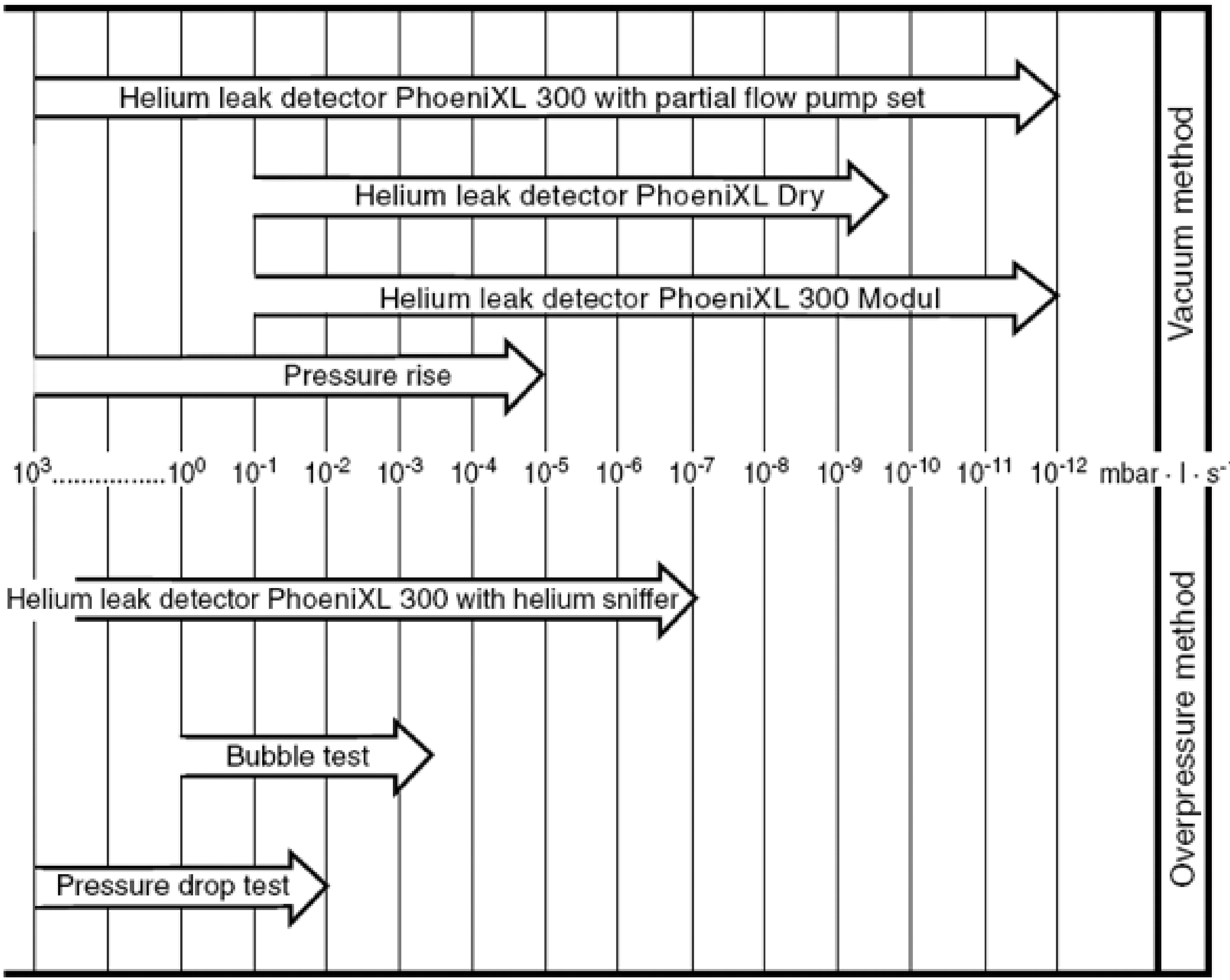
Leak detection systems

The successful obtaining of the low pressure in the vacuum system depends on the correctly selected pumping system and the leak tightness of the whole system. It depends on the leak tightness of individual elements and connections .

A user of vacuum equipment is mostly interested in capability to identify a leakage point and determine its quantity in the event if it is not possible to repair it, by replacement of a faulty element or have serviced by specialists.

Since in case of small leakages, the short-term methods consisting in sealing these leakages using for example relevant greases and polymer chemo- and thermosetting lacquers, could be applied.

Specification of LEAK DETECTION



By Leybold

„soap bubble” test

for relatively large leakages

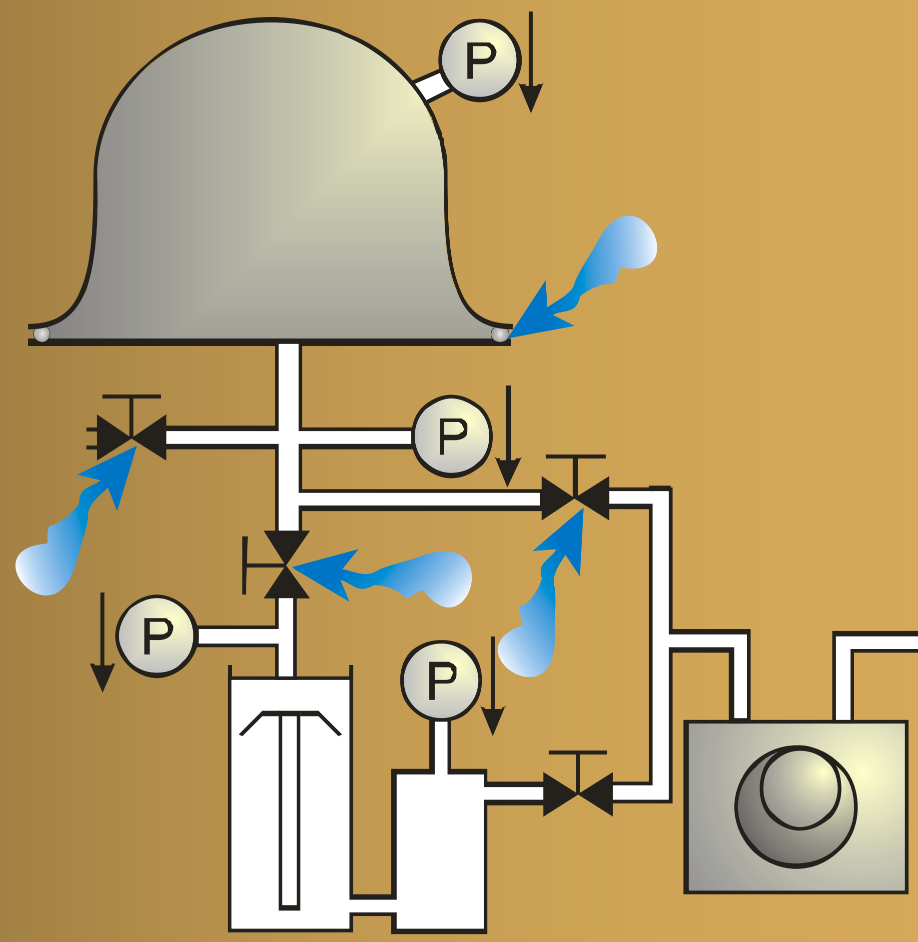
$$I = \frac{pV}{\tau} = \frac{4p\,r^3}{3\tau} \quad [\mathrm{mb\ m^3/s}]$$

where: p = atmospheric pressure
r = radius of an air bubble being formed
τ = time of forming the bubble.

Static method consists in pumping off the system to the possible low pressure and observing the indication of the vacuum gauge after switching off the pump. The sensor located closer to the leakage shall indicate a faster increase in pressure than the others.

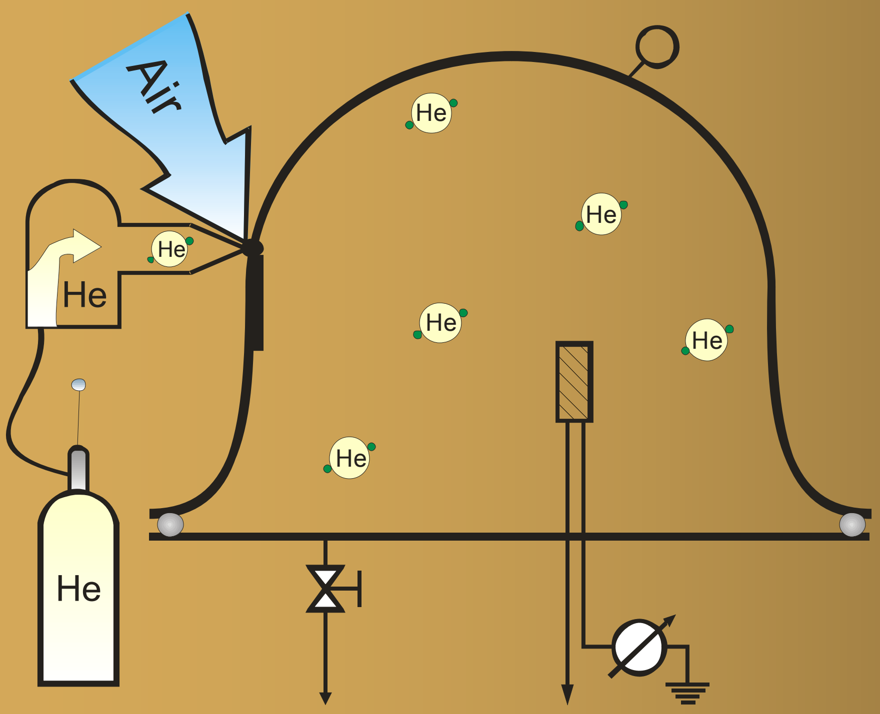
Dynamic method consists in continuous pumping off the system and observing the sensors. The sensor located nearst to the leakage shall indicate a higher pressure, and at the moment of moving it close to the point being tested, the suction of a very volatile medium (for example ether, acetone) is demonstrated by a rapid increase in indications of a gauge

observational methods



Helium detector

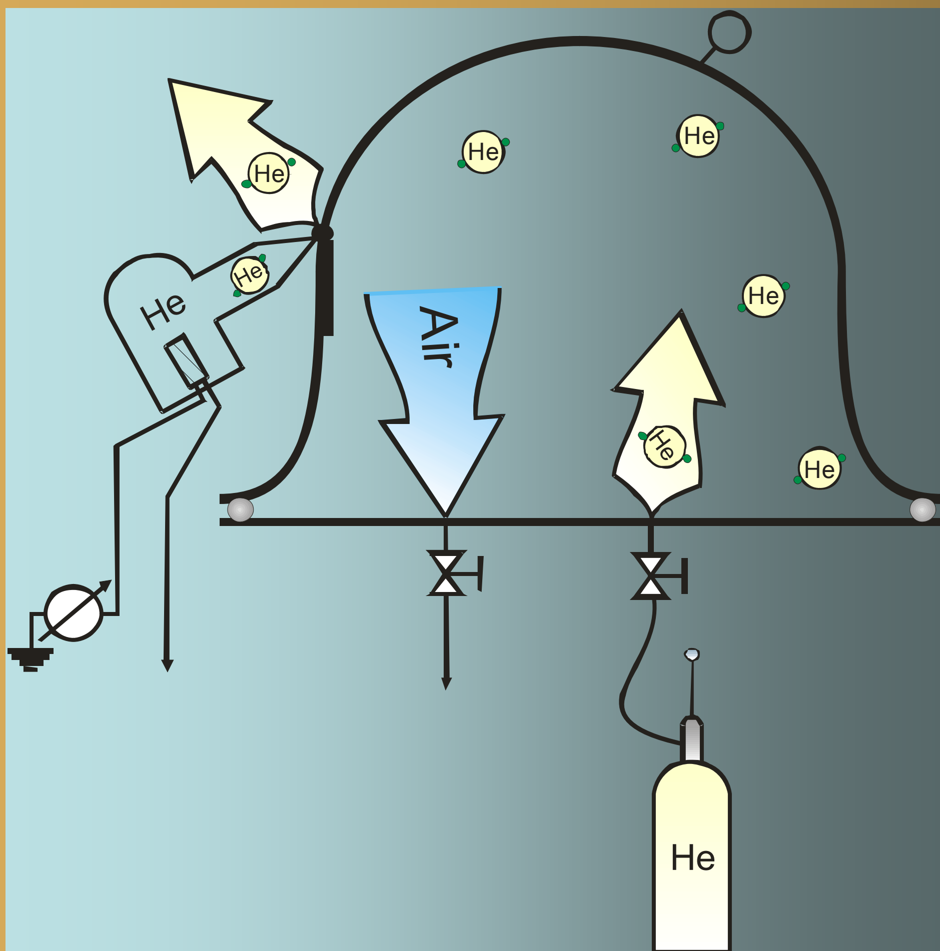
vacuum method



There are two methods of detection:

The first is a vacuum method where the sensor is located inside the vacuum system, which is fanned with helium from outside, using for this purpose the blowing probe with a nozzle allowing the leakage to be precisely spotted.

Overpressure method



The second is an overpressure method

where the system after initial evacuating the air is filled with helium to a low positive gauge pressure and with the aid of a searching probe, also with a nozzle, the leakage point is detected. The searching probe sucks the air with the higher concentration of the helium in a place where the likage is recorded.

Leak detector

PhoeniXL 300

Processes, which require the vacuum enviroment

I grup (500-10^{-1}mba)

freeze-drying, preservation and impregnation, packaging for sterile and hydrophobic products, disinfection, plastic moulding, degassing of moulding sand, centrall installations of small transport and sucking off

II grup (10^{-1}- 10^{-3} mba)

vacuum metallurgy, electronc techniques, heat treatment and welding technologies, CVD and PVD techniques

III grup (below 10^{-3}mba)

nanotechnologies, research equipments

preservation by lyophilization

It is a process consisting in dehydrating the wet material in the frozen state by vacuum sublimation of ice, its airtight sealing and then restoring to the initial state preserving its original properties.

In the food industry it allows preserve the structure, the aroma and the biological activity of plants and meat products similar to natural forms.

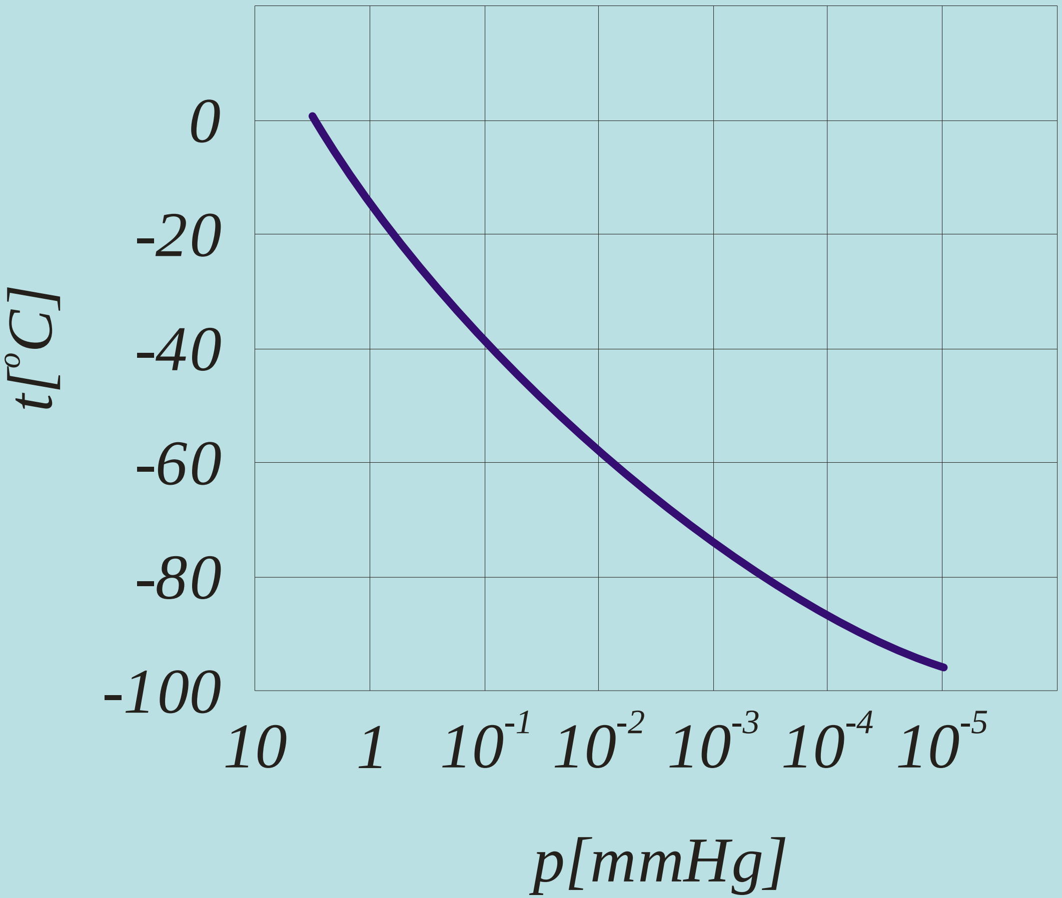
As the temperature is decreasing the pressure of aroma and ester vapours, that shape taste and smell virtues, is dropping.

In the pharmaceutical industry it makes it possible to obtain the biochemically active extracts and antibiotics. It allows the biological activity of plasma, cells and some (connective and osseous) tissues to be preserved.

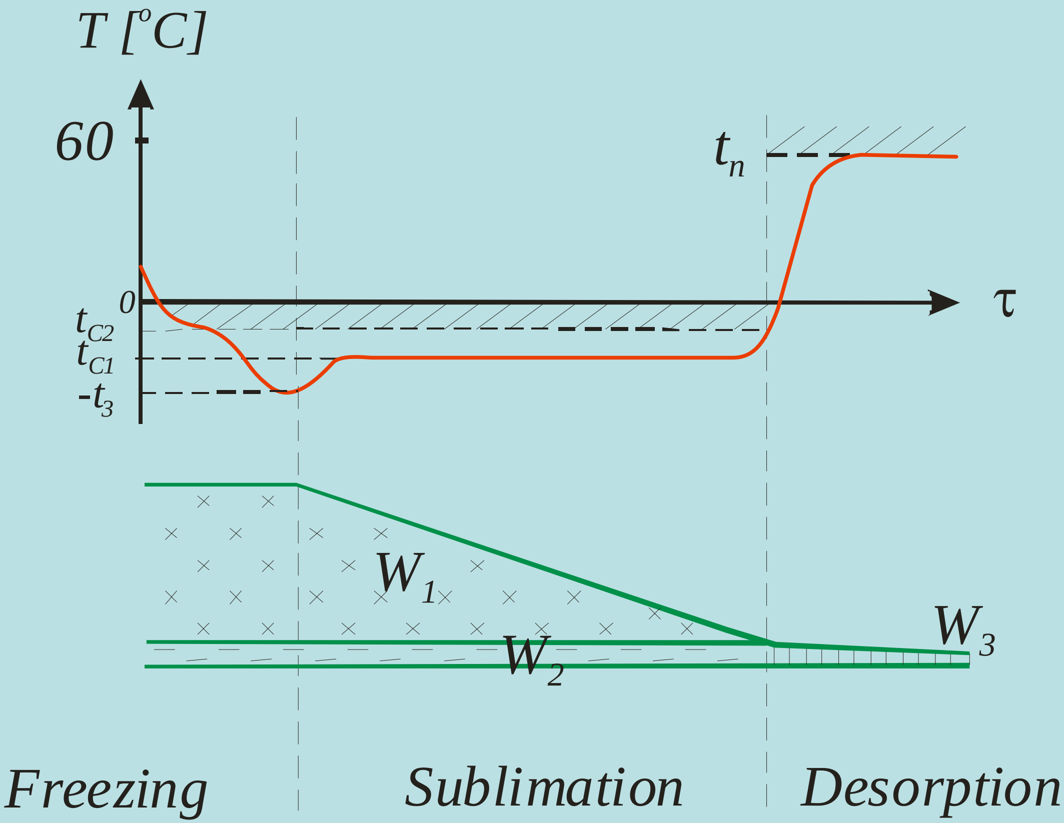
In the drying process under frozen conditions, the important part plays the rate of the product solidification, so that there was not any growth of ice crystals, which could mechanically damage the cells or tissues or bring to the distribution of solution.

Freeze drying

Pressure of ice vapour



A typical production cycle for the fruit-vegetable pulp



t_3 = freeze temperature

t_{c1} = lower temperature of sublimation

t_{c2} = higher temperature of sublimation

t_n = maximal temperature of product

W_1 = freezed pulp

W_2 = not freezed pulp

W_3 = product to packaging

It's important for the product to be at the temperature close to the melting point. If that temperature were exceeded, the obtained liquid would be subject to rapid evaporation (boiling)

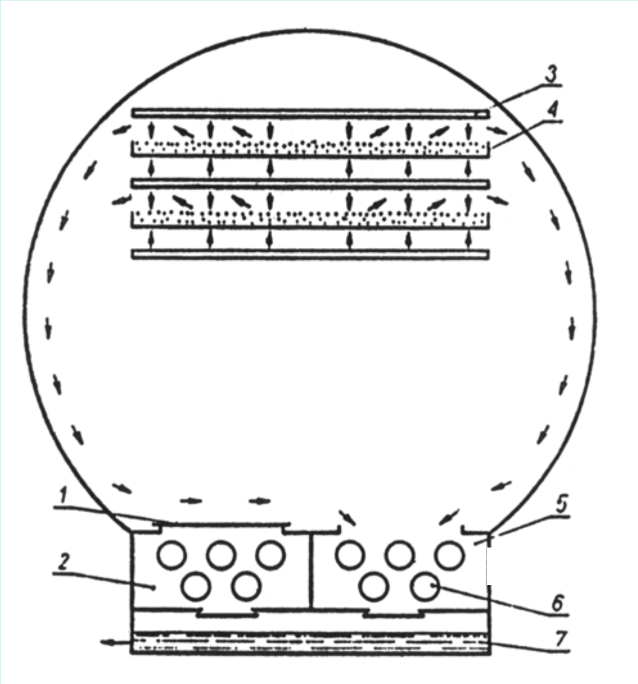
The frozen product is delivered to the freeze-drying chamber and arranged on trays, which are situated on heating panels or are suspended over them.

Then the vapour pressure is generated but applying the high vacuum isn’t necessarily required. The sublimated steam is condensed in the lower part of the chamber on so-called scrubbers-condensers, which are situated in two independent chambers.

They are operated alternately, when the steam on the first scrubber-condenser is frozen, the second one is defrosted. The obtained water is sucked off outside.

The dried and out-gassed products require the hermetic protection mainly against moisture. Therefore, they are vacuum packed in foil boxes using for this purpose packing machines adapted to working in centres or in line.

Freeze-drying chamber



1- shutter,
2,5- scrubbers ,
3- hot plates,
4- plates with products,
6- condensors,
7- tank

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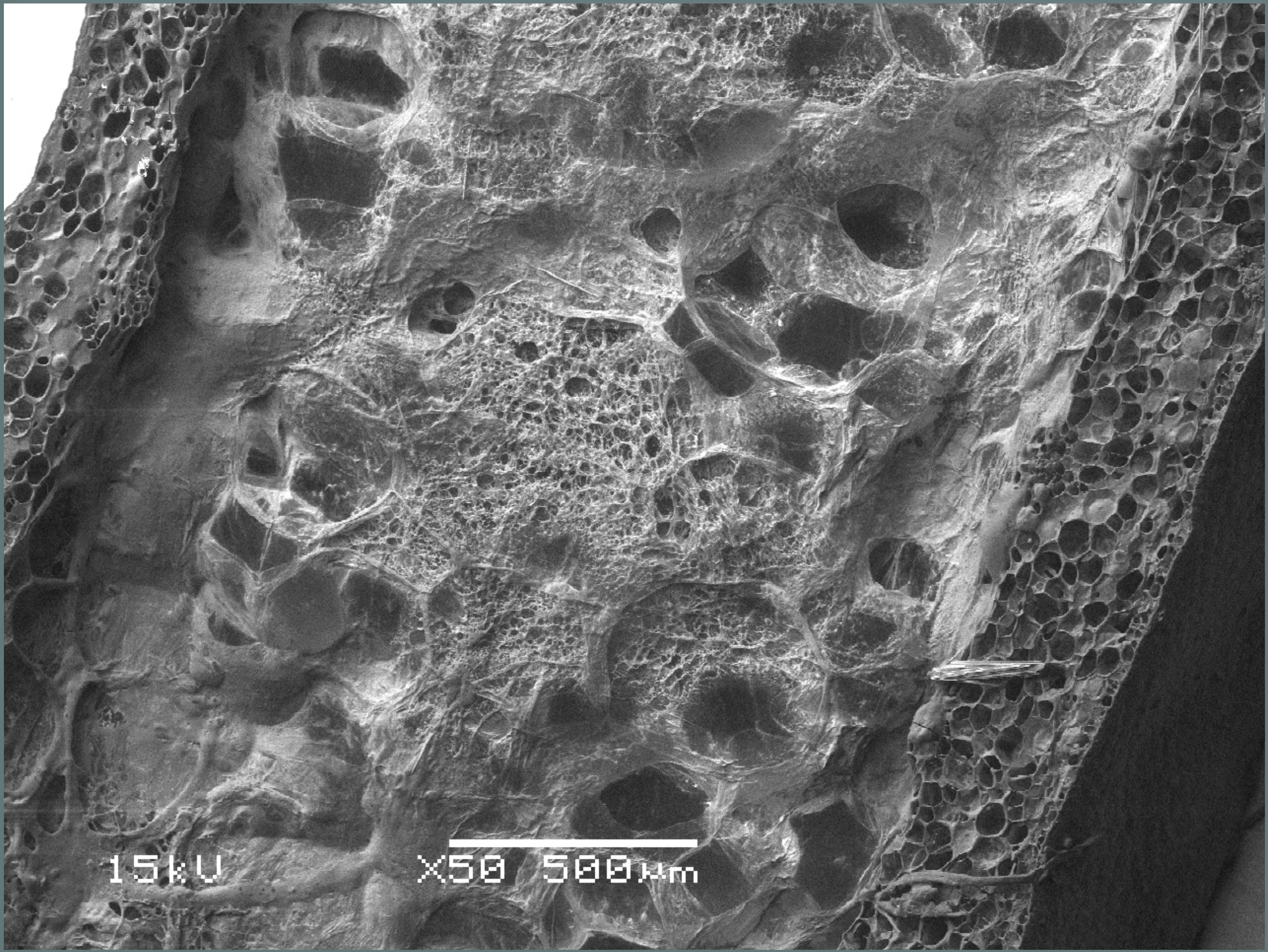
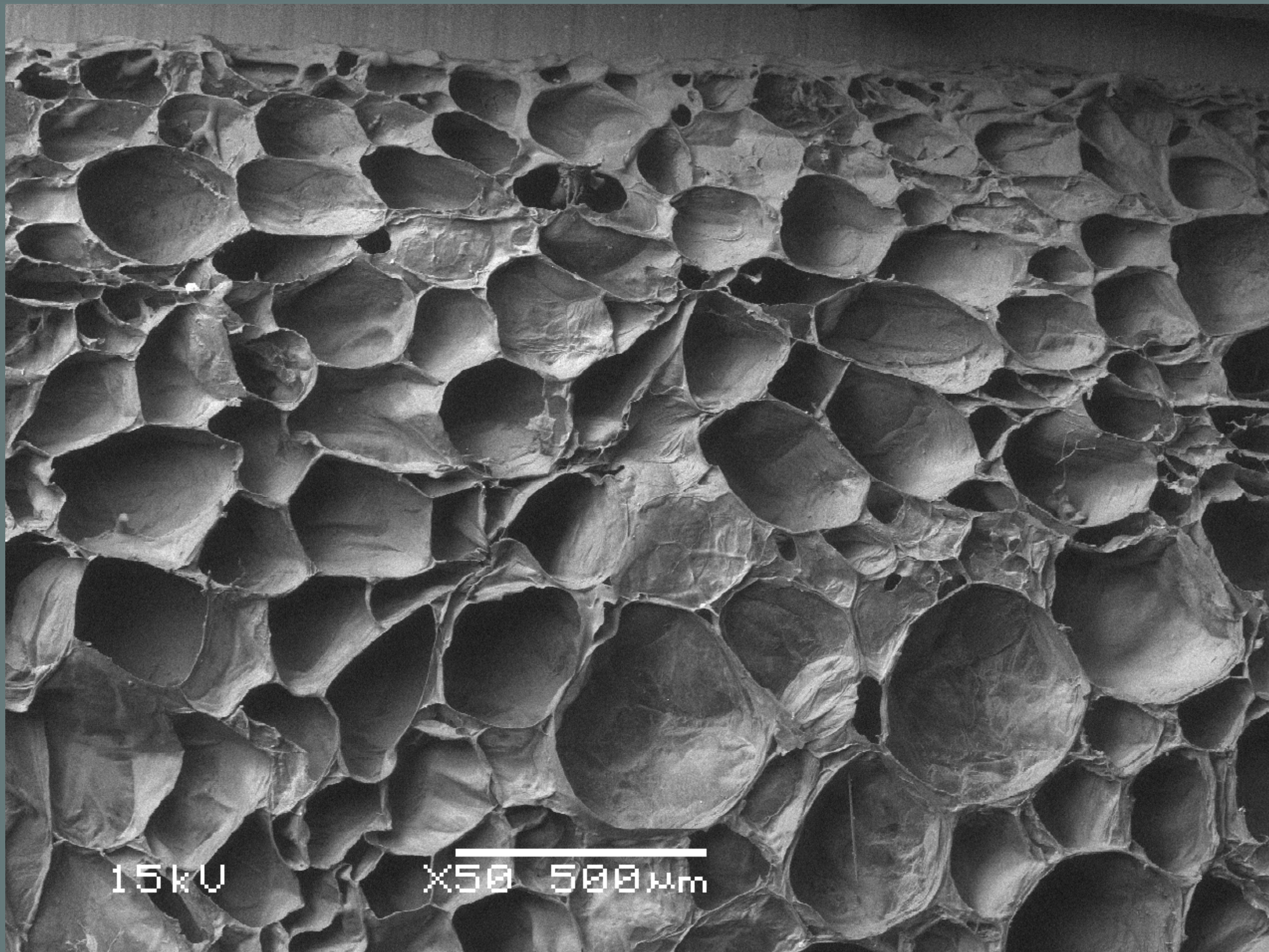
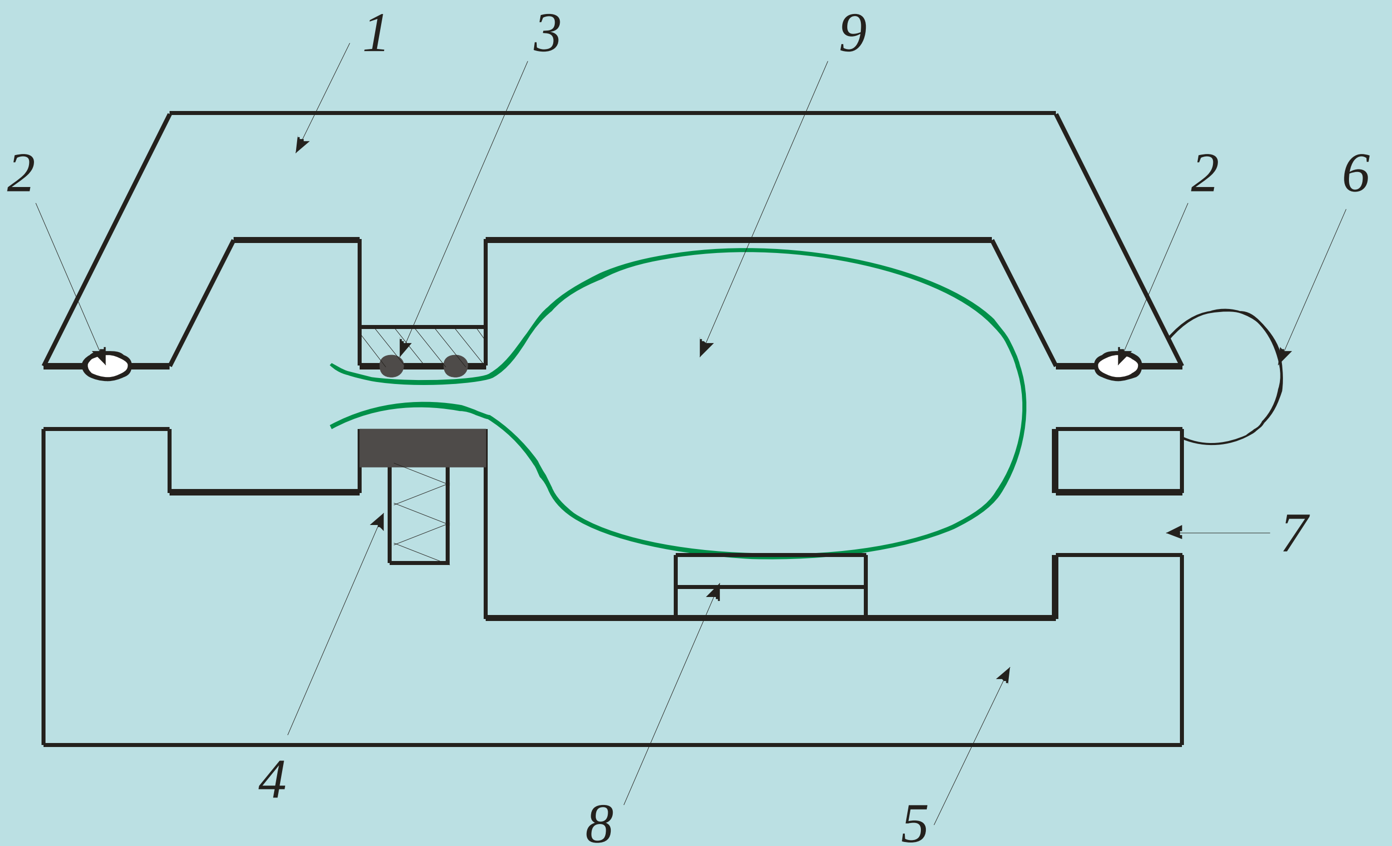
Aloe



Potato



Vacuum packaging



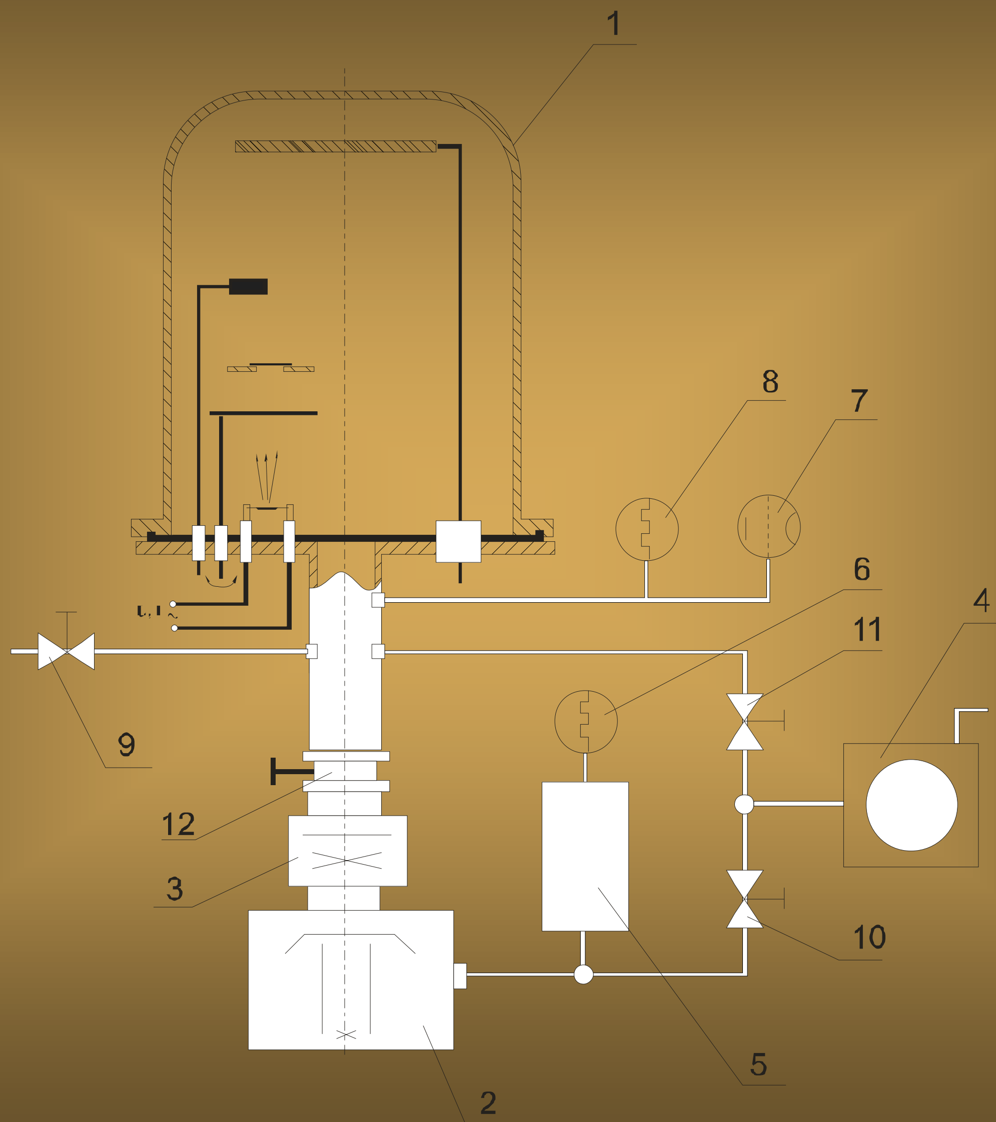
1 - cover plate
2 - gasket,
3 - heater
4 - blankholder,
5 - carcas,

6 -spring of plate,
7 - outlet canal to
vacuum pump
8 - butt plates,
9 - folil bag.

Sets with higher efficiency

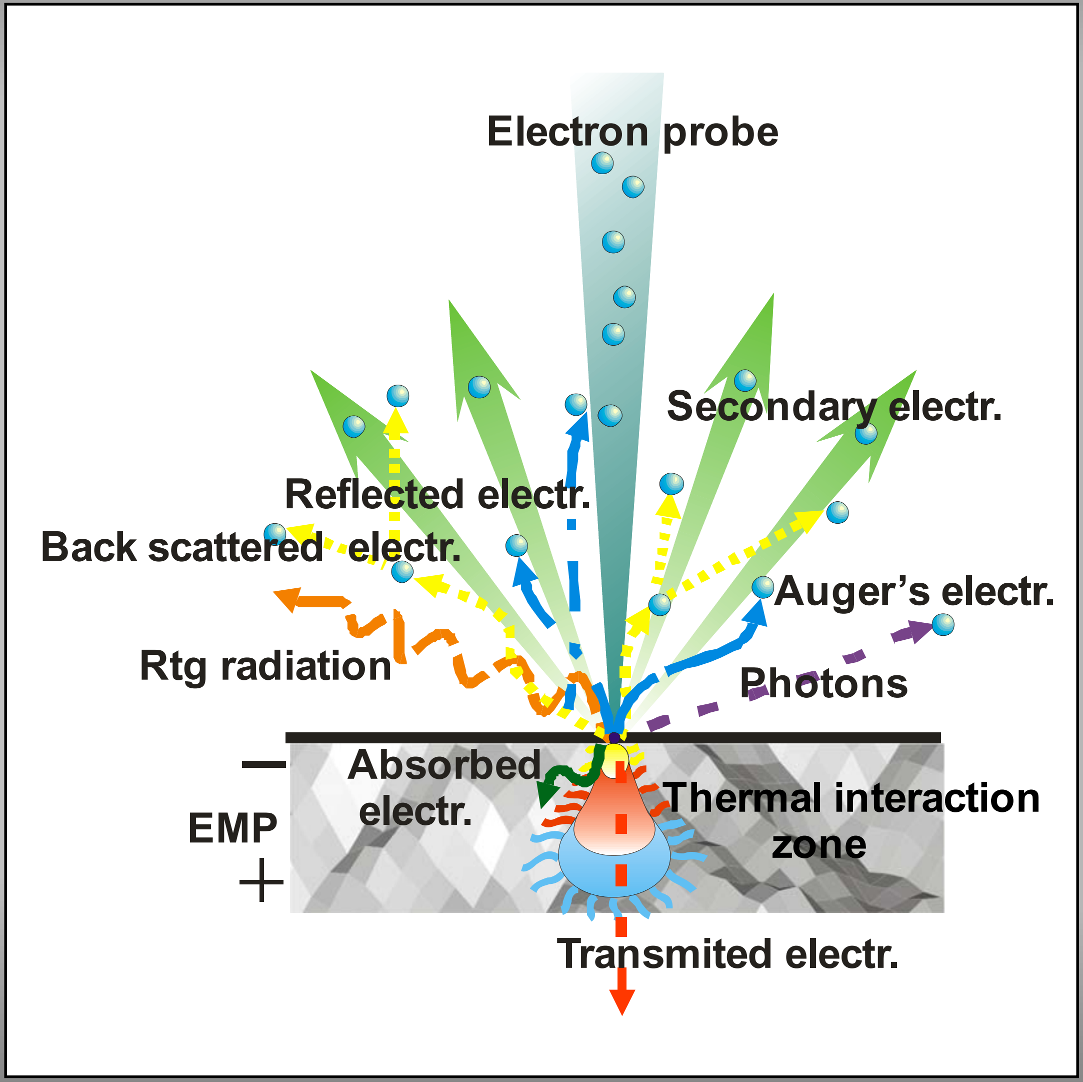
Coatings and electron beam technique

Typical vacuum set for coating, arranged on diffusion and rotary vane pumps.



HITEC set for coating with magnetron sources

Reaction of an electron beam with a solid material

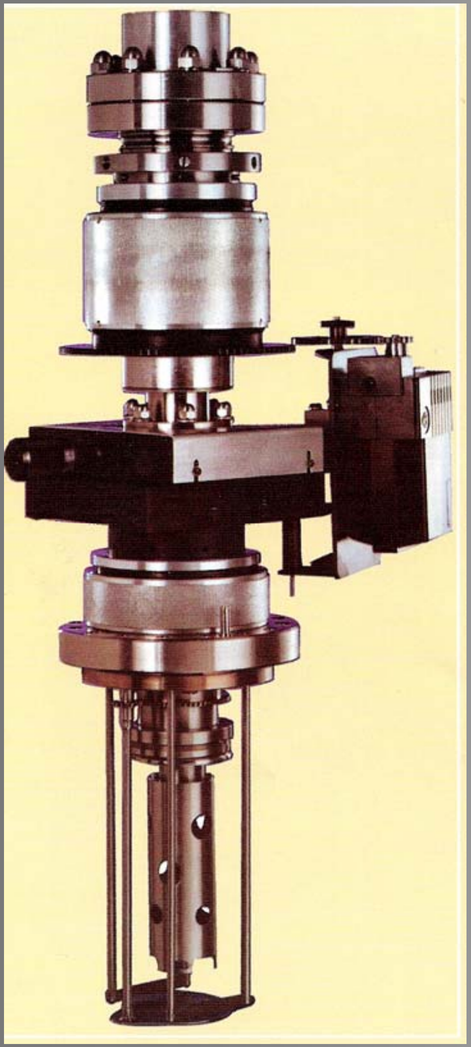


Electron guns

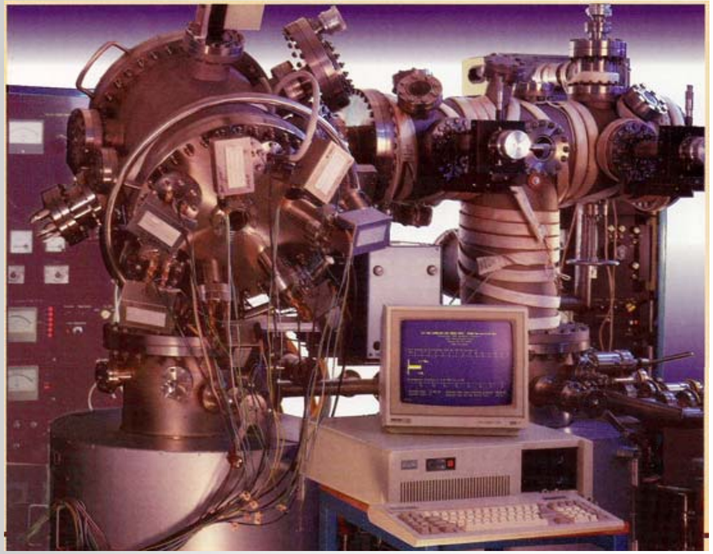
Electron guns arranged vertically or horizontally have found application depending on destination, where more often the thermoemission of electrons, and rather seldom the field emission were used. The field emission is more expensive.

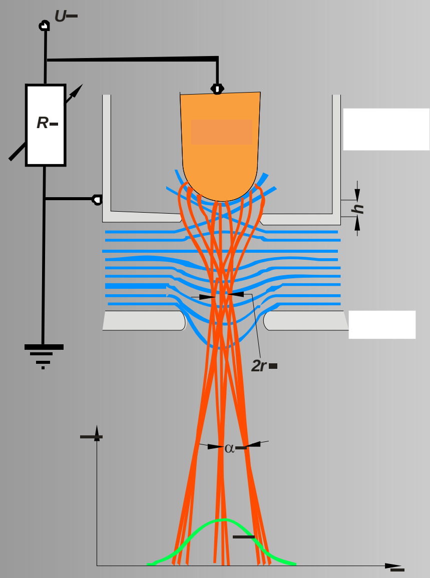
The systems of this type are mainly applied to vacuum metallurgy, thermal treatment, welders, electro-erosion machines and electronic techniques.

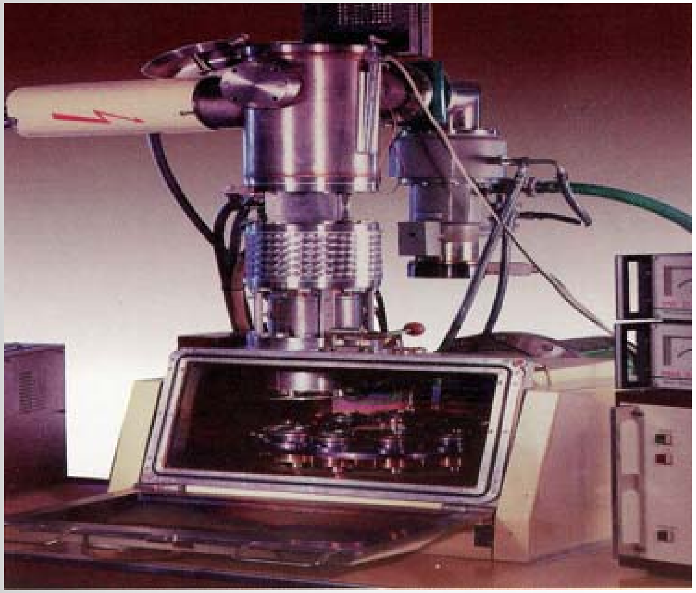
Vertical electron gun



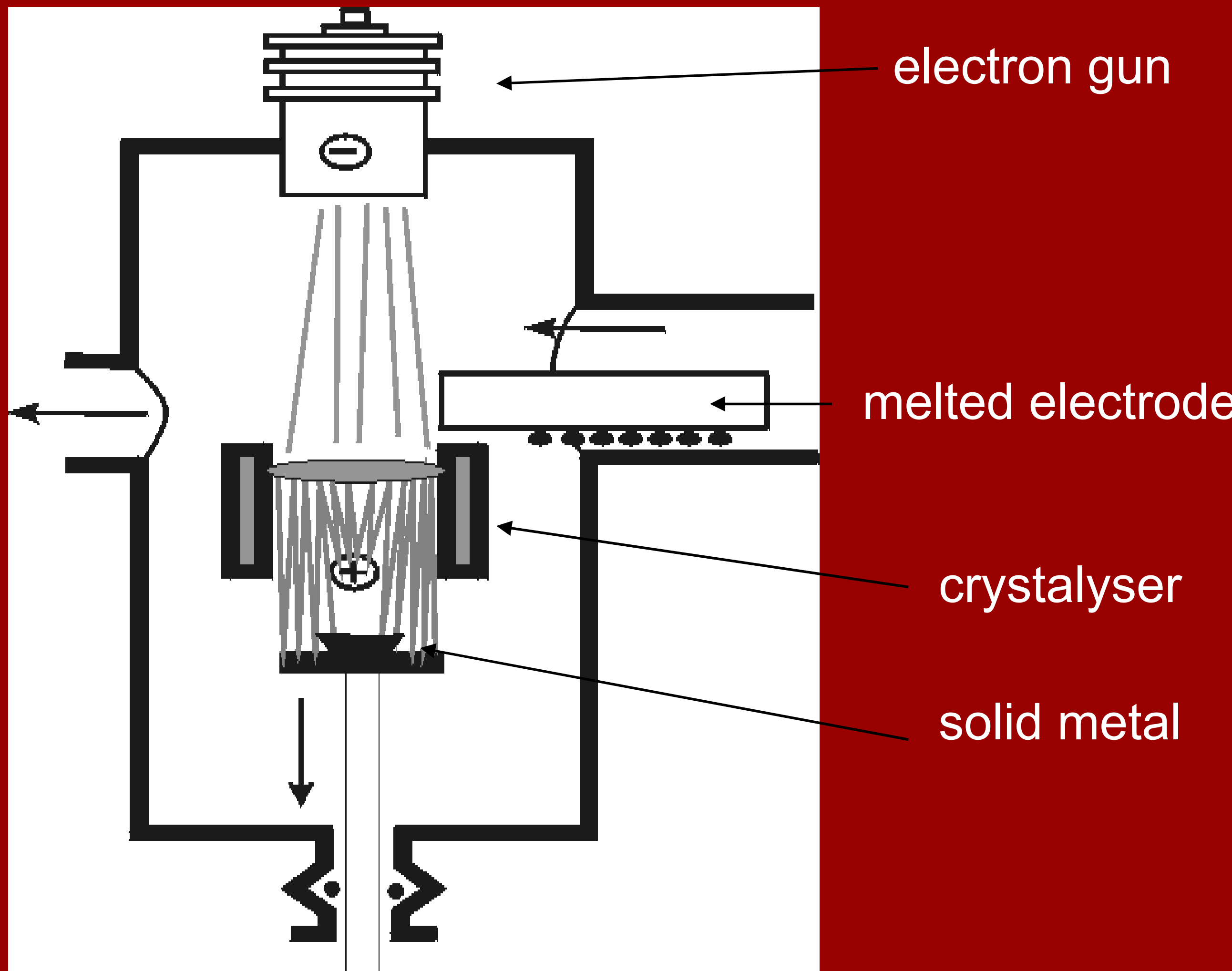
Ion implantator set

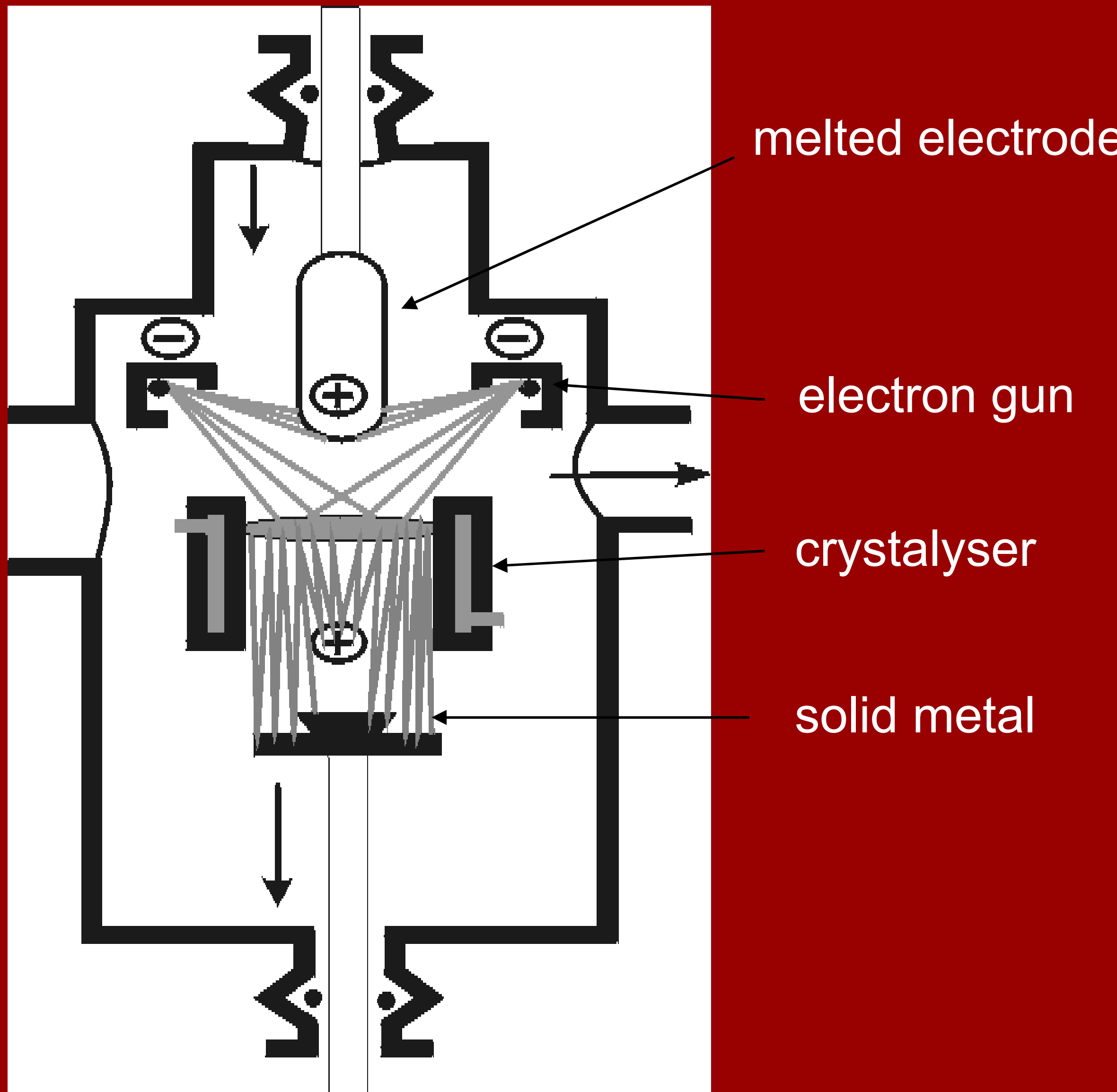






Welding set


electron gun
melted electrode
crystalyser
solid metal

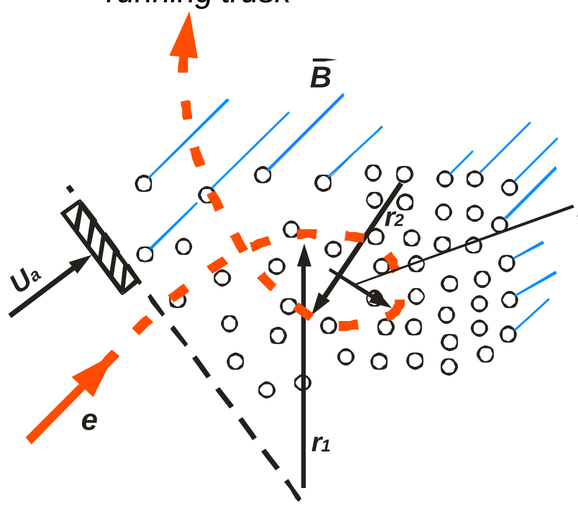

melted electrode
electron gun
crystalyser
solid metal

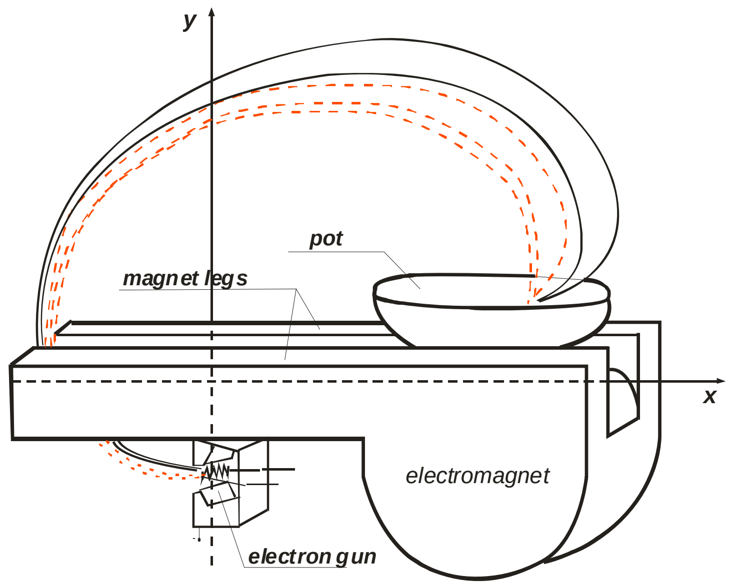
Horizontal electron gun

Horizontal arrangements, for example with a beam deflected at an angle of 240^0 are mainly applied to vacuum evaporation plants, vacuum metal deposition and small furnaces for vacuum arc remelting.

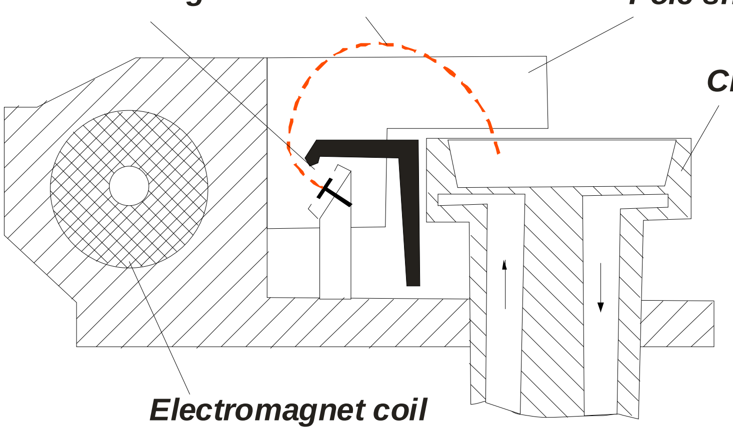
A magnetic system is used to impart motion to electrons along a track similar to elliptic and direct it to the crucible, which allows the gun size to be reduced.

Horizontal electron gun

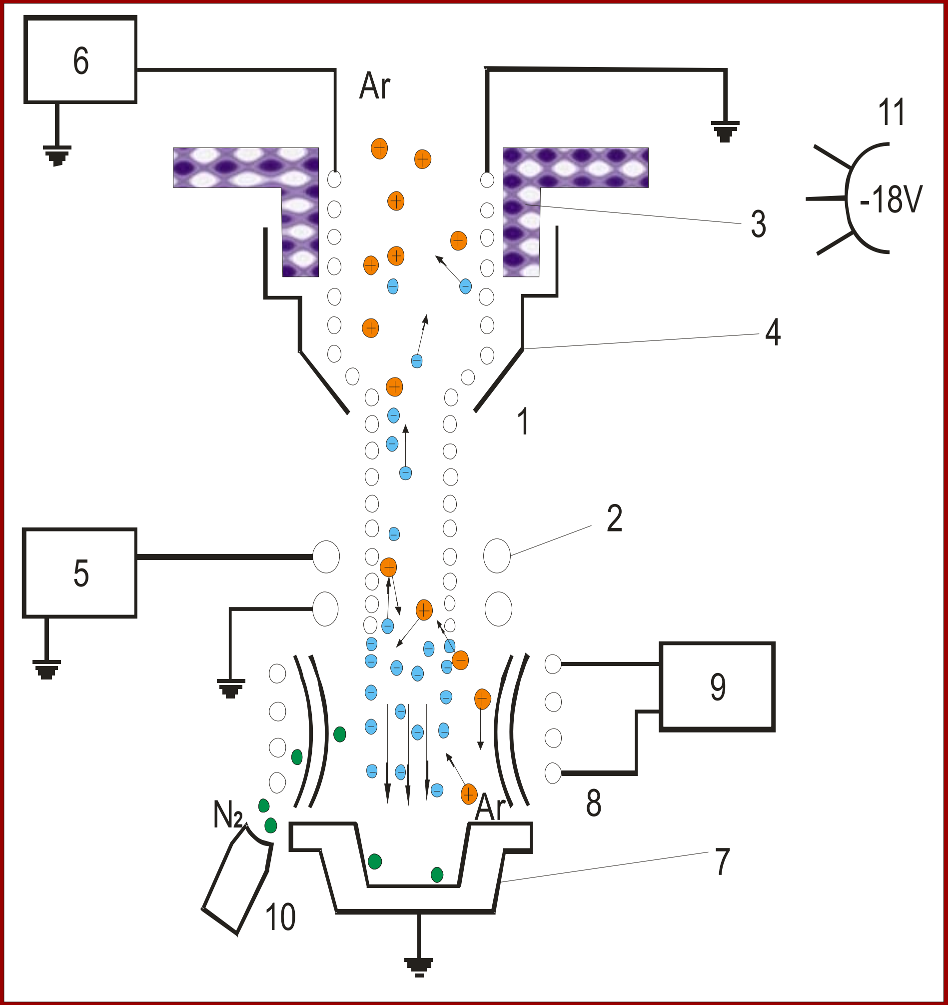




Running truck of electrons across the magnetic field with different tension. In the part with a lower tension the turn radius of elecrton is bigger than in the part with higher tension.



Hollow catod



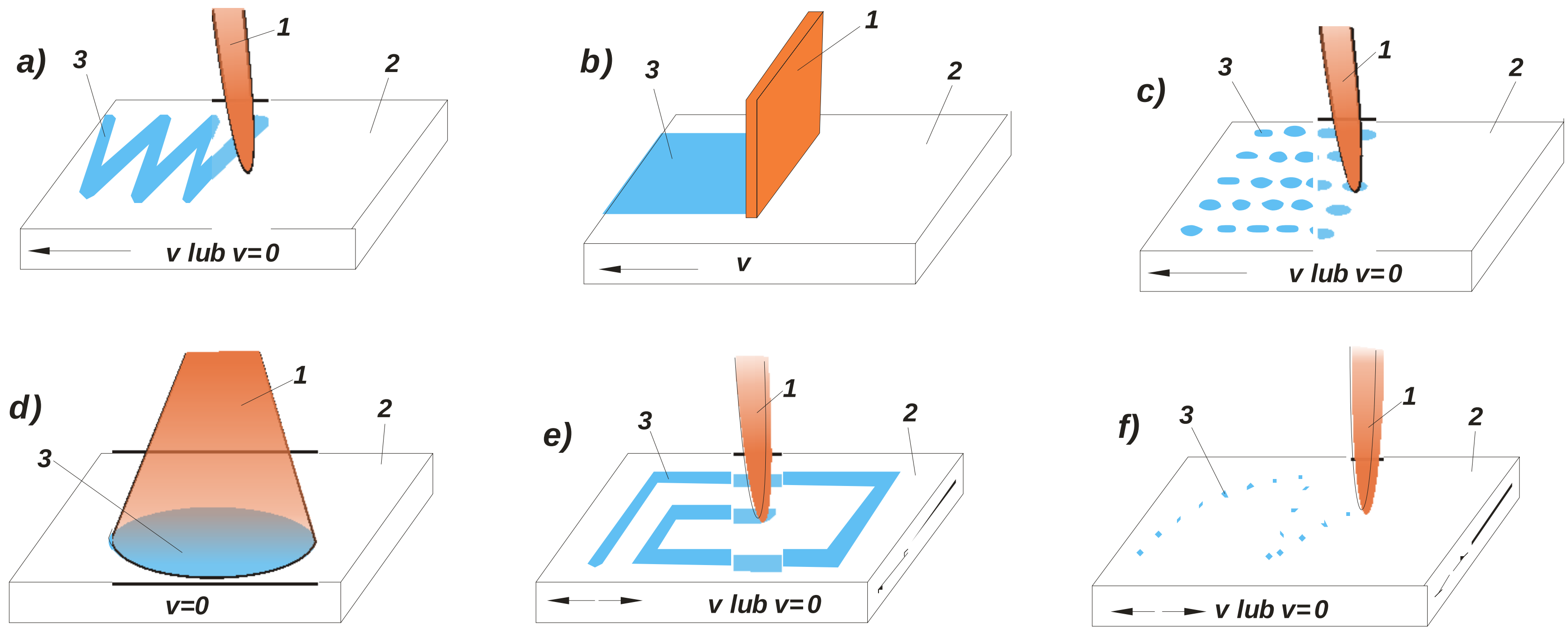
is an entirely different type of an electron-beam source. It’s shaped in the form of a pipe made of a tungsten spiral.

Emmision of electrons is obtained from the face of spiral as a result of ionisation of argon supplied inside. It is heats enough to trigger of the thermoemission of electrons.

Then they are pulled out due to a zero potential of the crucible on which they are fall. It causes heating, than melting and evaporating the charge .

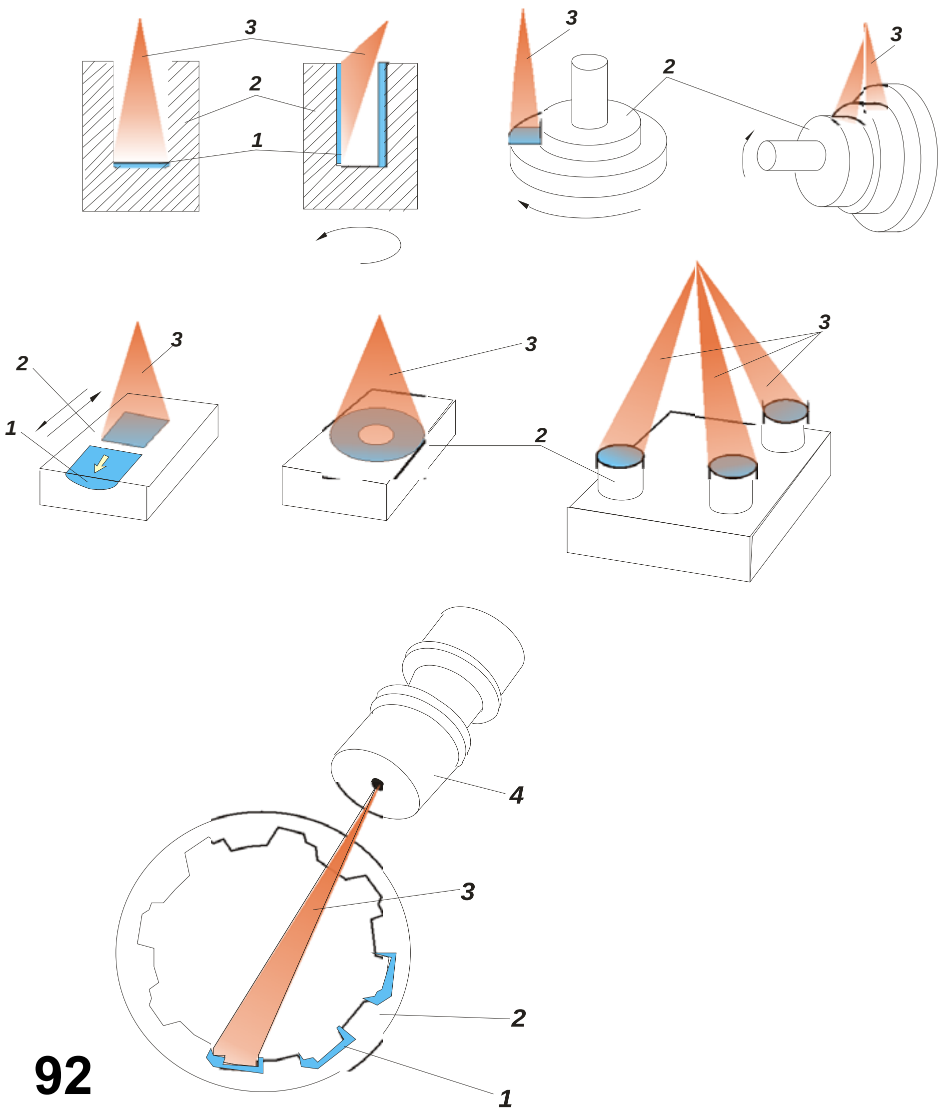
Different ways of shaping the electron beam for thermal treatment the surface.

Scanned e-b **Swept line e-b** **Pulse e-b**



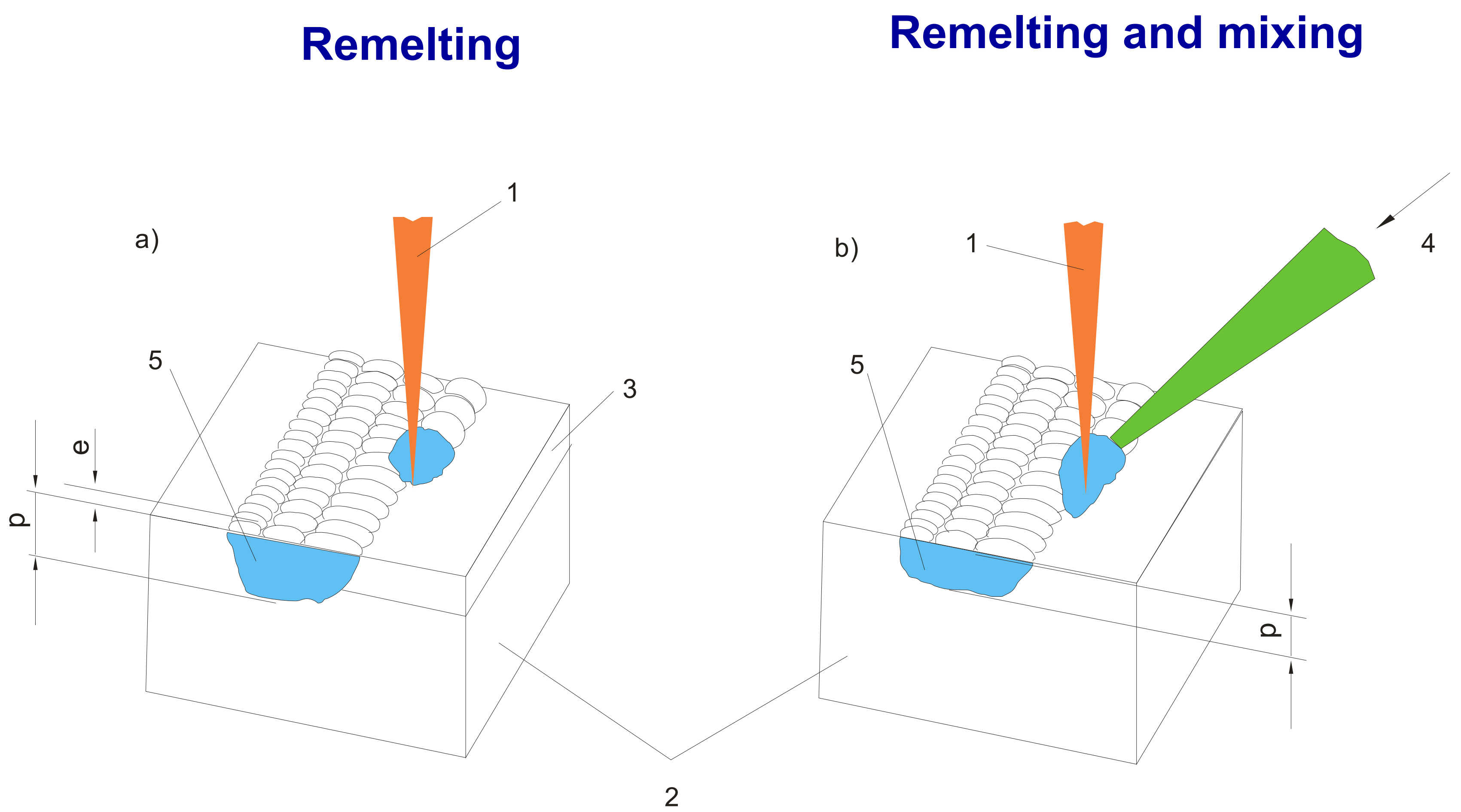
Islan–like e-b **Freely programable e-b**

Examples of shaping the electron beam for pulse hardening

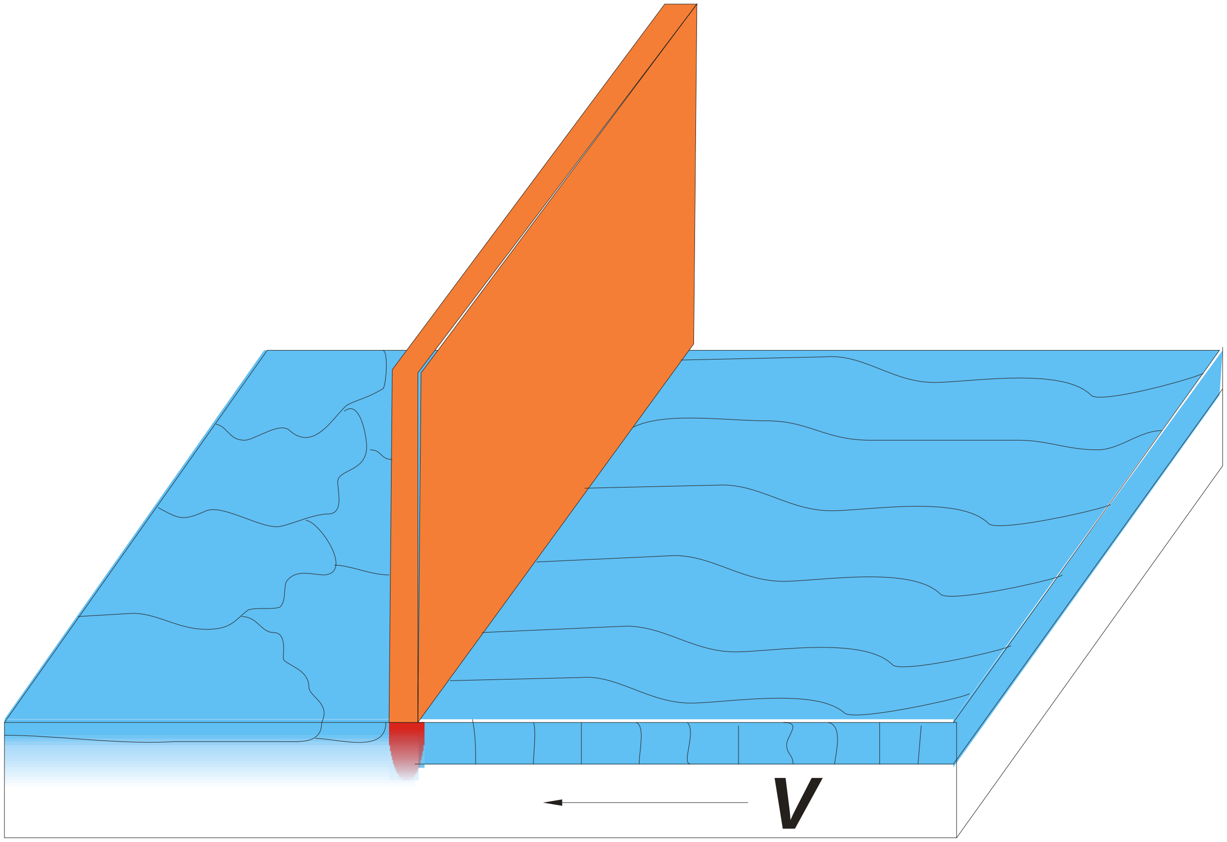


Dependently of the shaping the electron beam can be used for pulse hardening.
In addition to which it is possible to make use of the self-cooling effect that is equal to 105 K s-1 (countable for a given range of temperatures).

-1 hardened layer, 2 - workpiece, 3 - electron beam, 4 - electron gun.

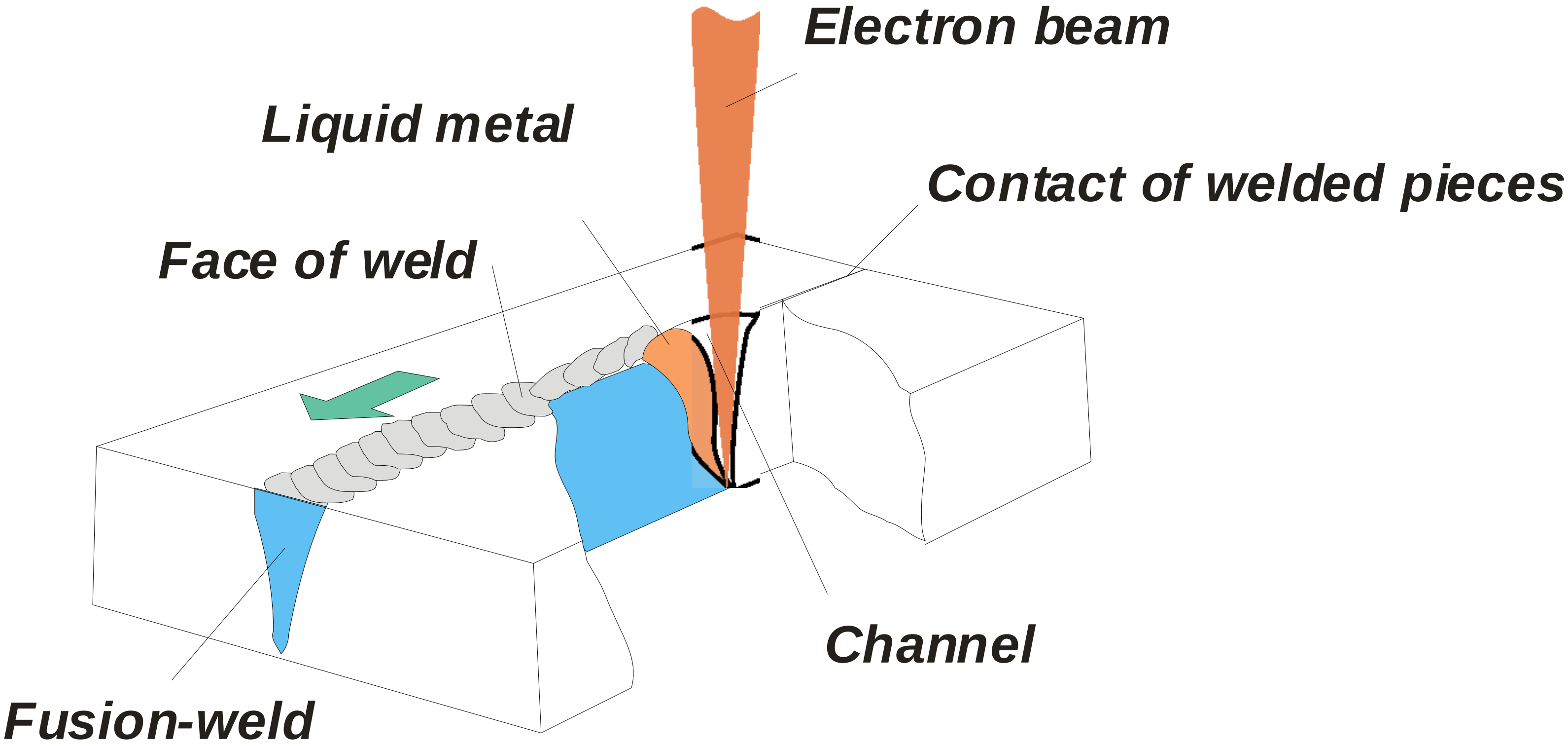

Remelting
Remelting and mixing
a)
b)
1
1
2
3
4
5
5
e
p
p

Glazing or densification



Electron-beam welding method is mainly marked by capability to integrate two significantly different metals respecting their composition and other properties, provided that the weld will be sufficiently flexible to overcome the stress difference.

Welding


Electron beam
Liquid metal
Contact of welded pieces
Face of weld
Channel
Fusion-weld

ADVANTAGES

High velocity (up to several m/min),

Low heat-energy consumption,

Simple control of welding parameters,

Chemical neutrality,

Repeatability of weld joints (steady quality),

Capability to make one-pass welds without necessity of:

applying the filling material,
chamfering,
treatment after welding.

DRAWBACKS:

Necessity of using vacuum,

Expensive equipment,

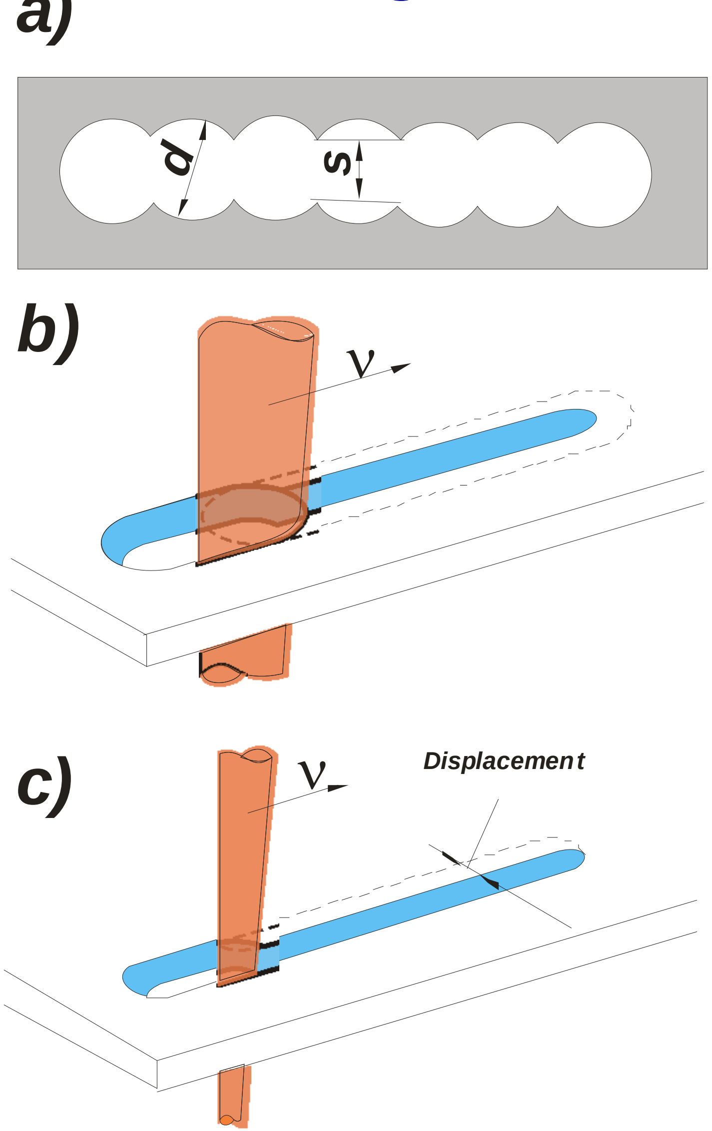
Occurrence of X-rays,

Porosity of joint penetration or lack of it,

Undercuts and fused zones,

Cracks and stresses, which may occur while joining different metals.

cutting with e-b



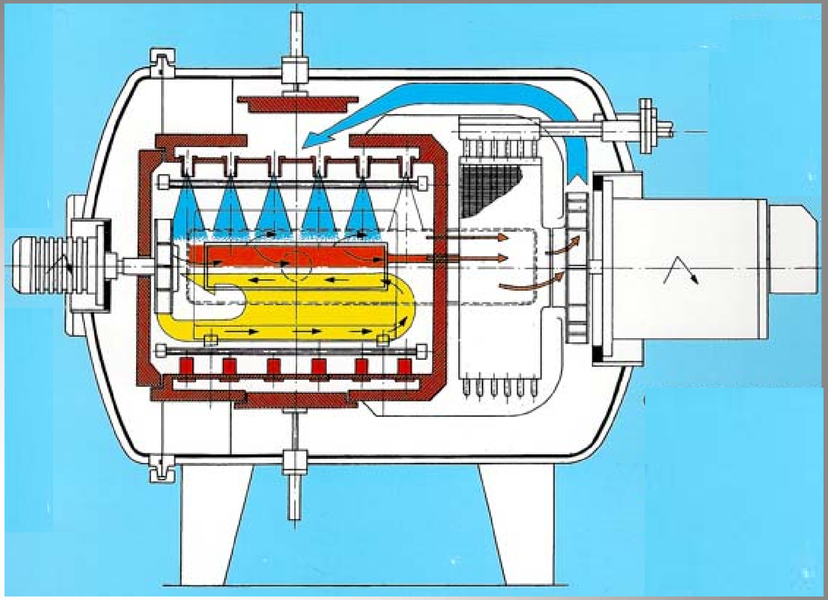
is obtained:

a) due to the geometric superposition of a series of single wholes made by a movable pulse electron beam;

b, c) method of polishing the edges by shifting the electron beam

The irregularities fluctuate depending on the applied material, within 2-20 mm. These irregularities could be reduced by using the rotational beam.

Vacuum furnace with gas cooling



IMNVT

Thank you for attention

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