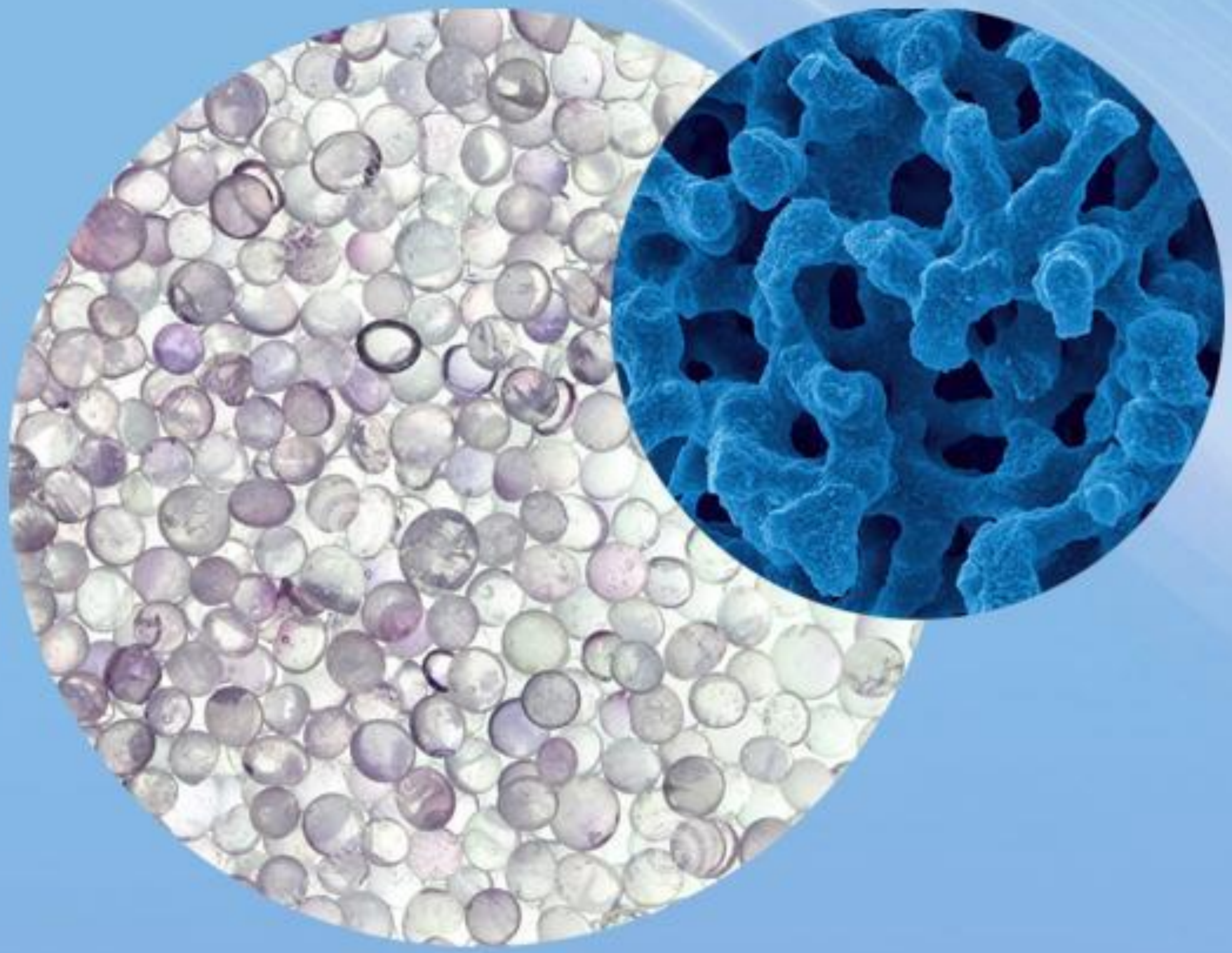


THE ADSORBENTS NANOPOROUS STRUCTURES REGENERATION FOR INDUSTRIAL DRYERS BY MICROWAVE ENERGY

KHARKOV 2021

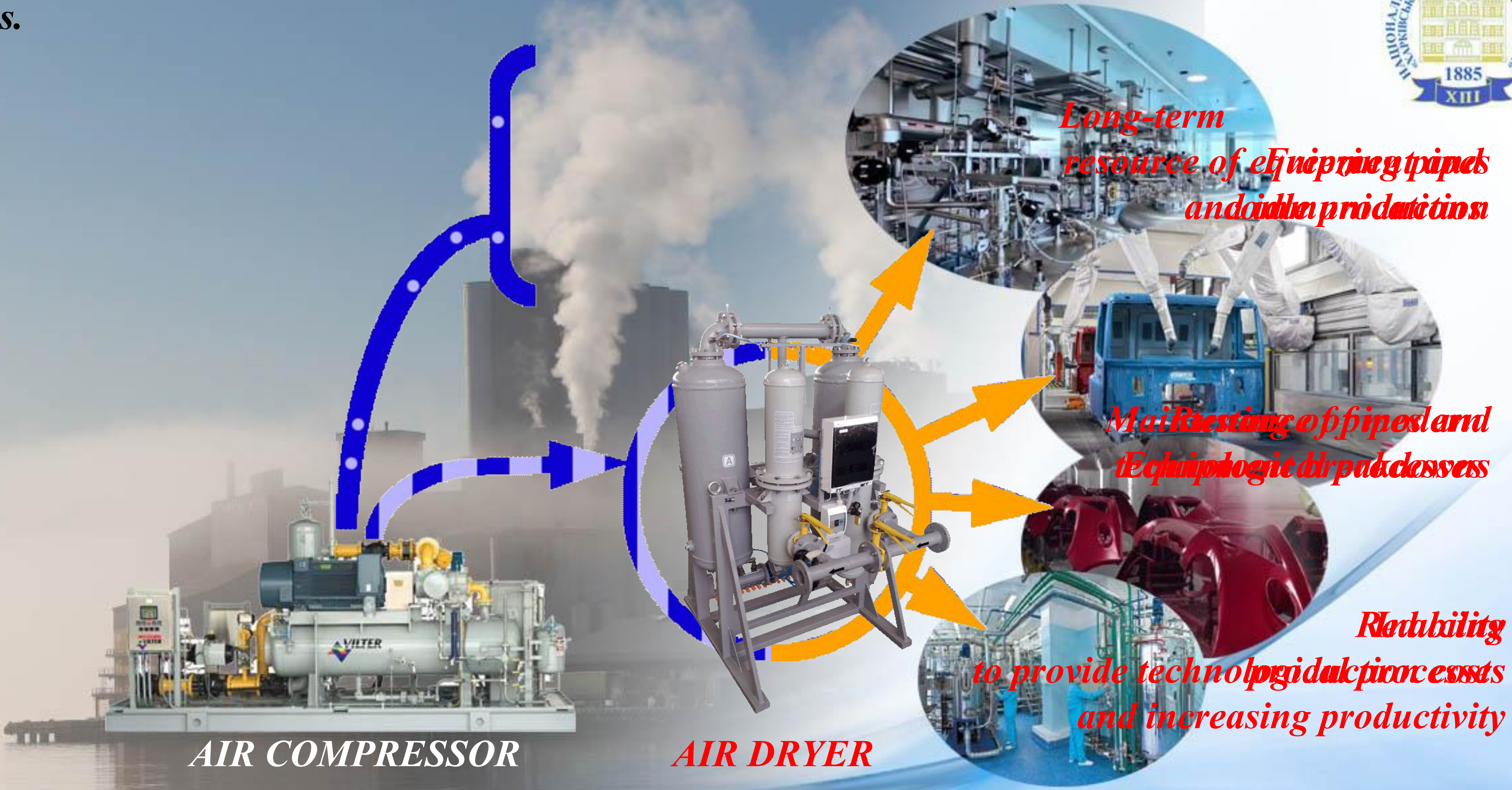
The main researches must be dedicated to a wider exploration of the means for reducing the atmospheric impact of other non-CO_2, gaseous emissions such as water vapor.

Aircraft running on hydrogen still emit water vapour and, in the case of hydrogen combustion, also NOx. On the other hand, particles may strongly be reduced.

The technology we propose can be used in the design of equipment that solves this problem.

As a consequence, high altitude phenomena have a substantial impact on the global impact of aviation on global warming through radiative forcing, may strongly be modifed. Decreasing the level of this impact is crucial in order to increase the environmental potential of H_2 aircraft.

Water is present in the atmosphere. It is pumped by compressors into the pneumatic systems.



The use of separators, filters and dryers solves these problems

The reason for the significant consumption of electricity by compressors is due to the laws of thermodynamics.

WET AIR

DRY AIR

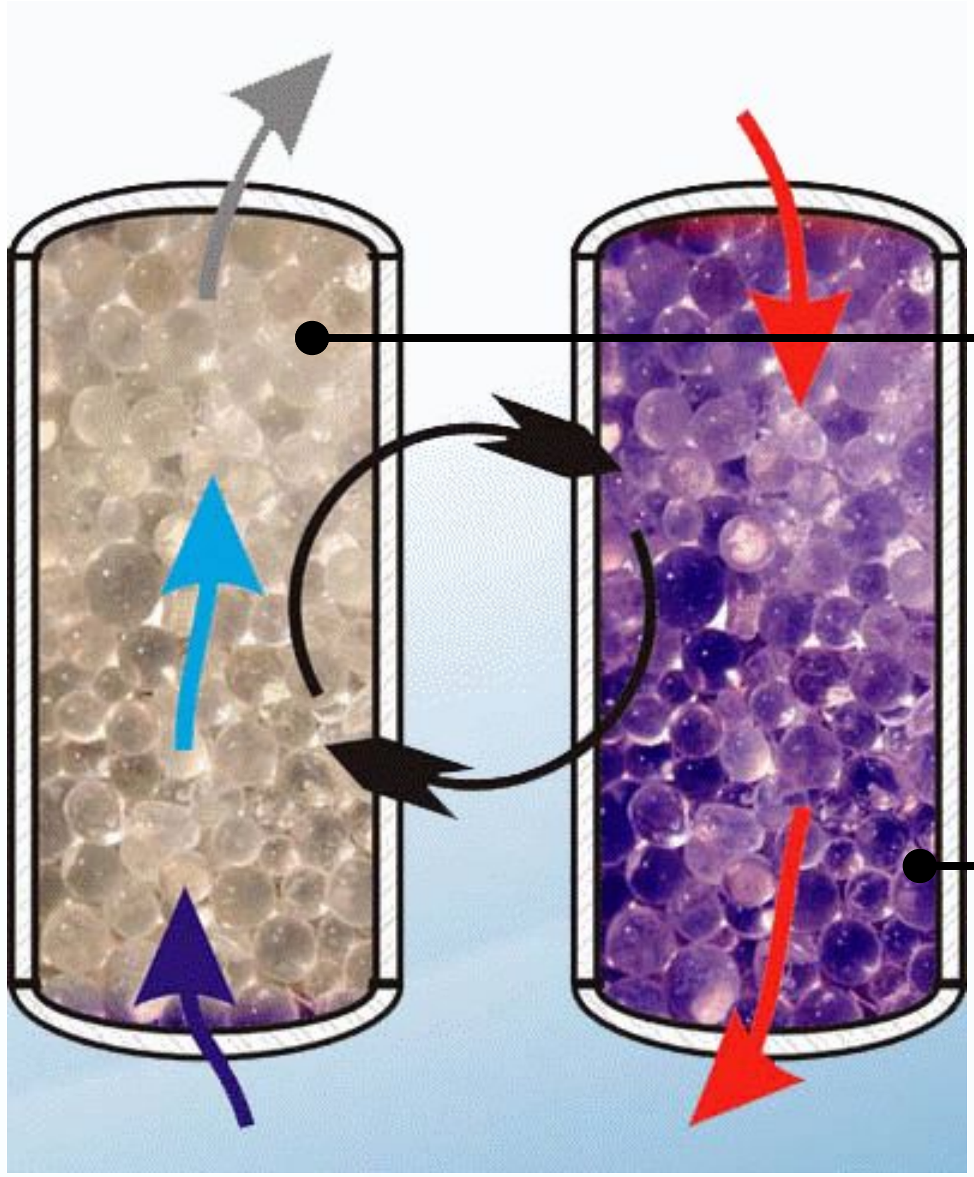
Blowing purge air losses

Water removal losses

UP TO 20 % AIR LOST

Reducing the amount of compressed air used to adsorbent regeneration is a challenge that must be addressed to reduce the cost of air production.

Adsorption columns of the dryer and their cyclic functioning.



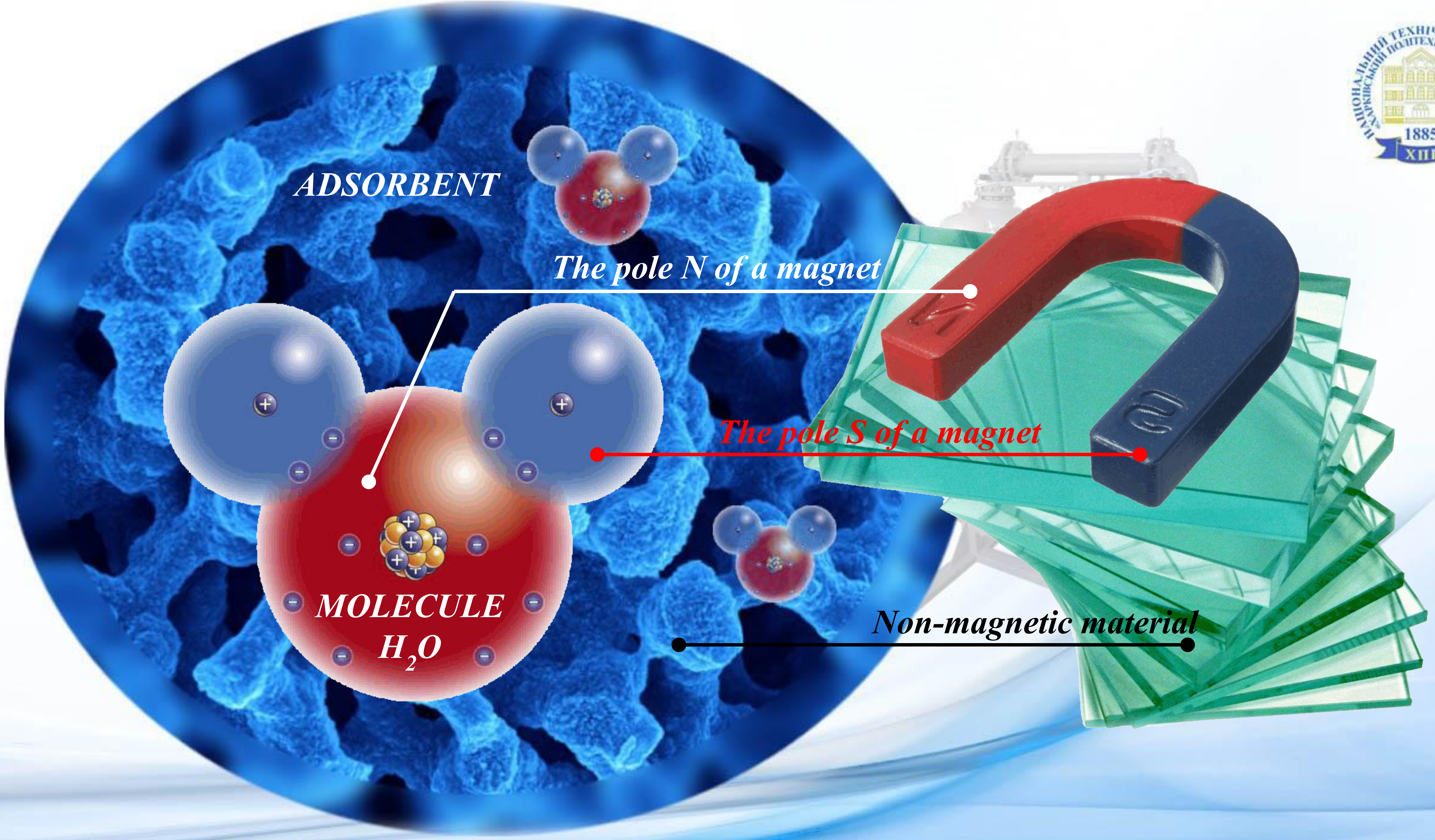
Adsorbtion columns

Dry air

Purge air, temperature 200 ^{0}C

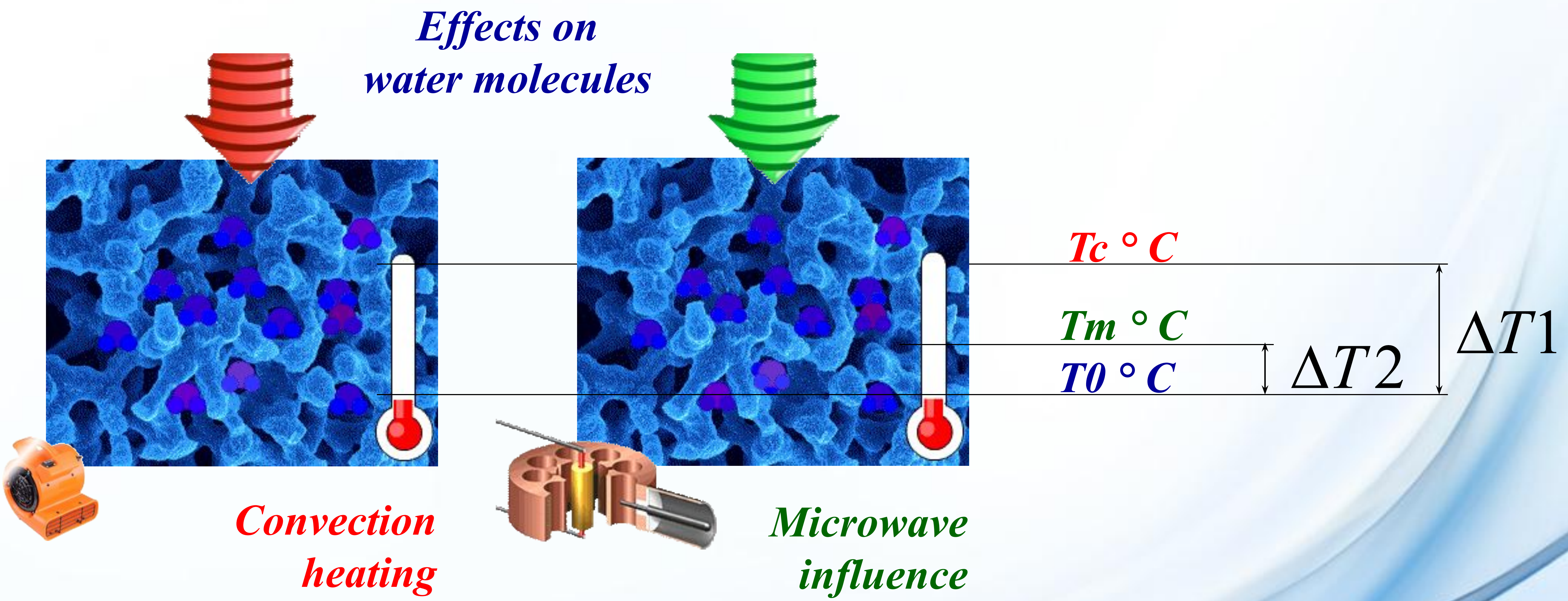
Being dryed air

AIR DRYER


ADSORBENT
The pole N of a magnet
The pole S of a magnet
MOLECULE
H2O
Non-magnetic material

A <u>lower</u> heating temperature of the adsorbent requires a <u>smaller</u> volume of dried air to cool the adsorbent to the adsorption temperature

If the $H_{u\_convection} = H_{u\_microwave}$



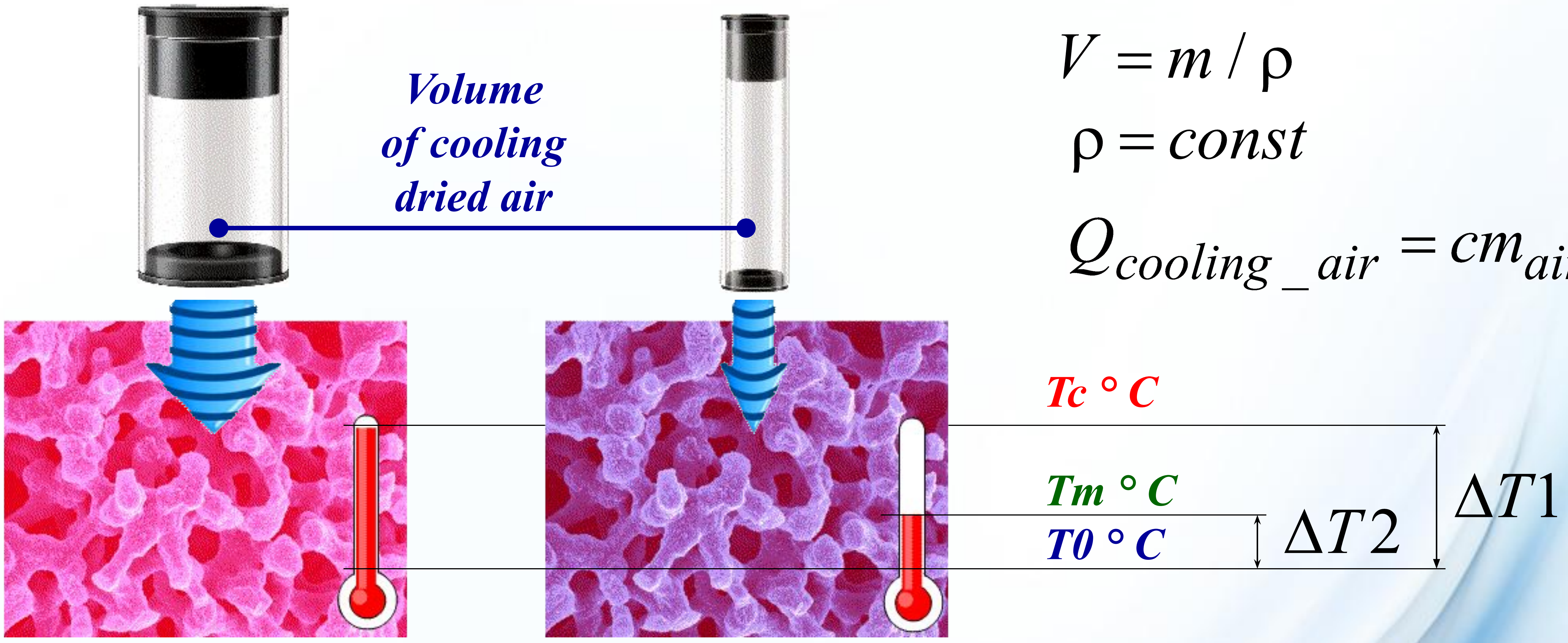
Then $\Delta T_{convection} > \Delta T_{microwave}$

COOLING ADSORBENT STAGE

$$V = m / \rho$$

$$\rho = const$$

$$Q_{cooling\_air} = c m_{air} \Delta T$$

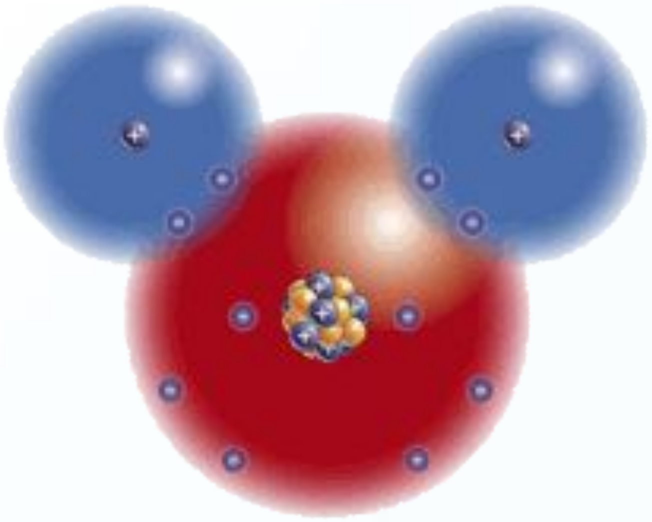


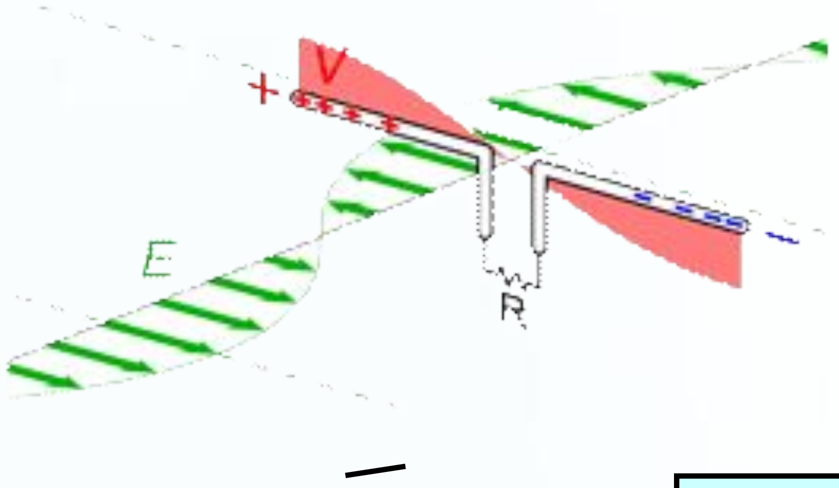
Convection heating

Microwave influence

$$m_{air\,(convection)} > m_{air\,(microwave)}$$

The action of high frequency radiation makes it possible to effect on water molecules directly.

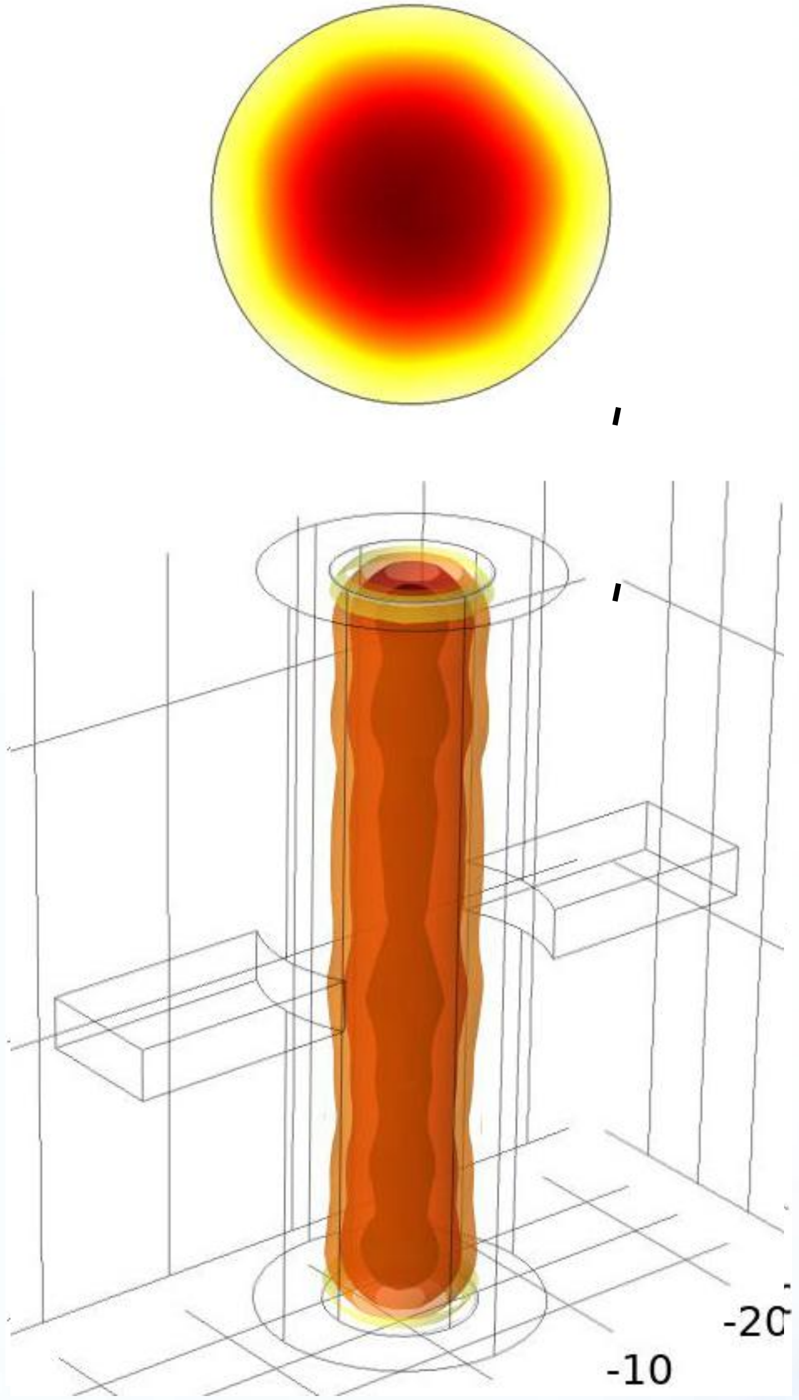




Electromagnetic field

Usually the impact is carried out using a magnetron, but this is uneven effect

Waveguide system



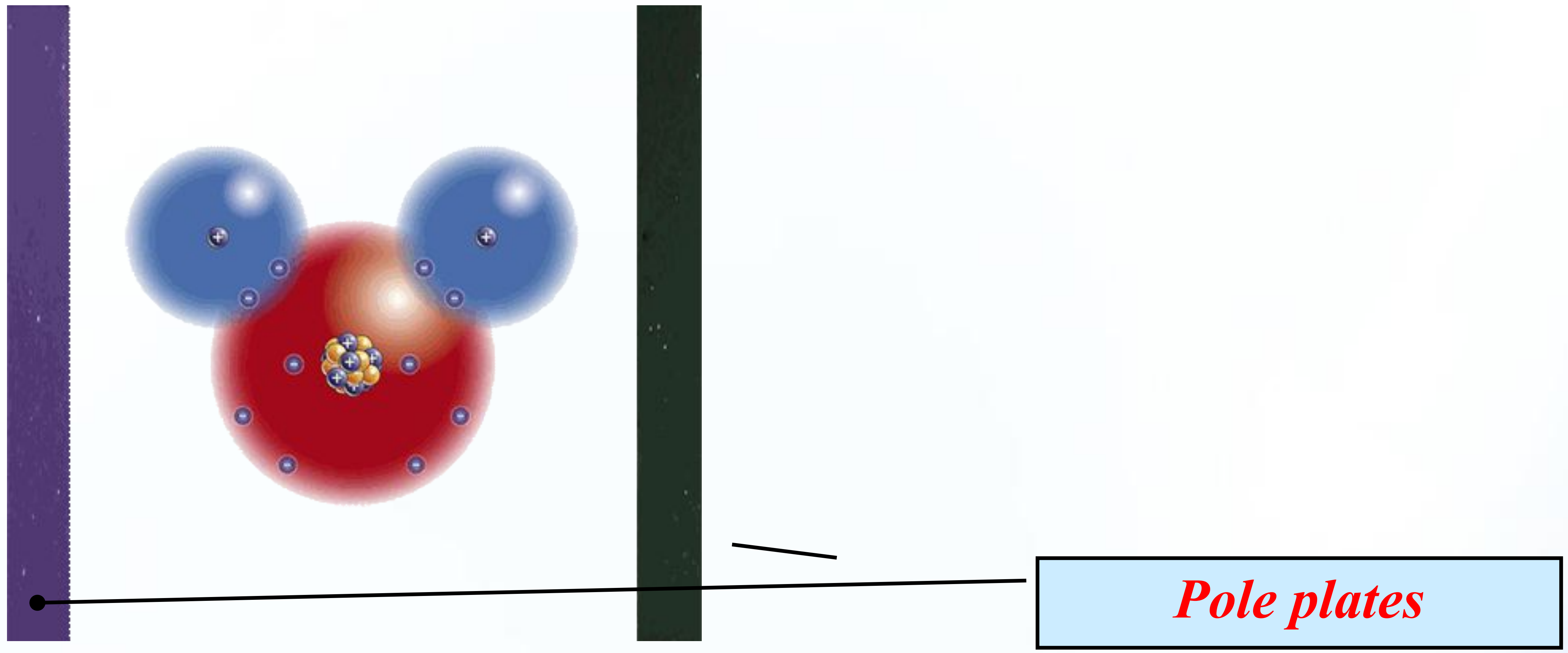
Low energy zone

Overheating zone

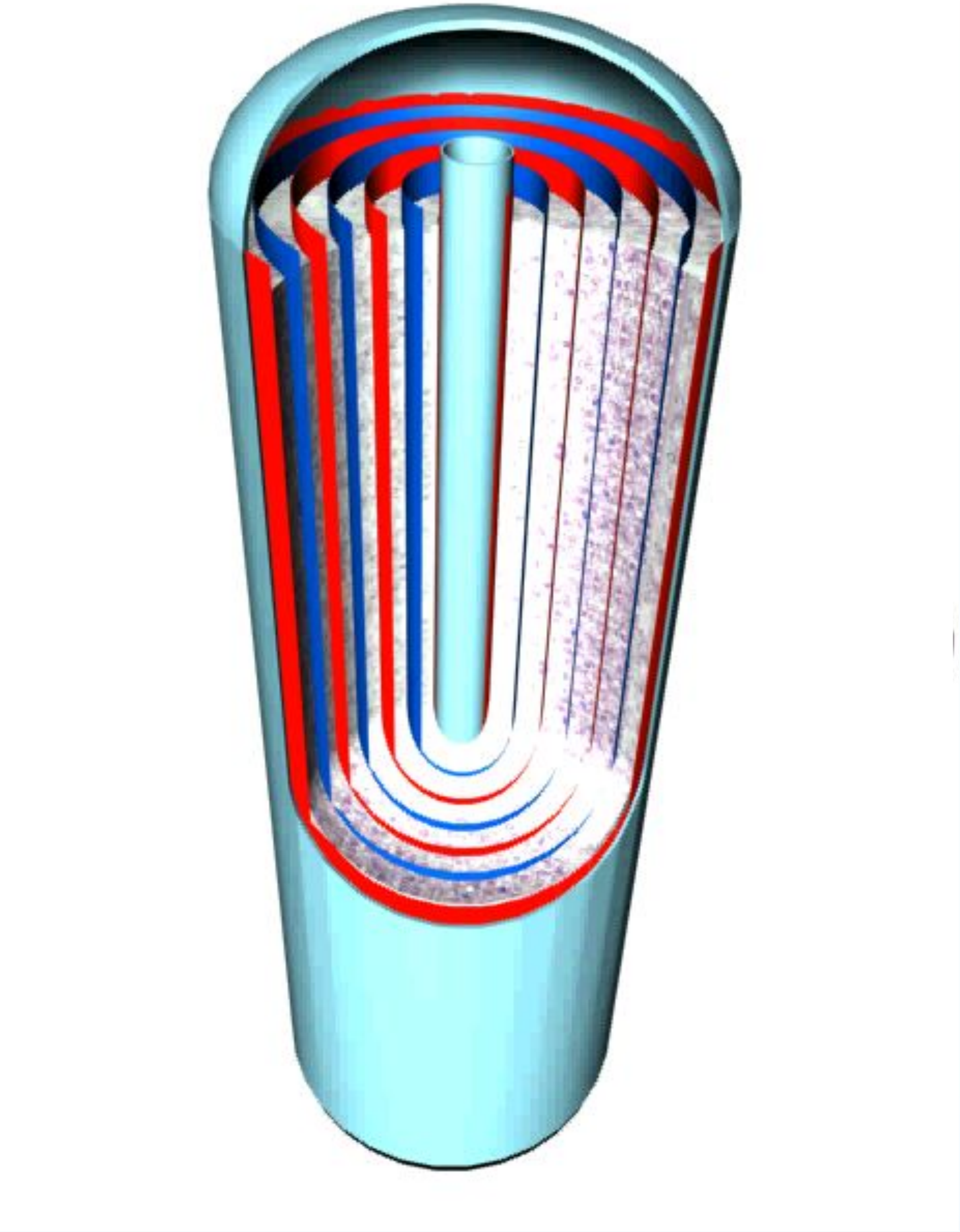
We have improved the uniformity of the magnetron energy distribution in the adsorbent volume

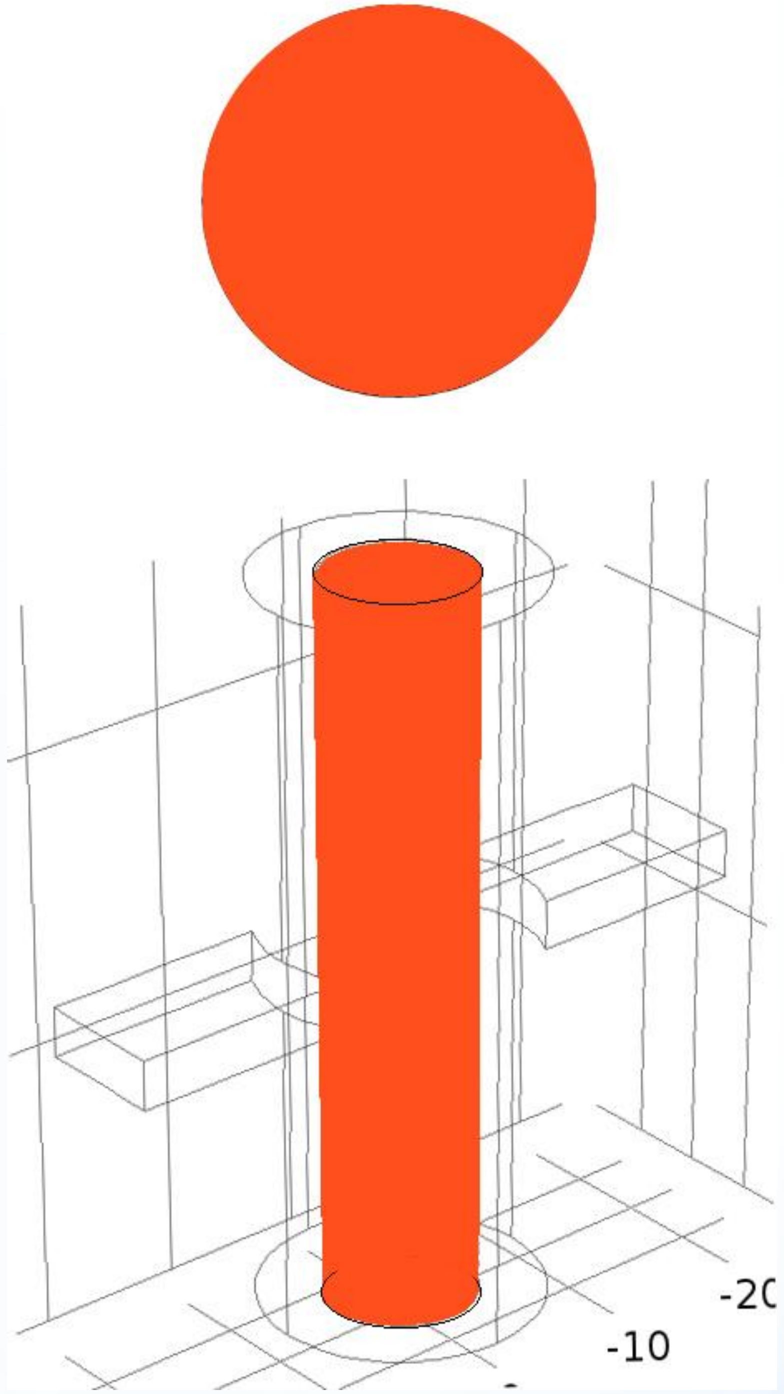
The problem of using one or a group of magnetrons to regenerate a large volume of adsorbent is the limited depth of wave energy penetration into the bulk of the material

The action of high frequency radiation makes it possible to effect on water molecules directly.



A similar effect can be achieved using pole plates

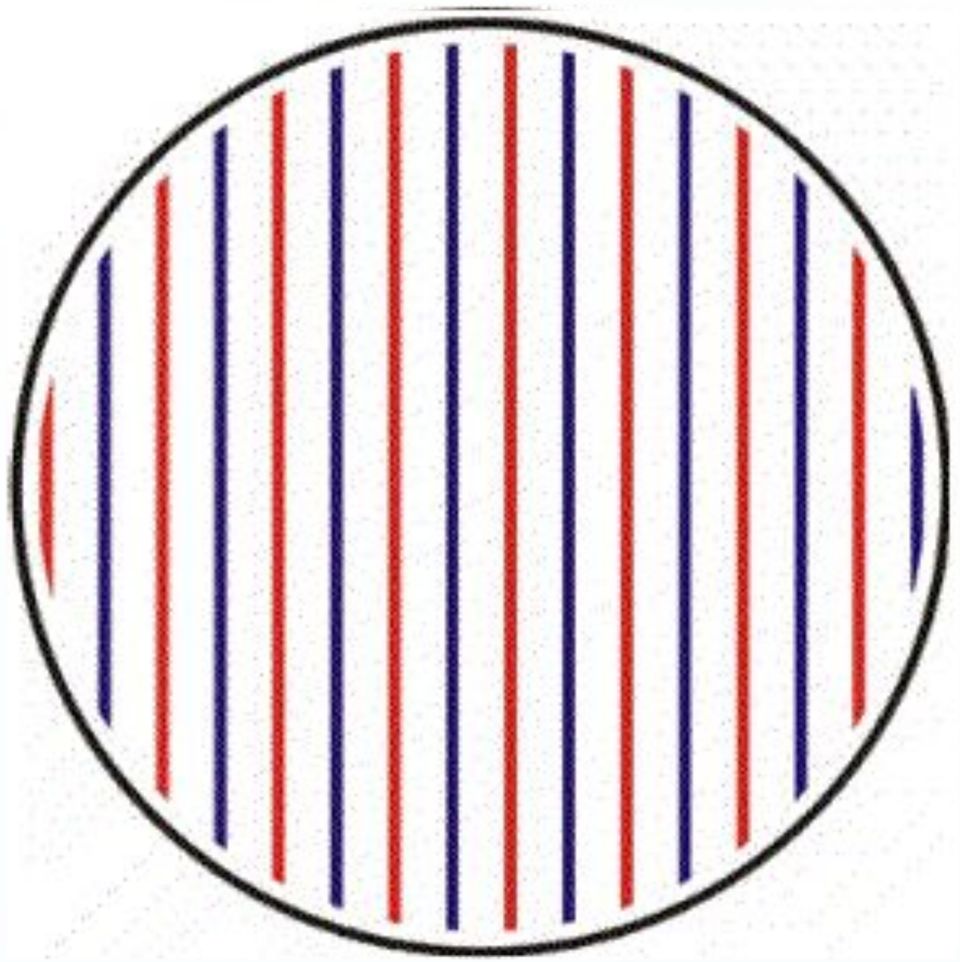


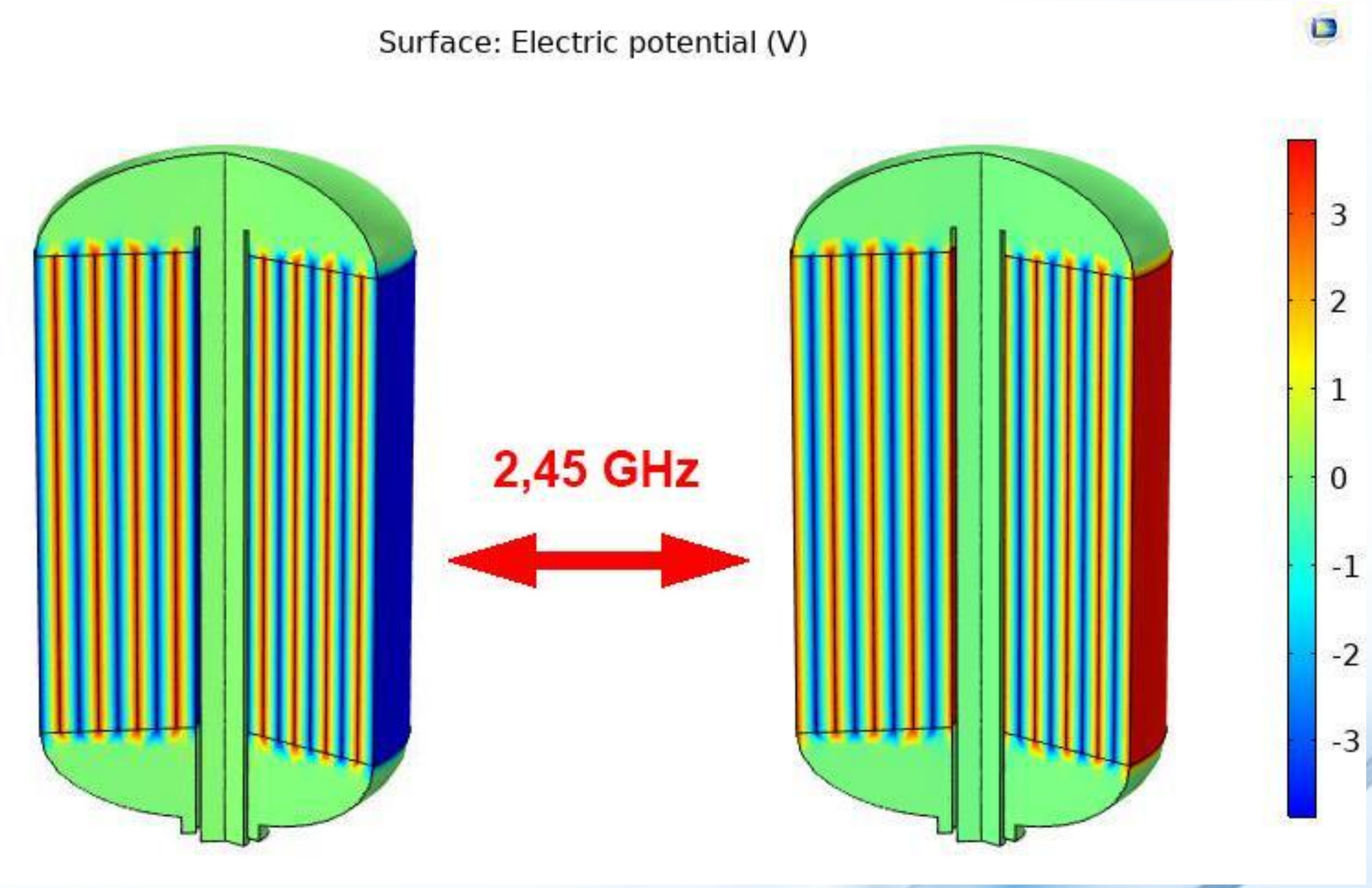


The technology we offer allows to achieve an even distribution of energy in large volumes and complex shapes

We propose to divide the entire volume of the adsorbent by parallel pole plates

We study various Pole plate designs
in terms of their placement in the volume of the adsorbent

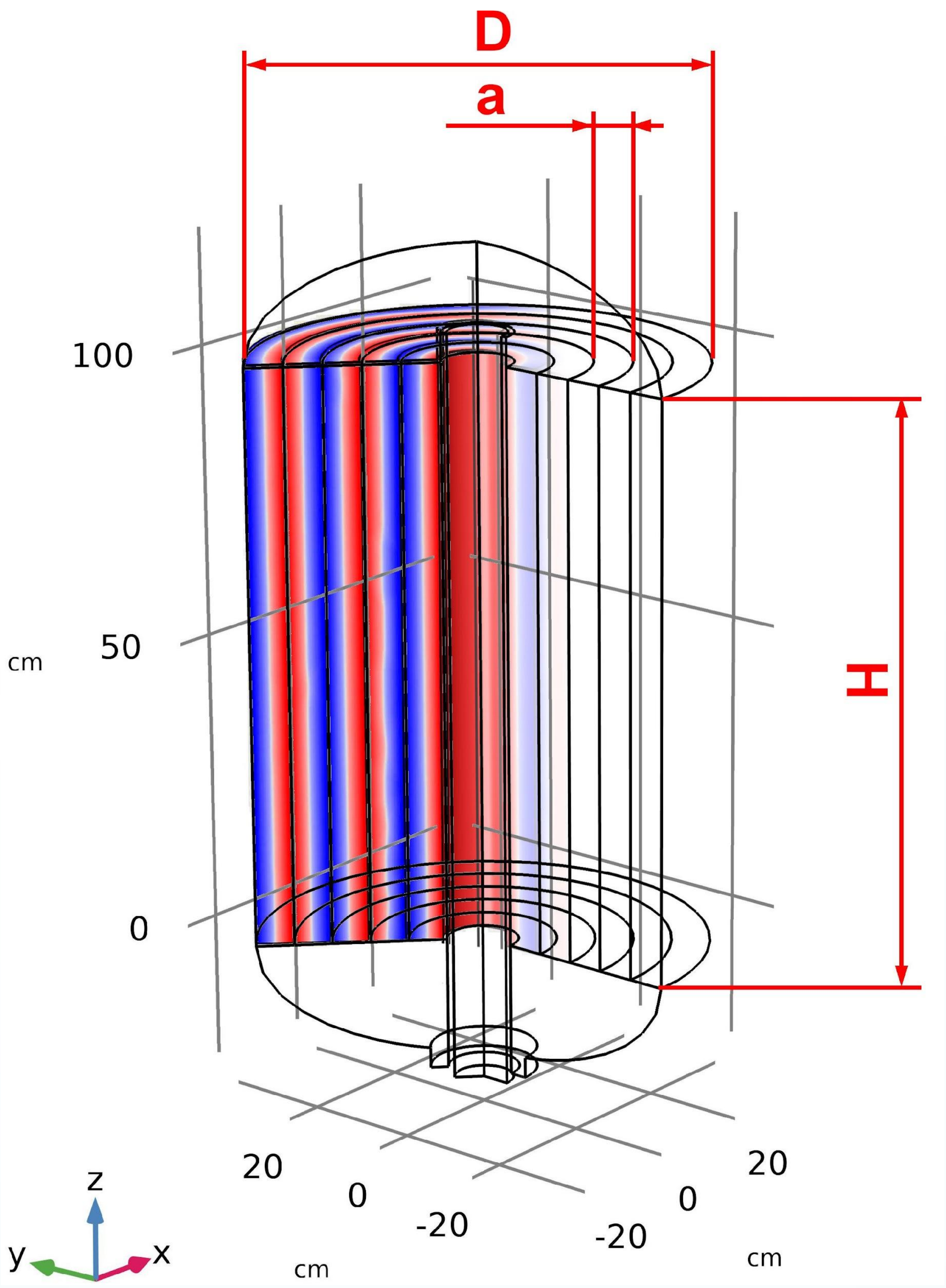




radial

spiral

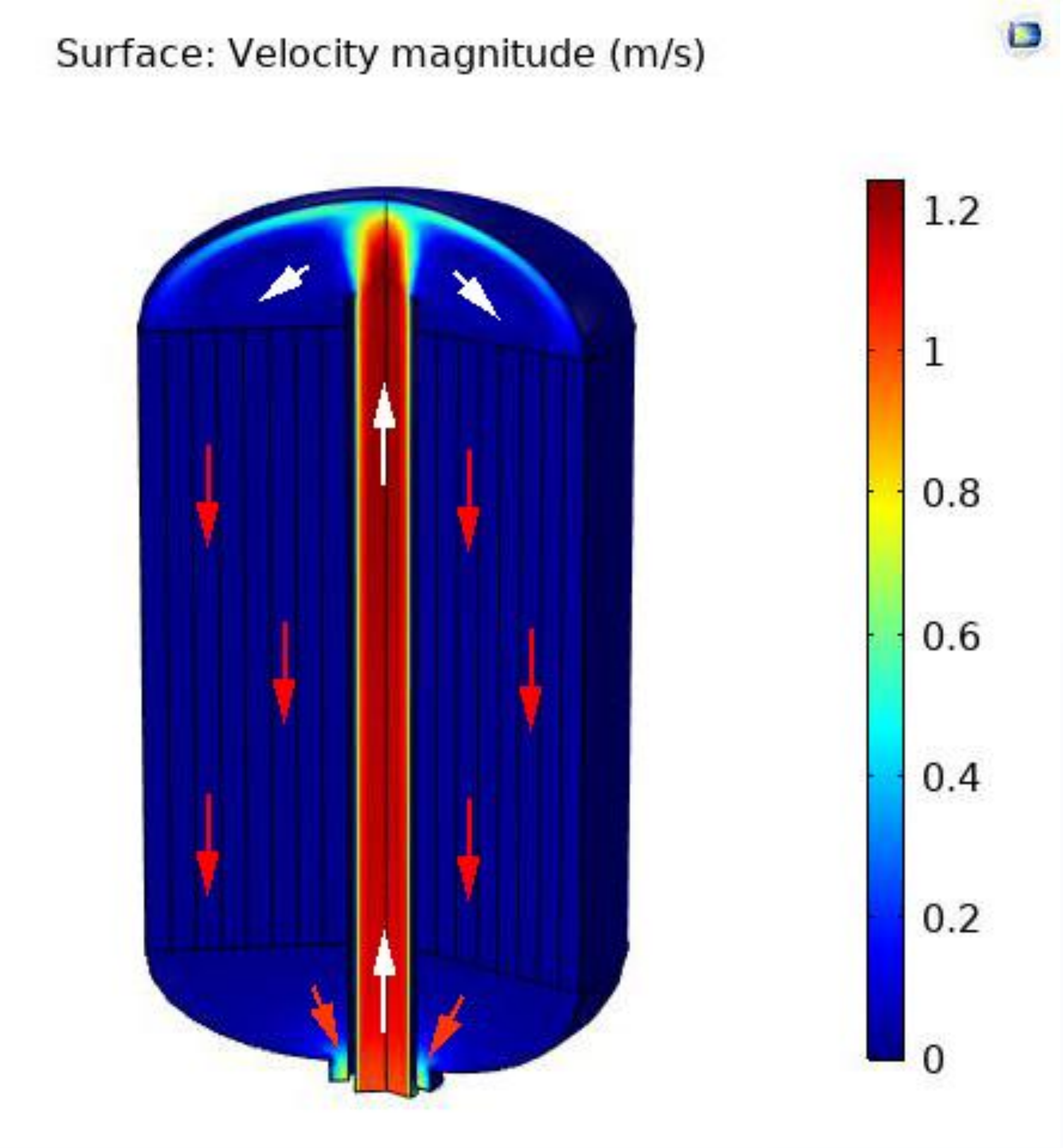
parallel



Our research was carried out on a computer model built by us with the following characteristics:

Dimension, mm:

Distance between the pole plates (a) 32 / 40 / 64
Column height (H) 1000
Column diameter (D) 760



Air velocity

The movement of air in the volume of the adsorbent was modeled as a motion in a porous medium.

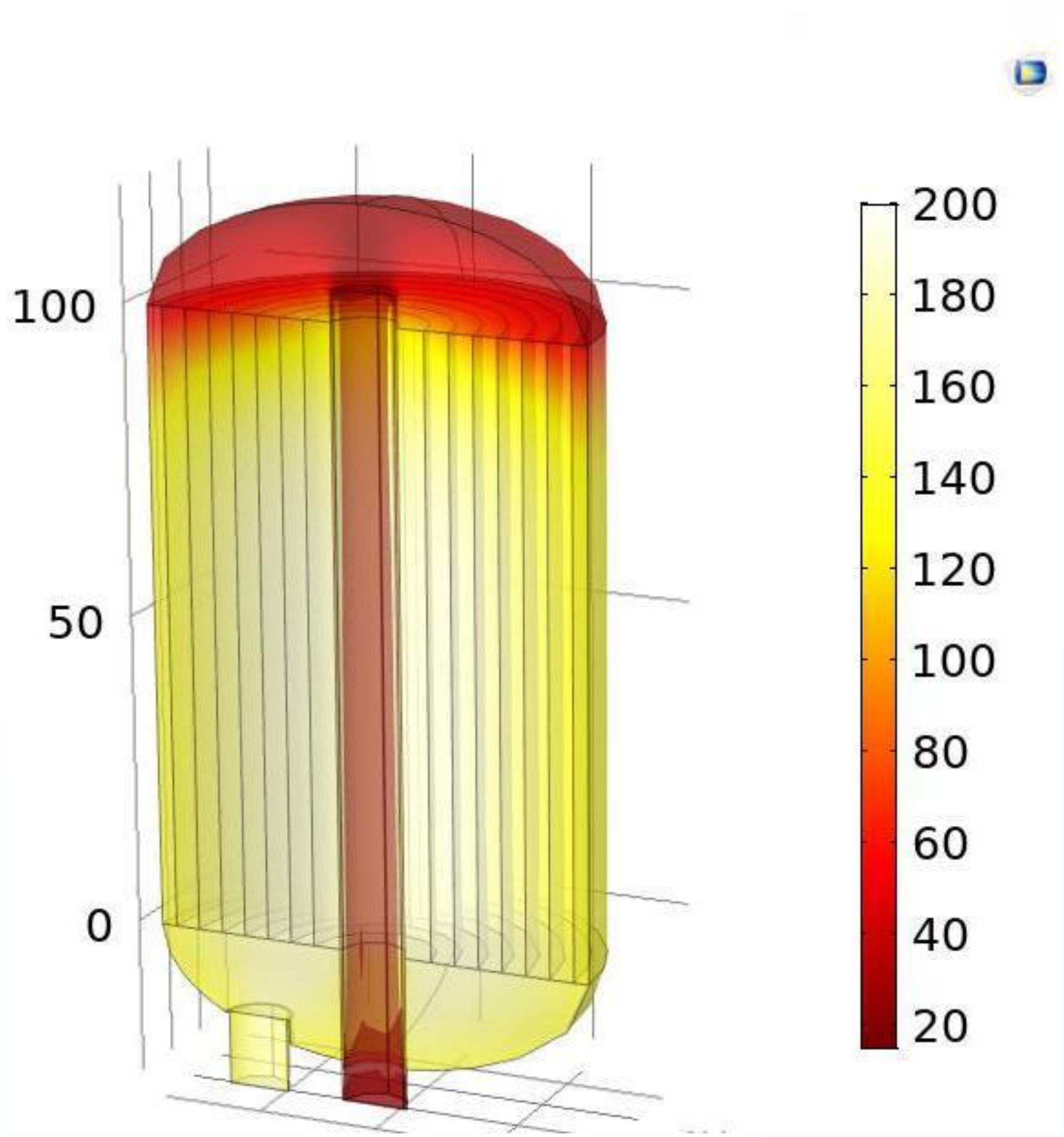
$$\rho\left(u\cdot\nabla\right)u=\nabla\left[-pl+\mu\left(\nabla u+\left(\nabla u\right)^{T}\right)-\frac{2}{3}\mu\left(\nabla\cdot u\right)l\right]+F$$

$$\nabla\cdot\left(\rho u\right)=0$$

$$\frac{1}{\varepsilon_p}\rho\left(\mathrm{u}\cdot\nabla\right)\mathrm{u}\frac{1}{\varepsilon_p}==\nabla\left[-p\mathrm{l}+\mu\frac{1}{\varepsilon_p}\left(\nabla\mathrm{u}+\left(\nabla\mathrm{u}\right)^{\mathrm{T}}\right)-\frac{2}{3}\mu\frac{1}{\varepsilon_p}\left(\nabla\cdot\mathrm{u}\right)\mathrm{l}\right]-$$

$$-\left(\mu k^{-1}+\beta_F\left|\mathrm{u}\right|\frac{\theta_m}{\varepsilon_p^{2}}\right)\mathrm{u}+F$$

$$\nabla\cdot\left(\rho u\right)=Q_m$$



Temperature

The influence of purge air flow on thermal processes in the column is calculated as dynamic heat transfer model

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p v_{trans} \cdot \nabla T + \nabla \cdot q = Q + Q_{ted}$$

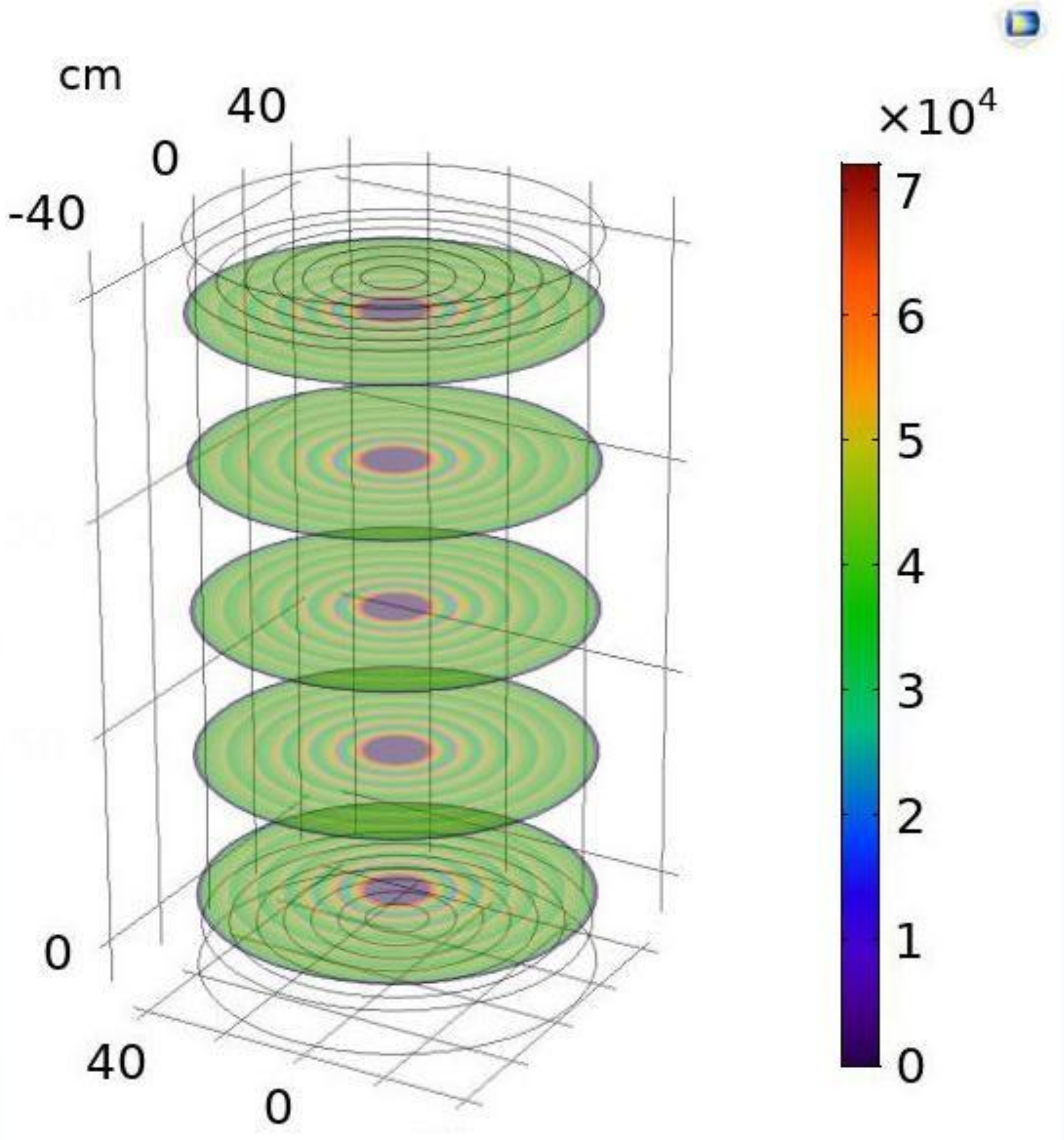
$$\rho C_p \mathrm{u} \cdot \nabla \mathrm{T} + \nabla \cdot q = Q + Q_{vd}$$

$$q = -k_{eff} \nabla \mathrm{T}$$

The heating of the adsorbent due to the effect of alternating voltage

$$\rho C_p u \cdot \nabla T = \nabla \cdot \left(k \nabla T \right) + Q_e$$

$$Q_e = J \cdot E$$



Electric field

The electric field generated in adsorbent volume

$$\nabla \times (\mu_\gamma^{-1} \nabla \times E) - k_0^2 \left(\varepsilon_\gamma - \frac{j\sigma}{\omega \varepsilon_0} \right) E = 0$$

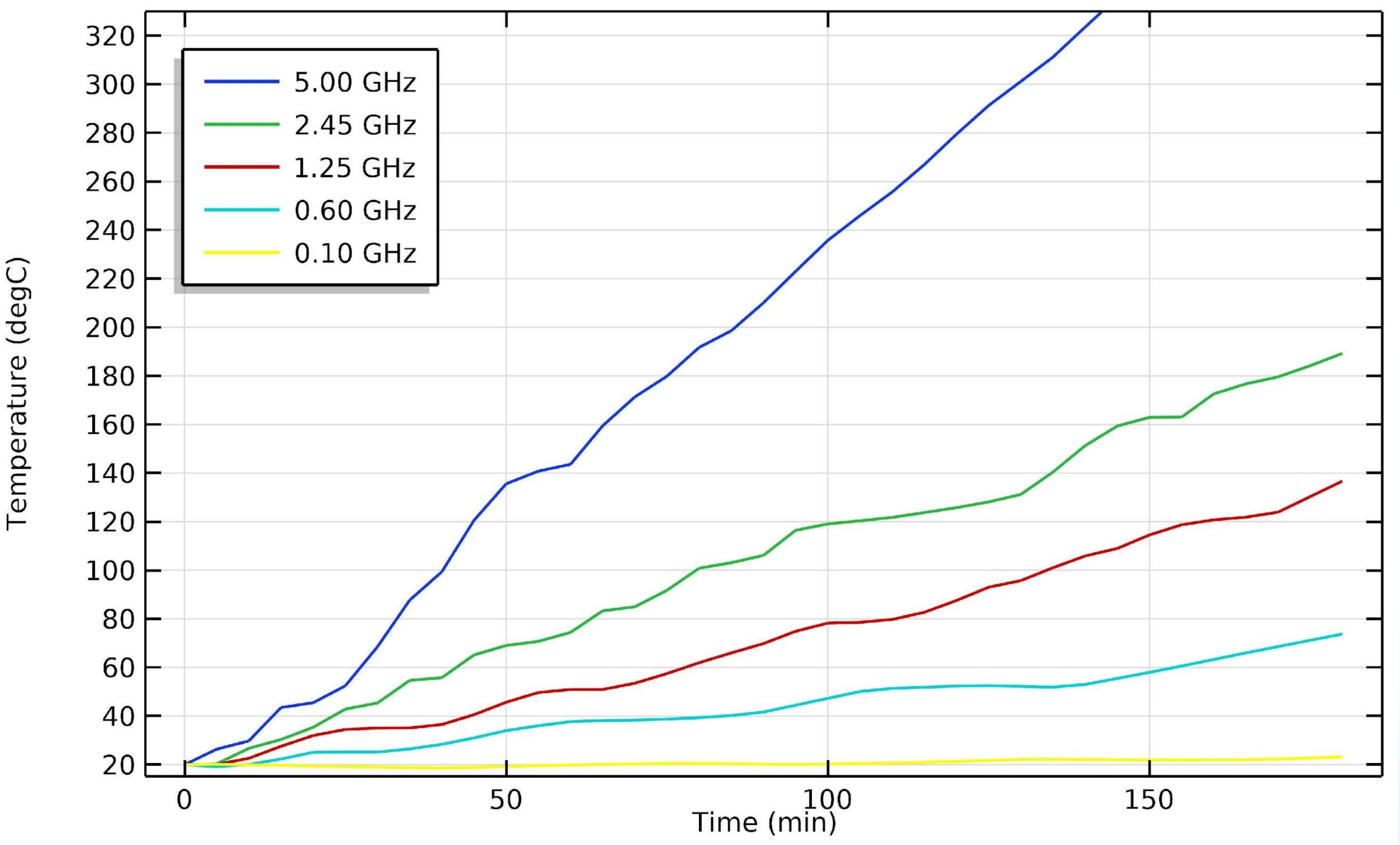
$$\nabla \cdot J = Q_{j,v}$$

$$J = \sigma E + j\omega D + J_e \qquad \omega = 2\pi f$$

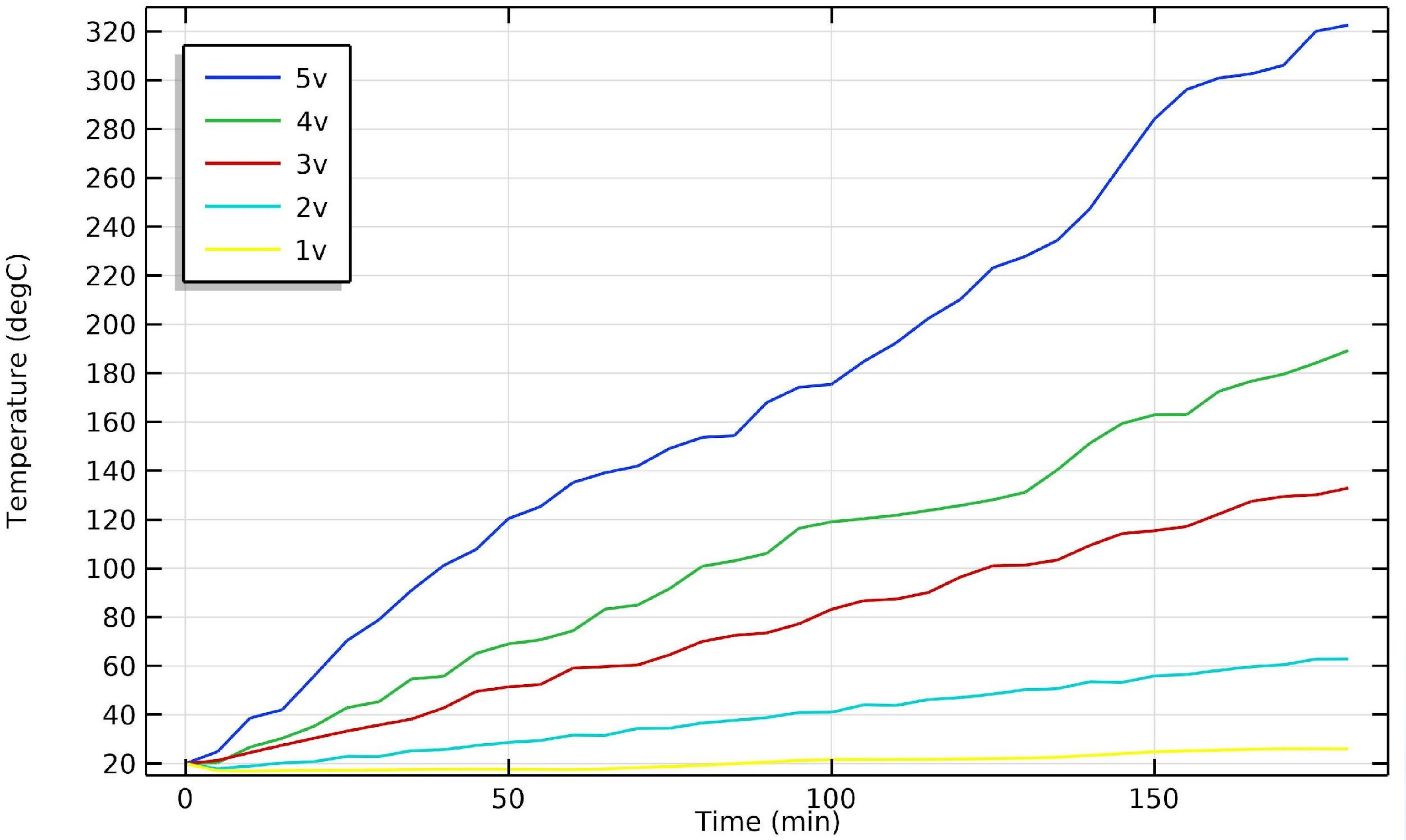
The force, which is affects on the water molecule

$$\bar{F} = \bar{\rho} \cdot \bar{E} \qquad E = \frac{U}{d}$$

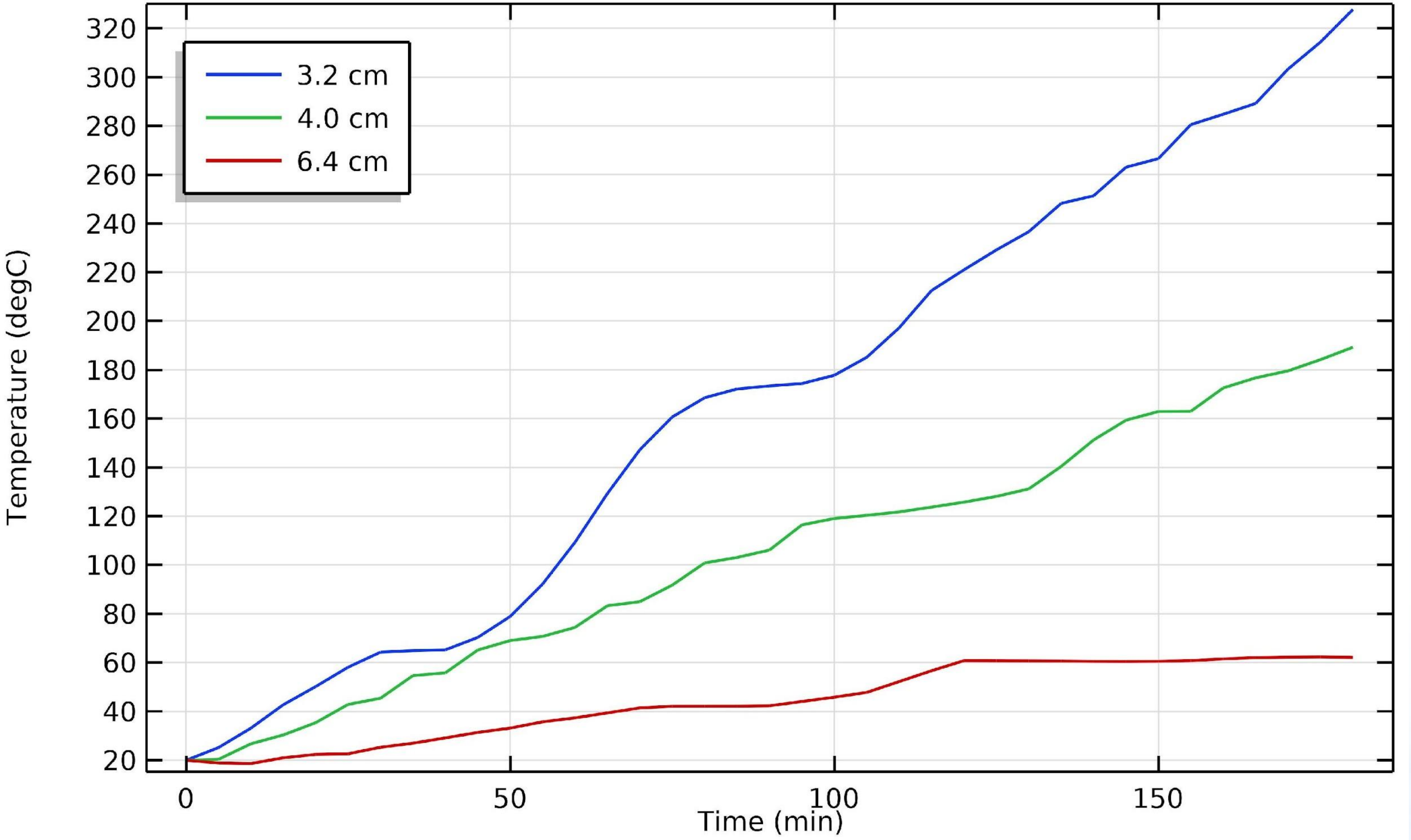
$$F = \Sigma_i \frac{\partial \bar{E}}{\partial x_i} \rho_i \qquad E = -\nabla V$$



The dependence of the heating intensity of exposure to microwave frequency [GHz]

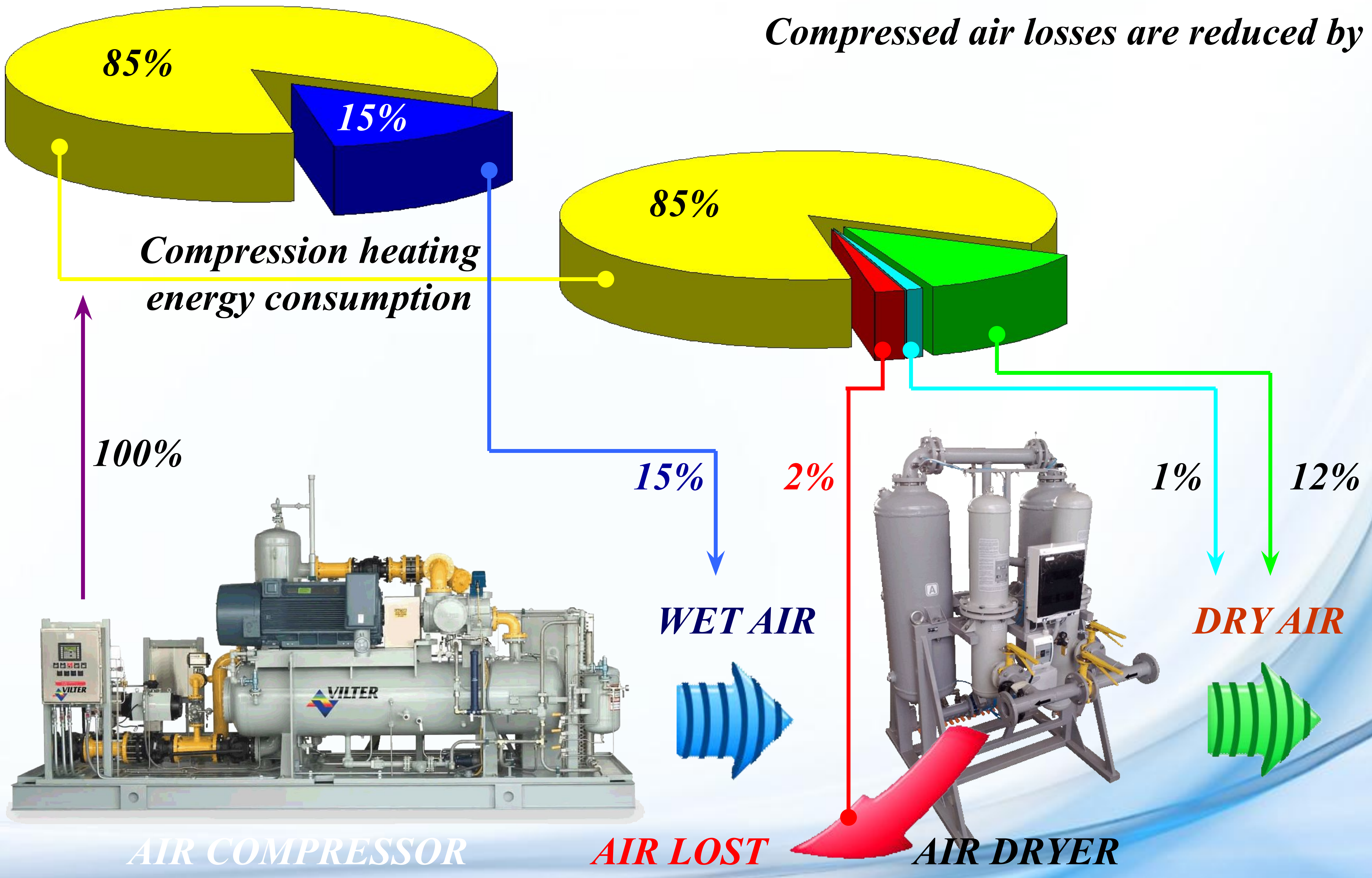


The dependence of the intensity of microwave exposure on the peak voltage on the pole plates [V]



The dependence of the intensity of microwave exposure on the distance between the pole plates [cm]

Compressed air losses are reduced by



The studied design allows the use of microwave regeneration in high-capacity dryers, reducing compressor energy consumption in the production of high-quality compressed air

Thank You for Your time and attention!

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