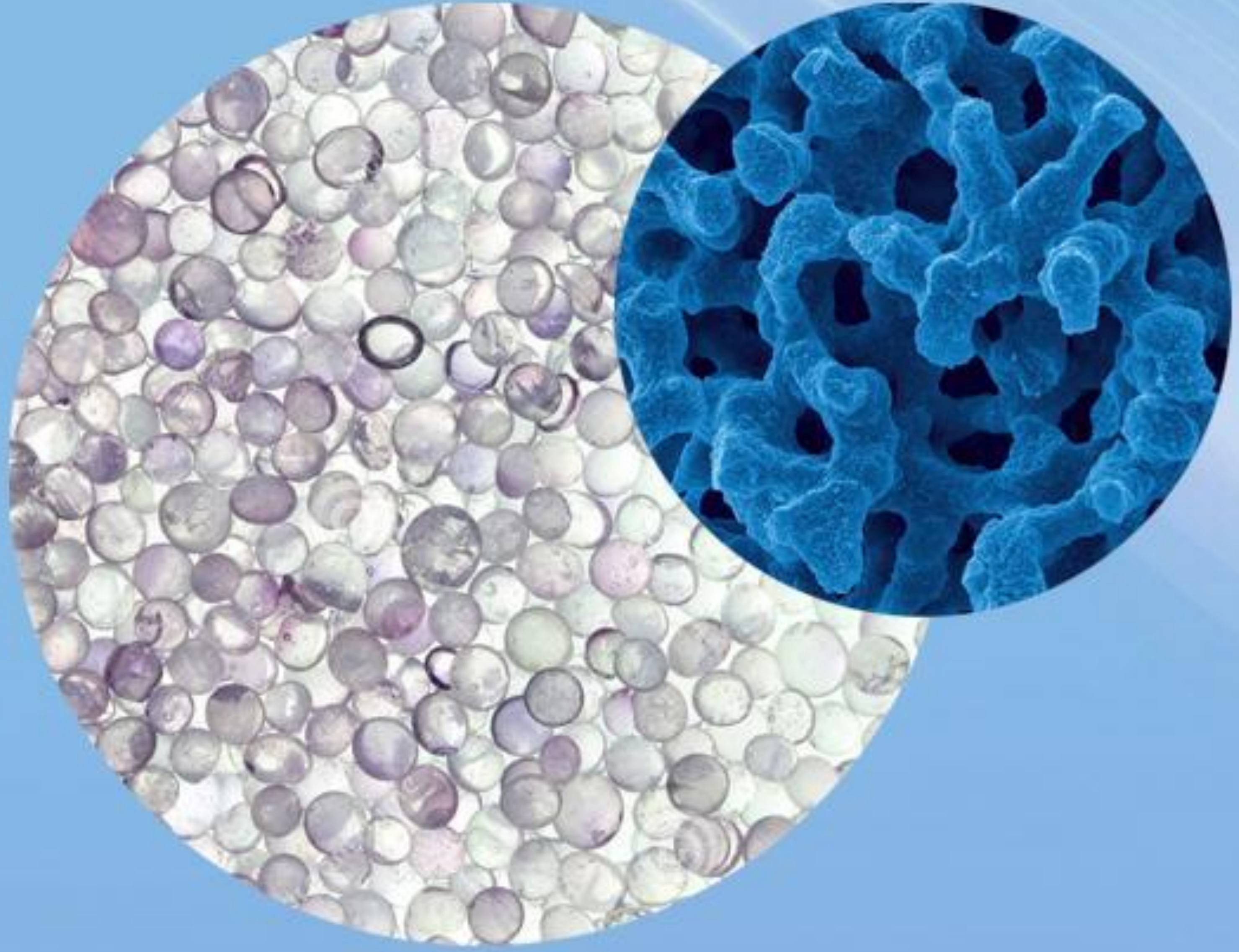
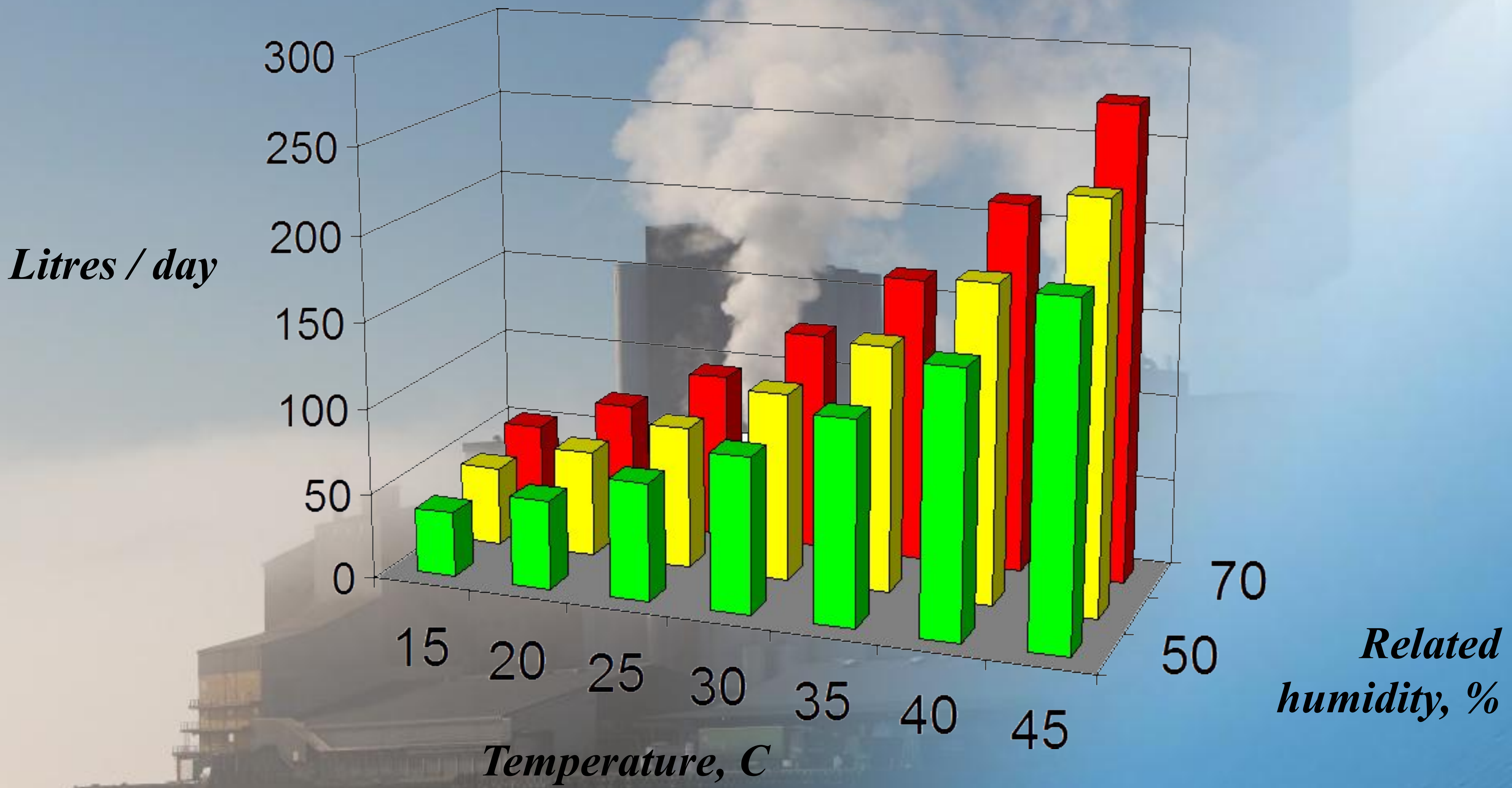


DOBROTVORSKIY S. S.
DOBROVOLSKA L. G.
ALEKSENKO B. A.

USING ALTERNATIVE TYPES OF ENERGY IN THE PROCESS OF REGENERATION OF THE ADSORBENTS

KHARKOV 2017

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



Intake of moisture at suction flow rate 250 m3/h and outlet pressure 8 bar.

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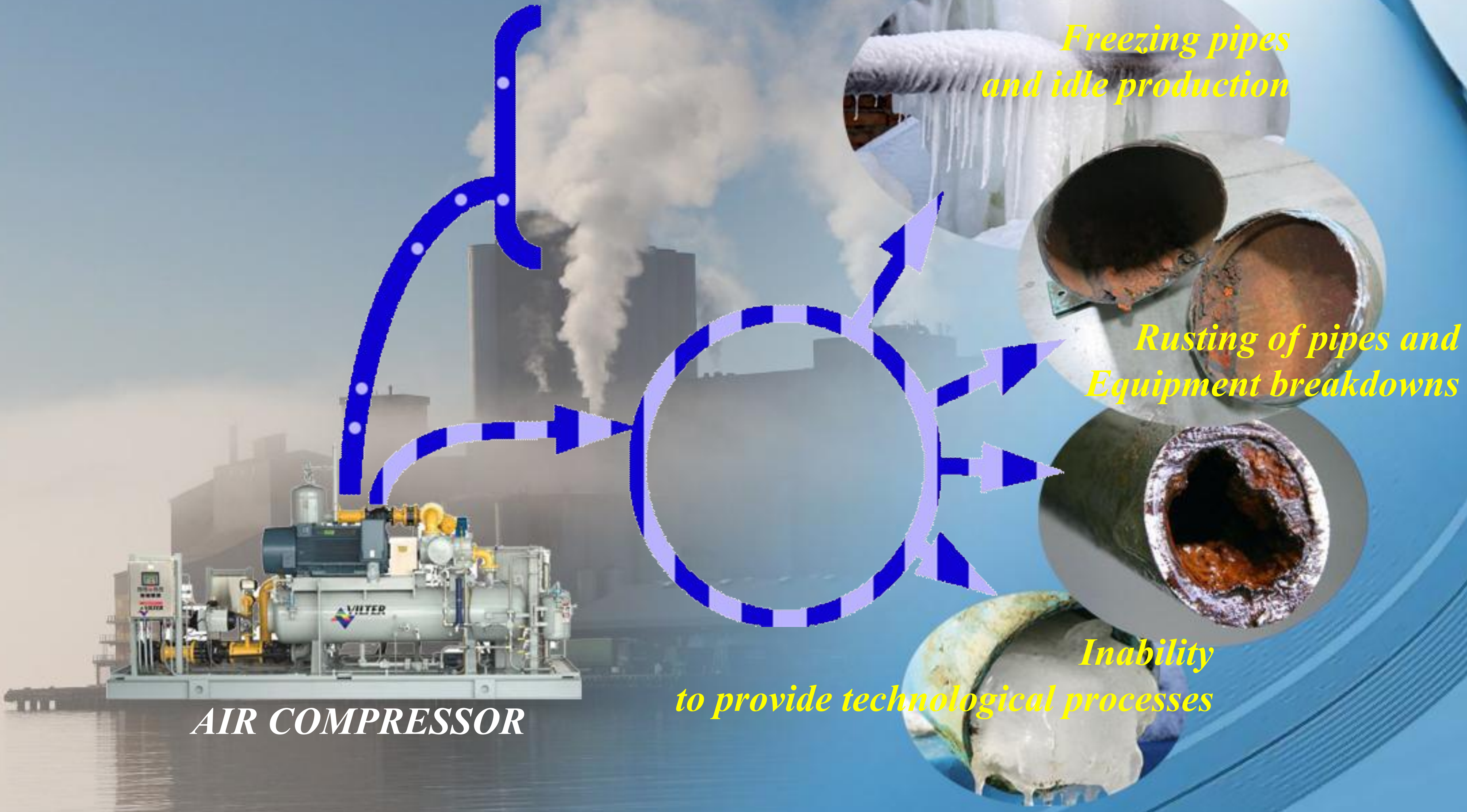

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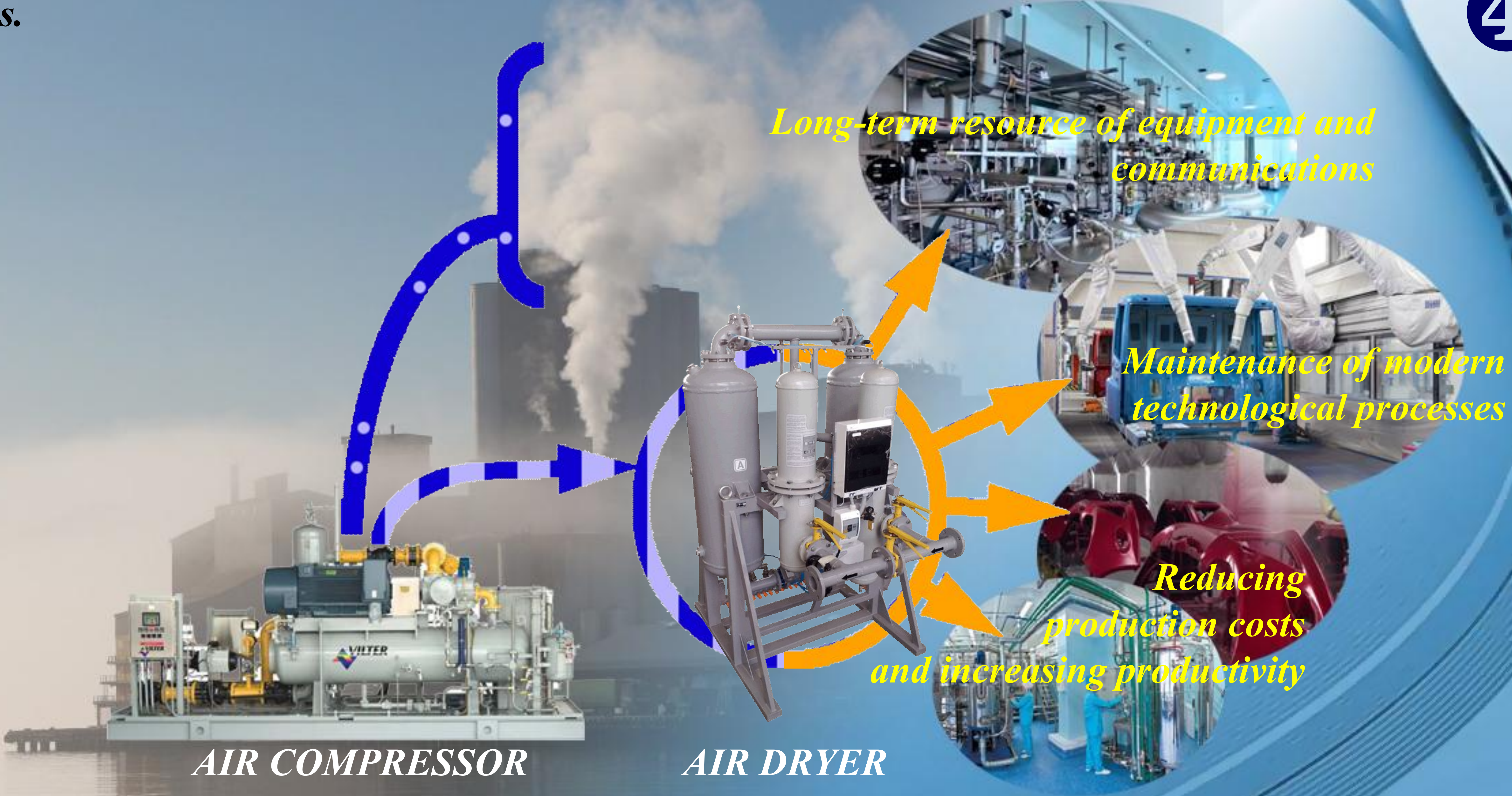

The use of separators, filters and dryers solves these problems

DIN ISO 8573-1

	Particles		Water		Oil
	[µm]	[mg/m³]	DTP [°C]	[g/m³]	[mg/m³]
KLASS 0	More stringent than class 1				
KLASS 1	0,1	0,1	-70	0,003	0,01
KLASS 2	1	1	-40	0,12	0,1
KLASS 3	5	5	-20	0,88	1
KLASS 4	15	8	+3	6	5
KLASS 5	40	10	+7	7,8	25

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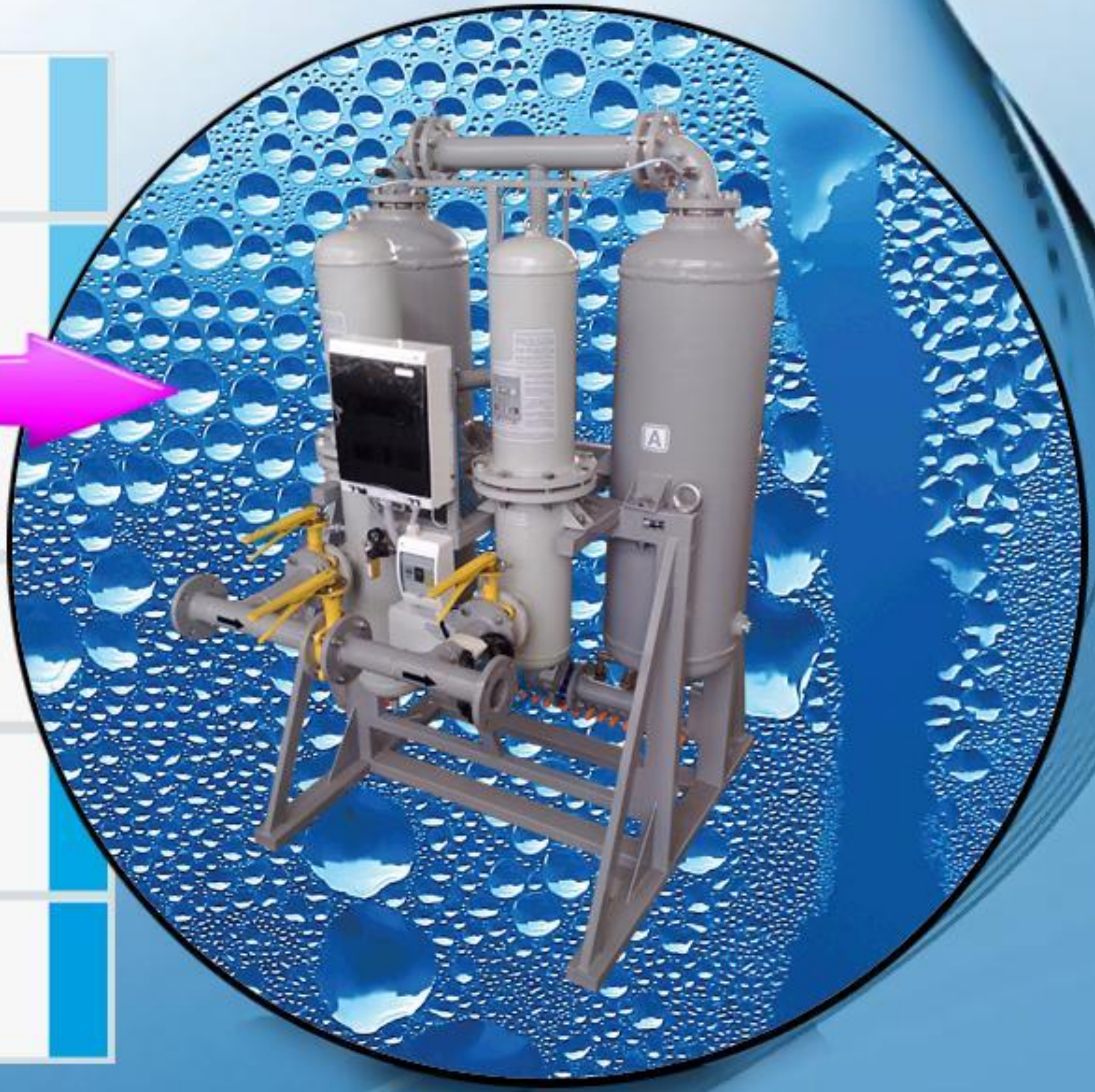
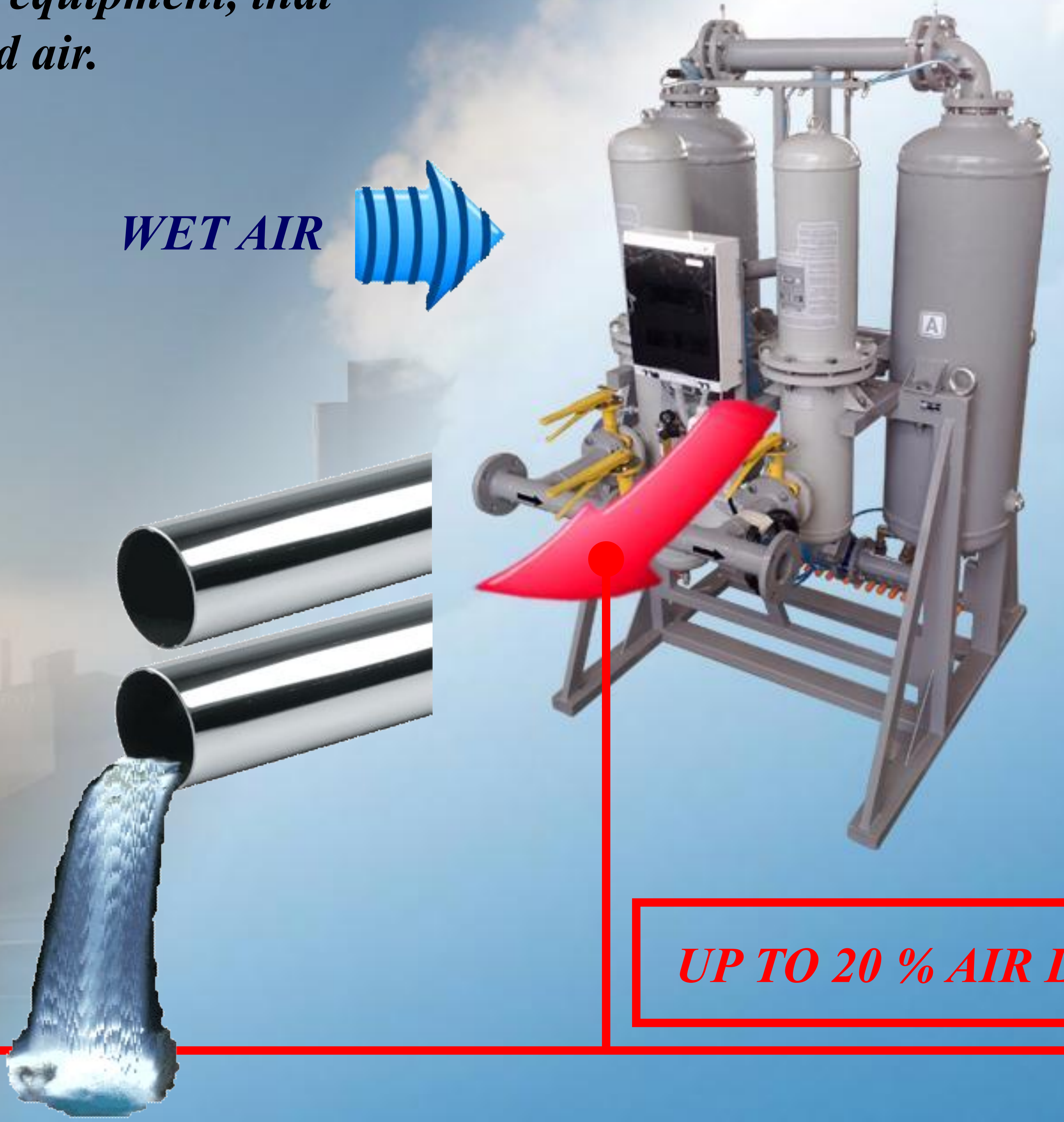


A dryer is an typre of equipment, that consumes compressed air.

WET AIR

DRY AIR

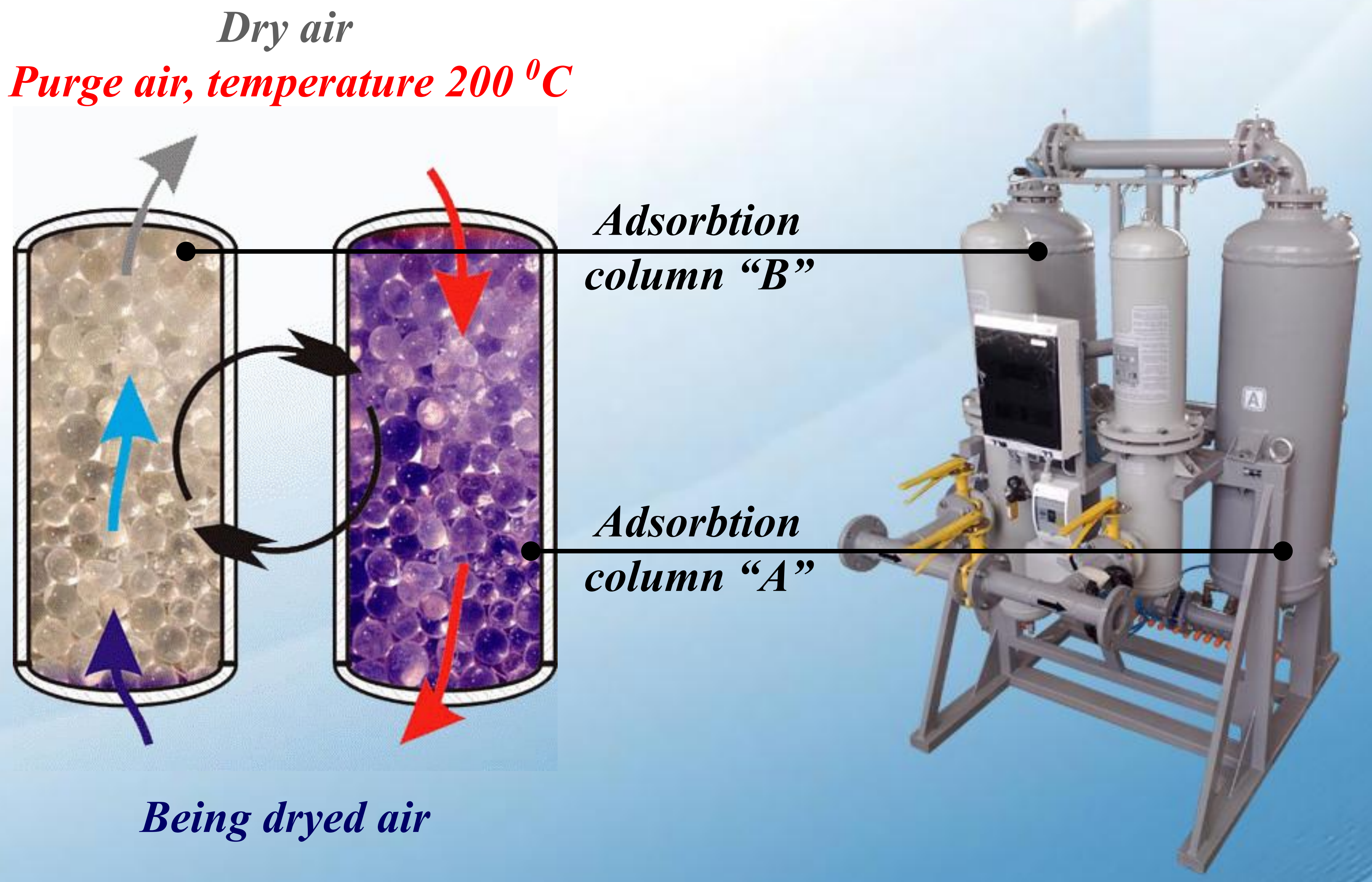


Reducing the amount of compressed air, used to adsorbent regeneration, is a challenge that must be addressed to reduce the cost of air production.

Blowing purge air losses

Water removal losses

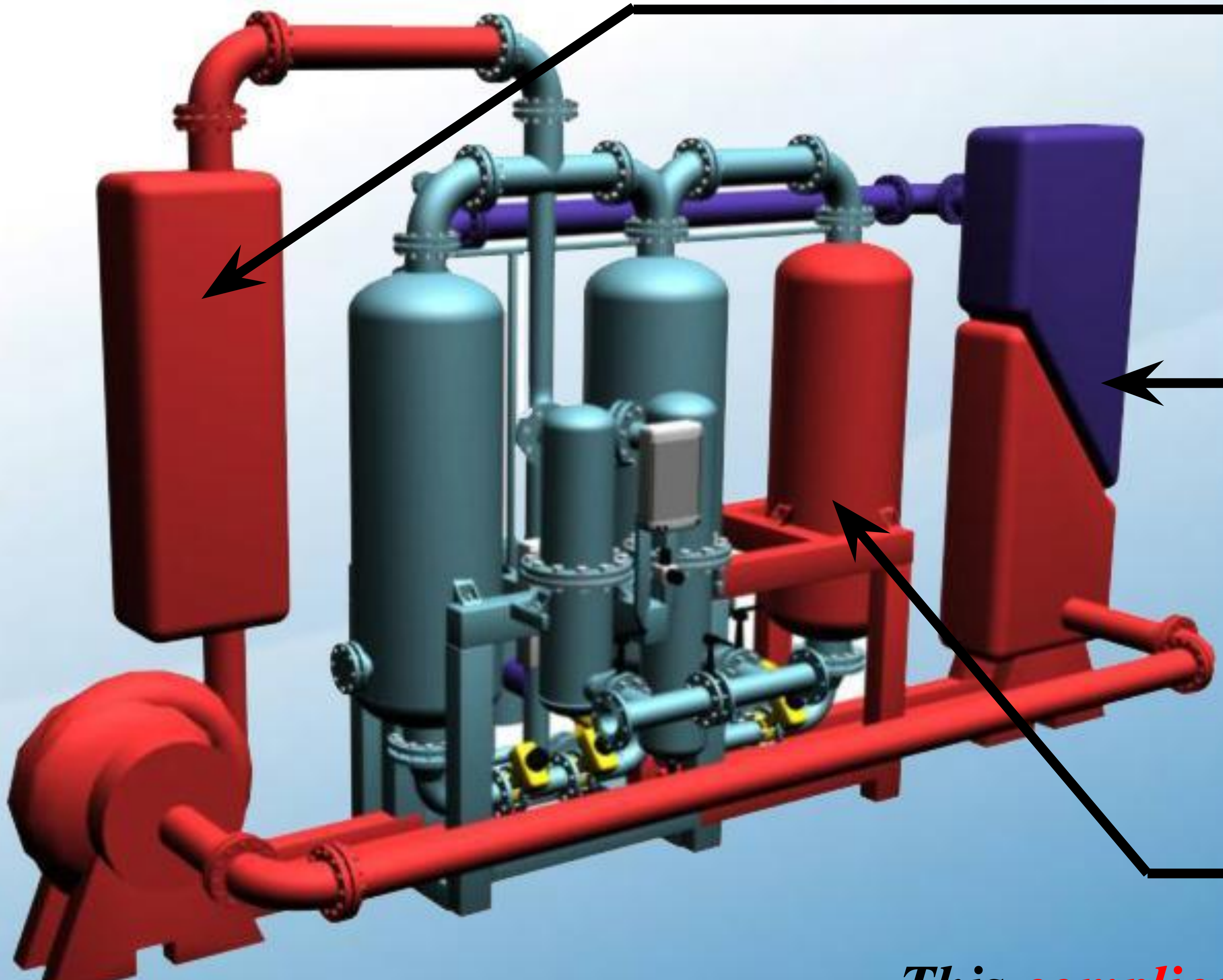
UP TO 20 % AIR LOST



Adsorption columns of the dryer and their cyclic functioning.

AIR DRYER

The design of the adsorption dryer should ensure efficient heating of the adsorbent and its subsequent cooling.
In the construction of the dryers uses:



- Complex systems of electric heaters and blowers,

- Since the heated purge air has a large amount of energy, heat recuperators are used,

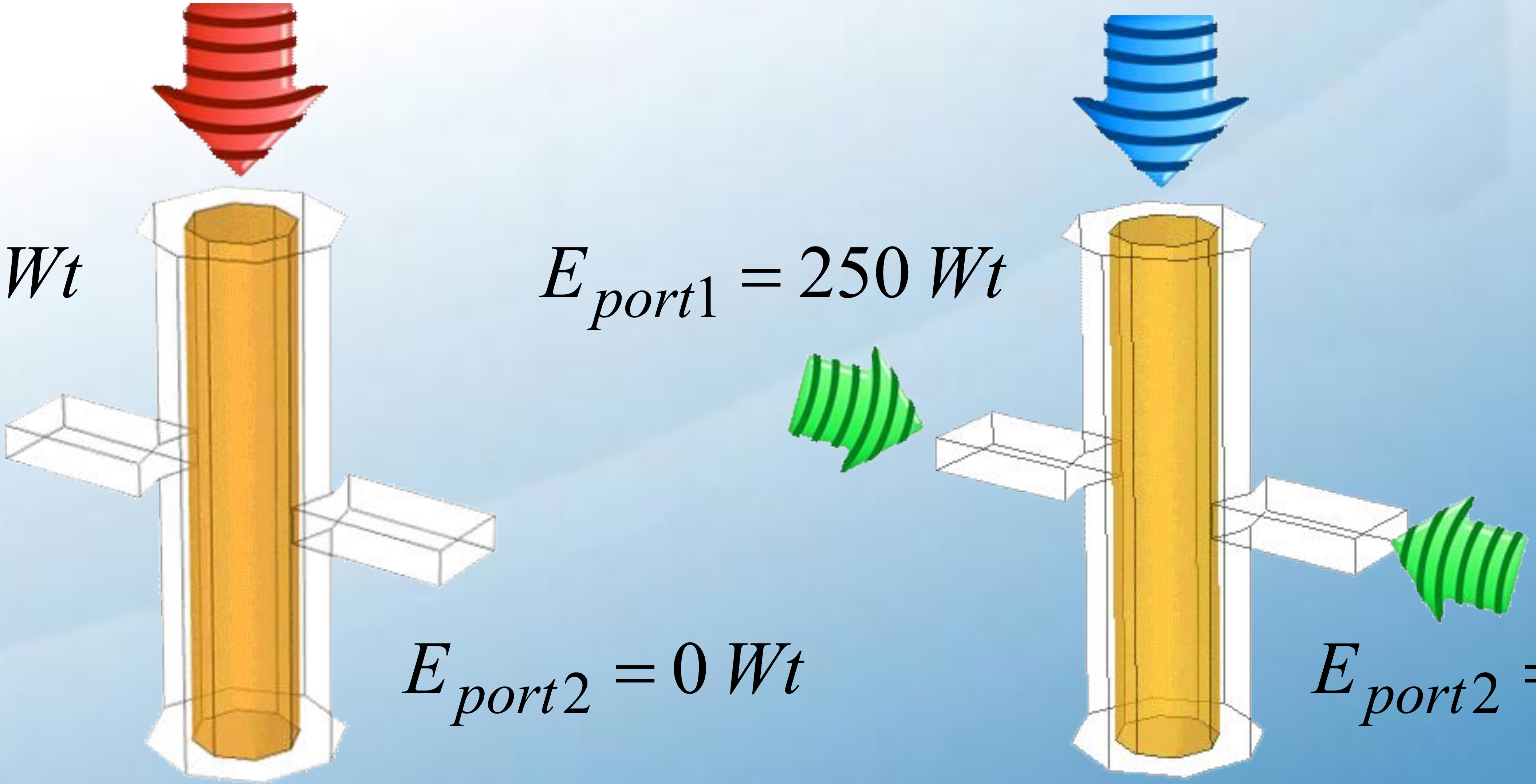
- If the drying process of the adsorbent lasts longer than the adsorption process, additional adsorption columns must be used.

This complicates the design and increases the cost of the dryer.

A comparative computer experiment was performed in which the humidity of the adsorbent was reduced to level H_u using convection and microwave radiation successively .

$t_{purge\_air} = 180\ ^0C$ $\quad$ $t_{purge\_air} = 20\ ^0C$

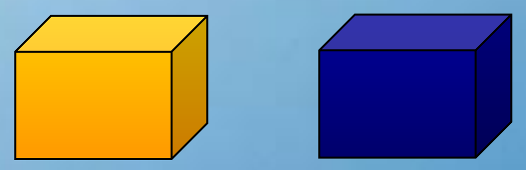
$E_{port1} = 0\ Wt$ $\quad$ $E_{port1} = 250\ Wt$



$E_{port2} = 0\ Wt$ $\quad$ $E_{port2} = 250\ Wt$

Humidity level change

$H_{u1} \rightarrow H_{u0}$



Convection regeneration $\quad$ ***Microwave regeneration***

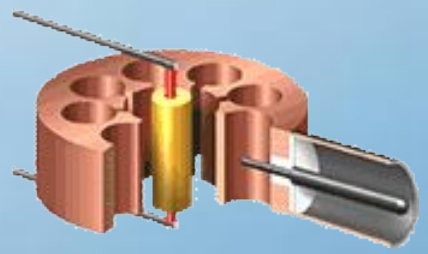
TARGET GUNCTION

$$\Delta Q = \int_{t(H_{u1})}^{t(H_{u0})} f(Q_{desorption\_convection} - Q_{desorption\_microwave})dt \rightarrow \max$$

$$\begin{cases} t = 180\ ^{0}C \\ E = 0\ Wt \end{cases}$$

OR

$$\begin{cases} t = 20\ ^{0}C \\ E = 500\ Wt \end{cases}$$



Convection regeneration conditions

Microwave regeneration conditions

In the process of mathematical modeling of the regeneration process using the convection desorption method, the following equations were used:

$$\begin{cases} t = 180\ ^{0}C \\ E = 0\ Wt \end{cases}$$

$$Q_{heat} = \rho Cp \frac{\partial T}{\partial t} + \rho Cp\, u \cdot \nabla T - \nabla \cdot (k \nabla T)$$

Purge air, temperature

$$Q_{evap\_heat} = H_{vap} \cdot K \cdot \left(\frac{p_{sat}(T)}{\mathrm{R}T} - c\right)$$

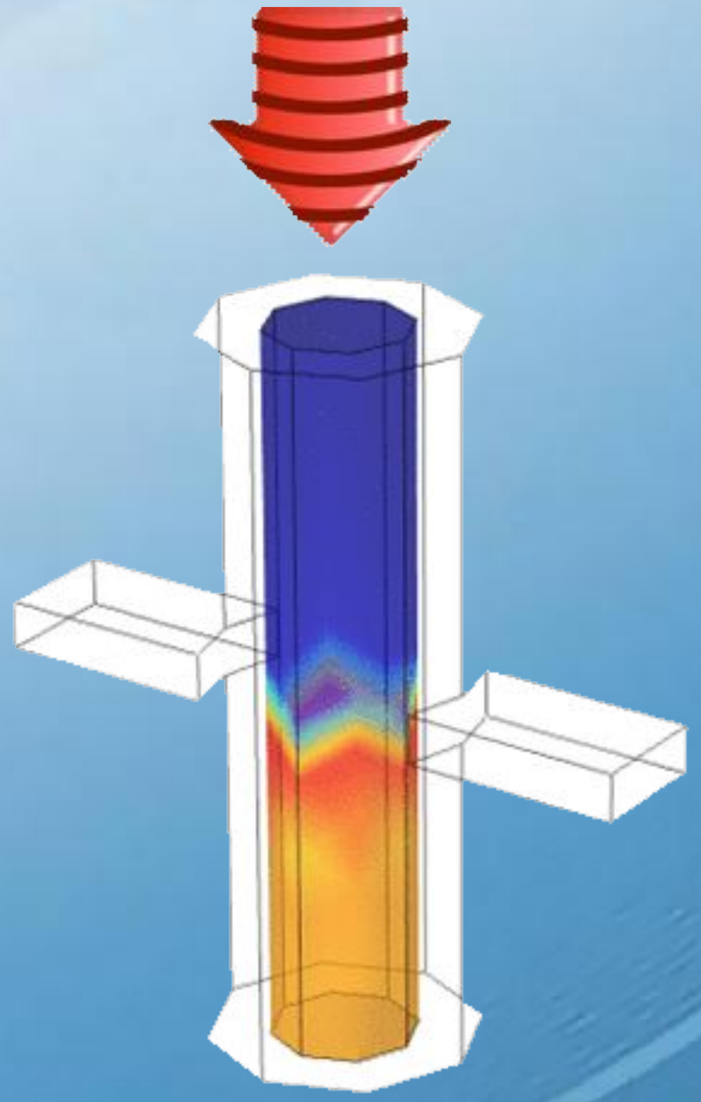
Evaporation heat

$$Q_{desorption\_convection} = cm\Delta T$$

Heat of desorbtion

$$Q_{convection} - Q_{evaporation} = Q_{desorption}$$

Heat balance equation



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$$\begin{Bmatrix} t = 20\ {}^{0}C \\ E = 500\,Wt \end{Bmatrix}$$

$$Q_{heat} = \rho c_p \frac{\partial T}{\partial t} H_{vap} + \rho c_p u \nabla T (k \nabla T)$$

Purge air, temperature

$$Q_{evap\_heat} = H_{vap} \cdot K \cdot \left(\frac{p_{sat}(T)}{\mathrm{R}T} - c\right)$$

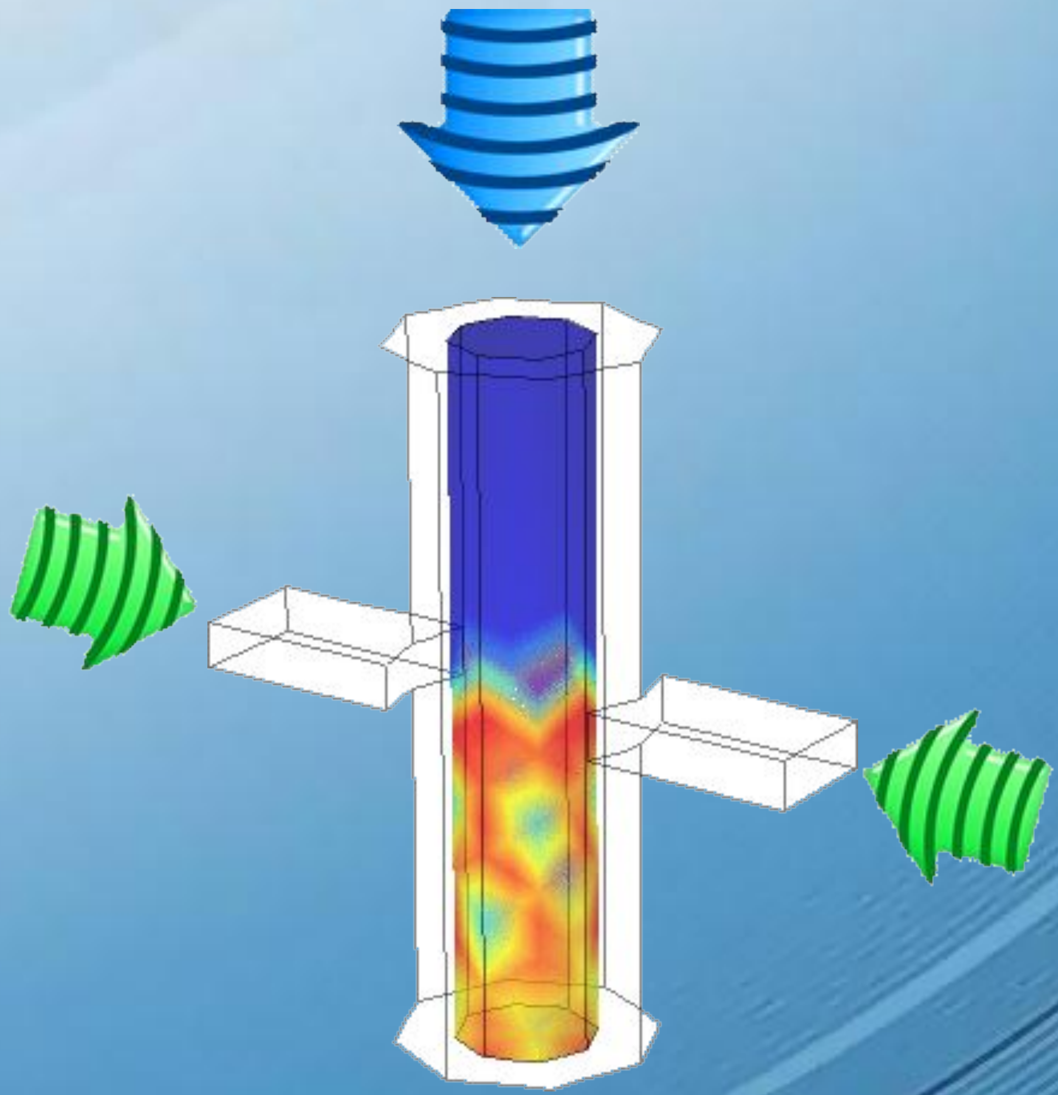
Evaporation heat

$$\nabla \times \left(\frac{1}{\mu_\gamma} \nabla \times E(x,y) \right) - k_0^2 \varepsilon_\gamma E(x,y) = 0$$

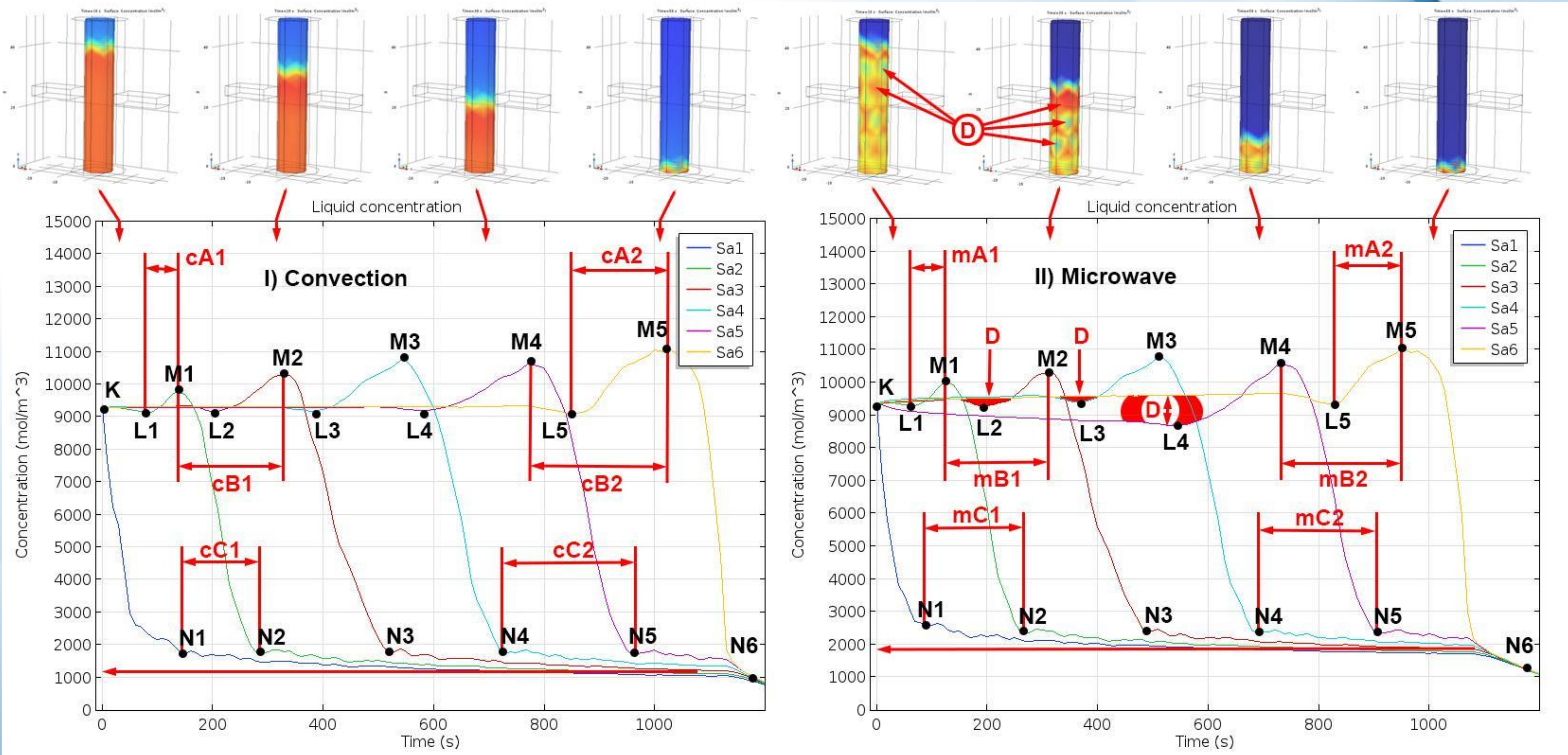
The electromagnetic field distribution

$$Q_{microwave} = E^2 \omega \varepsilon_r \varepsilon_0 tg\sigma$$

Microwave energy



A comparative computer experiment was performed in which the humidity of the adsorbent was reduced to level H_u using convection and microwave radiation successively .



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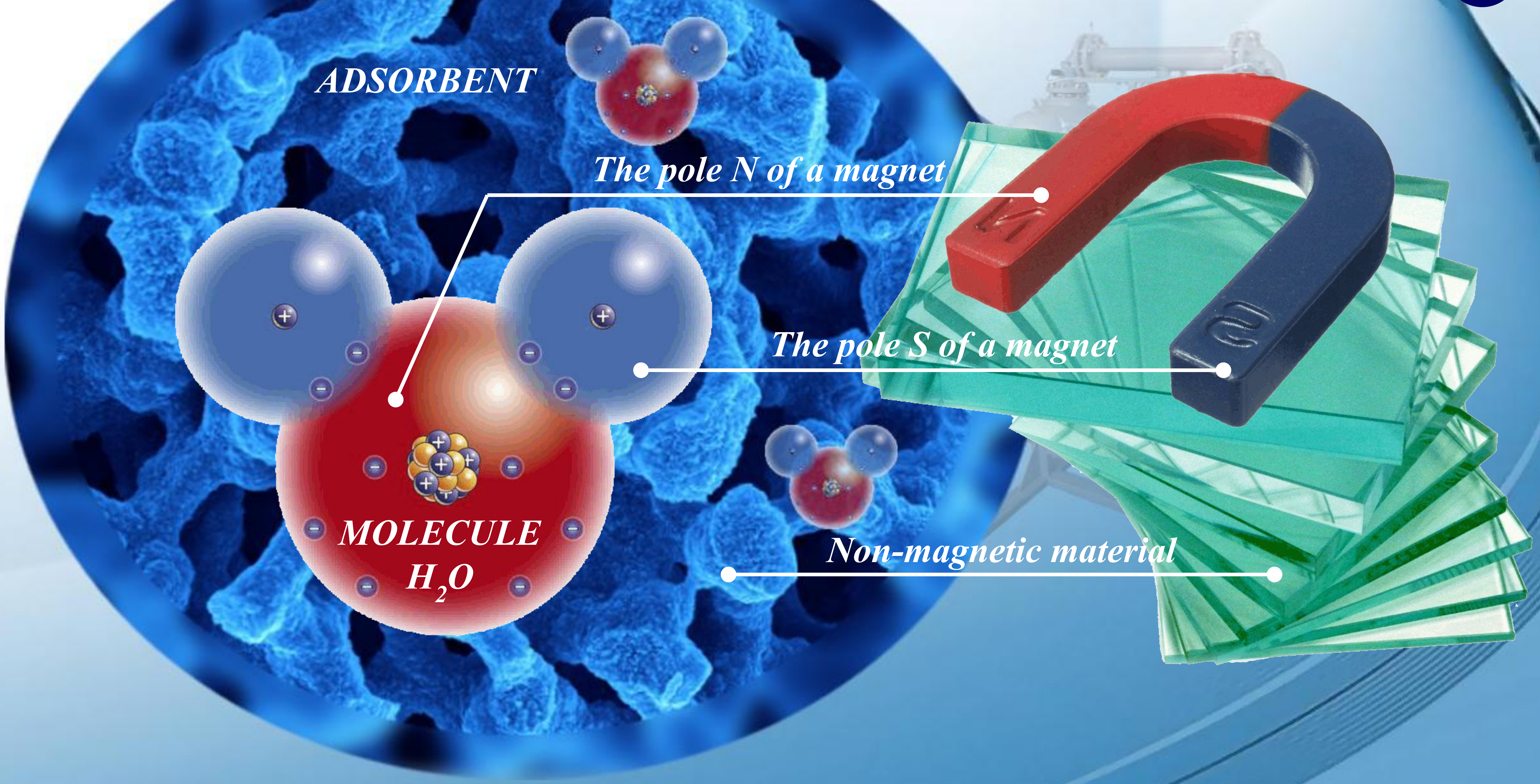
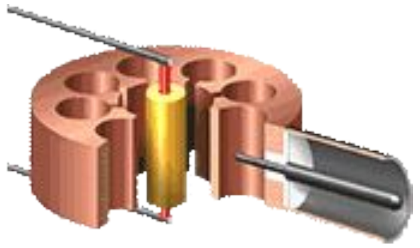


The action of microwave radiation makes it possible to effect on water molecules directly.



MAGNETRON

$$\nabla \times \left(\frac{1}{\mu_\gamma} \nabla \times E(x,y) \right) - k_0^2 \varepsilon_\gamma E(x,y) = 0$$

The electromagnetic field distribution

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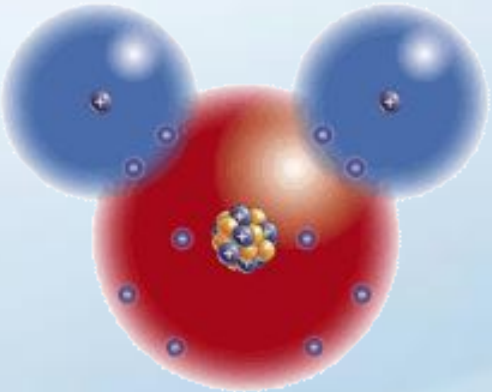
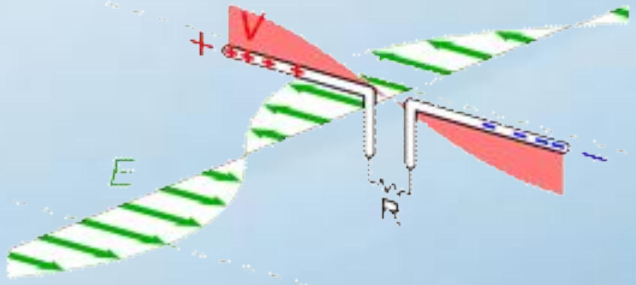
Microwave energy





$$\varepsilon_{H_2O} >> \varepsilon_{SIO_2}$$

The dielectric permittivity

The great value of the dielectric constant is explained by the peculiarities of the H2O molecule. The large value of the static permittivity of water (ε = 81) is due to the fact that water is a strongly polar liquid and therefore has a soft orientation degree of freedom (ie rotation of molecular dipoles).

$$Q_{MV\_action\_H_2O} >> Q_{MV\_action\_SIO_2}$$

The magnitude of the energy of microwave radiation

WATER DEPORISATION STAGE

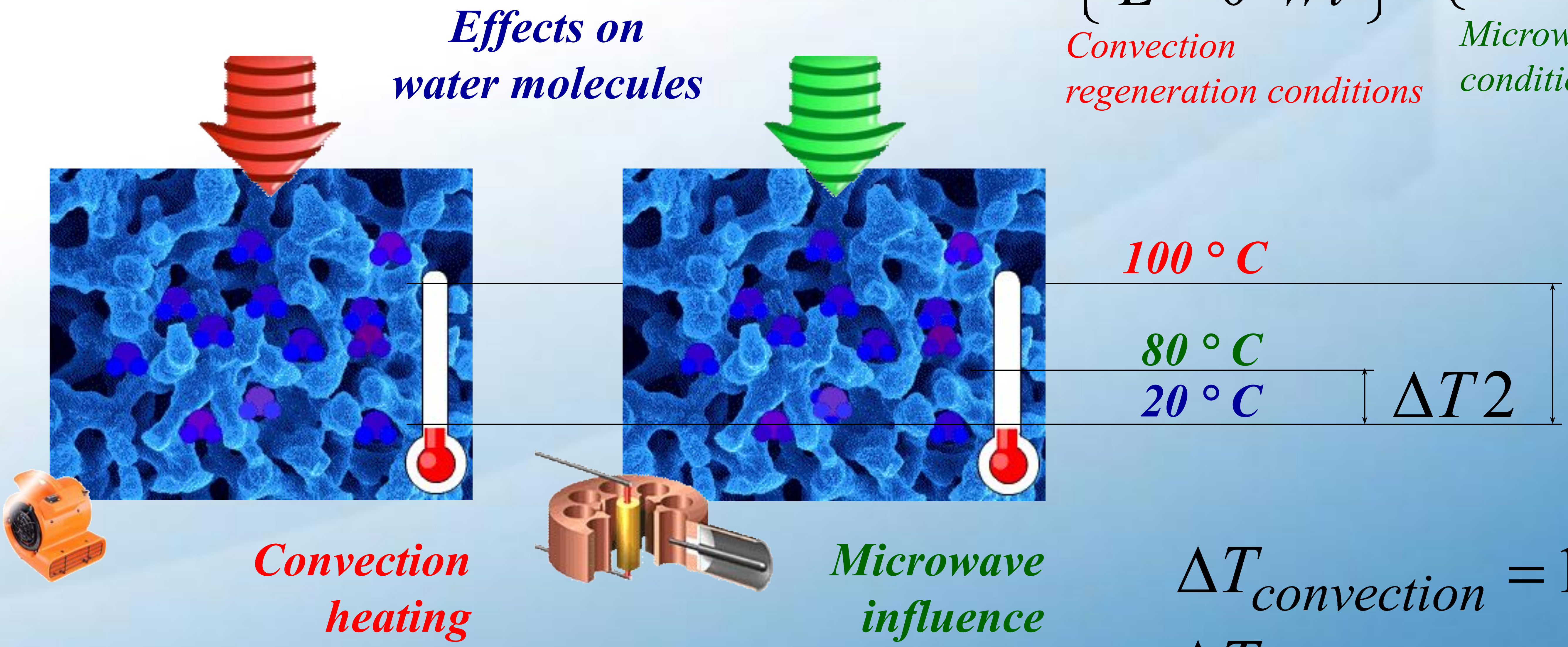
$$H_{u\_convection} = H_{u\_microwave}$$

$$\begin{cases} t = 180 \ {}^{0}C \\ E = 0 \ Wt \end{cases}$$

Convection regeneration conditions

$$\begin{cases} t = 20 \ {}^{0}C \\ E = 500 \ Wt \end{cases}$$

Microwave regeneration conditions



$$\Delta T_{convection} = 100^{o}$$

$$\Delta T_{microwave} = 60^{o}$$

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

Computer calculations showed, that when drying by convection, the temperature of the adsorbent was 100 ° C. And when it was dried with microwaves - 80 ° C only.

COOLING ADSORBENT STAGE

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

Required amount of cooling air

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

Convection heating

Microwave influence

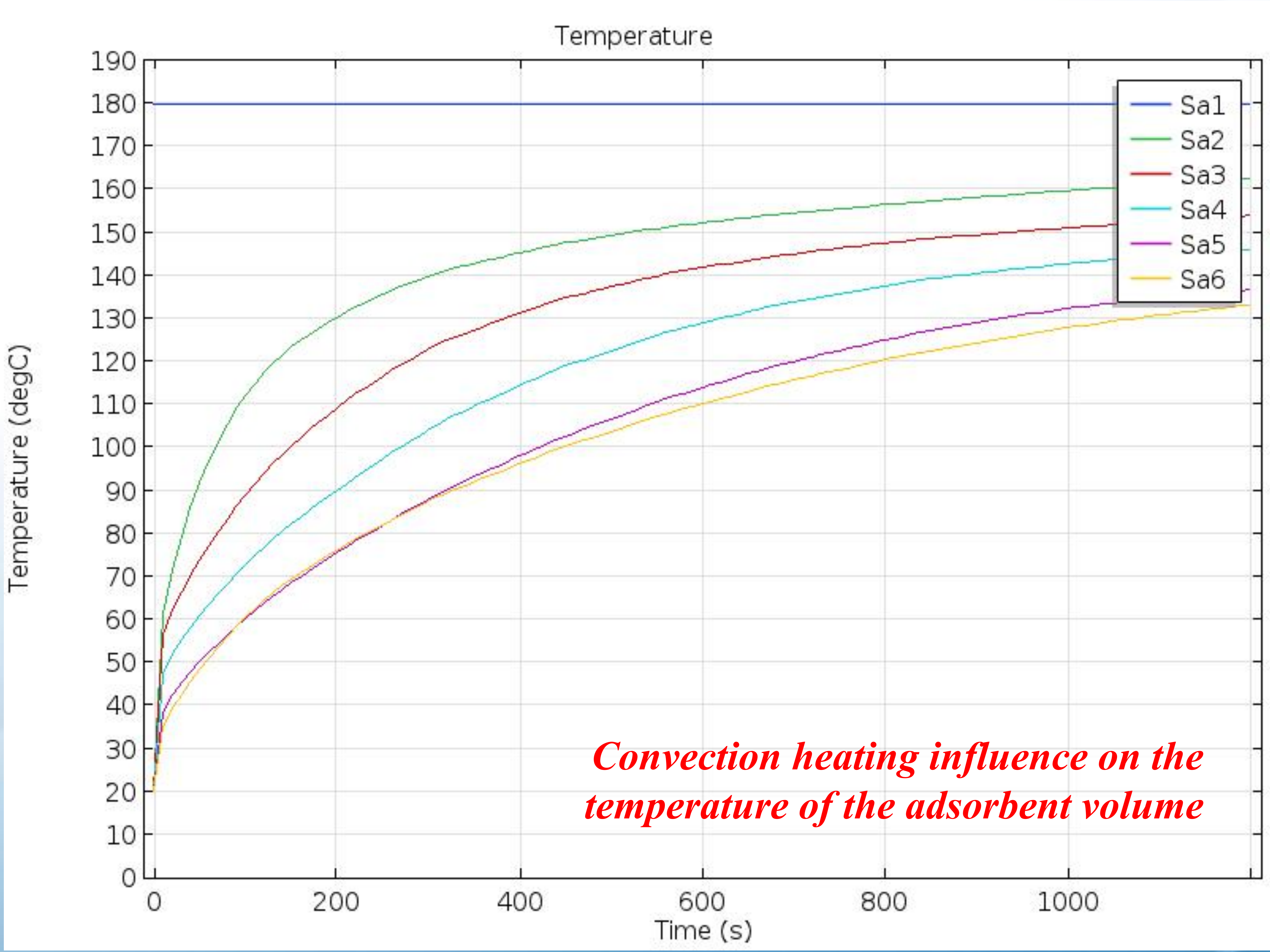
$$V_{air\,(convection)} > V_{air\,(microwave)}$$

Taking into account that

$V = m / \rho$ ***and*** $\rho = const$

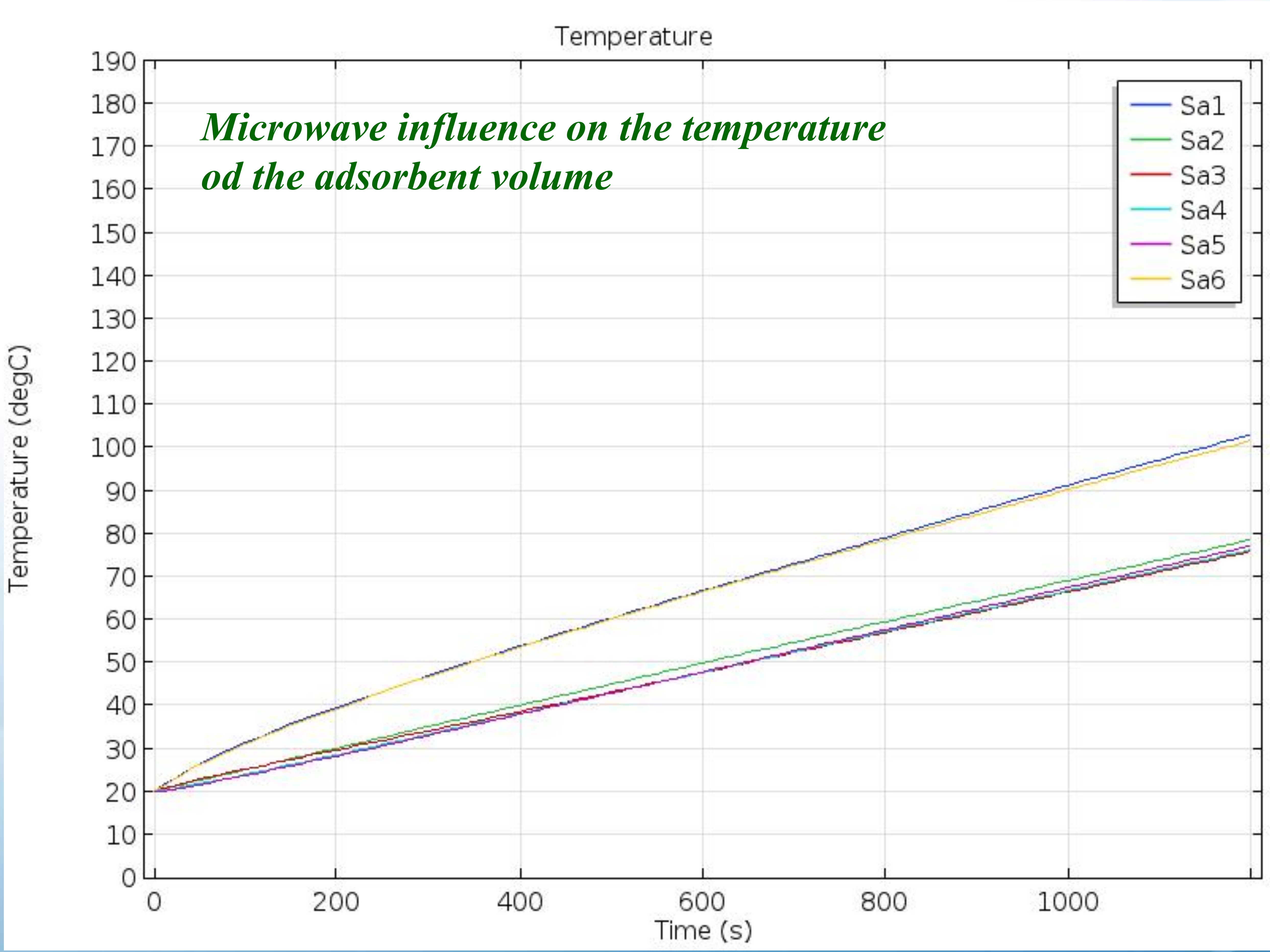
ensues, that

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



In the process of convection heating, data are obtained on the dynamics of temperature growth in the control layers Sa1, Sa2, Sa3, Sa4, Sa5 and Sa6 of the adsorbent volume.

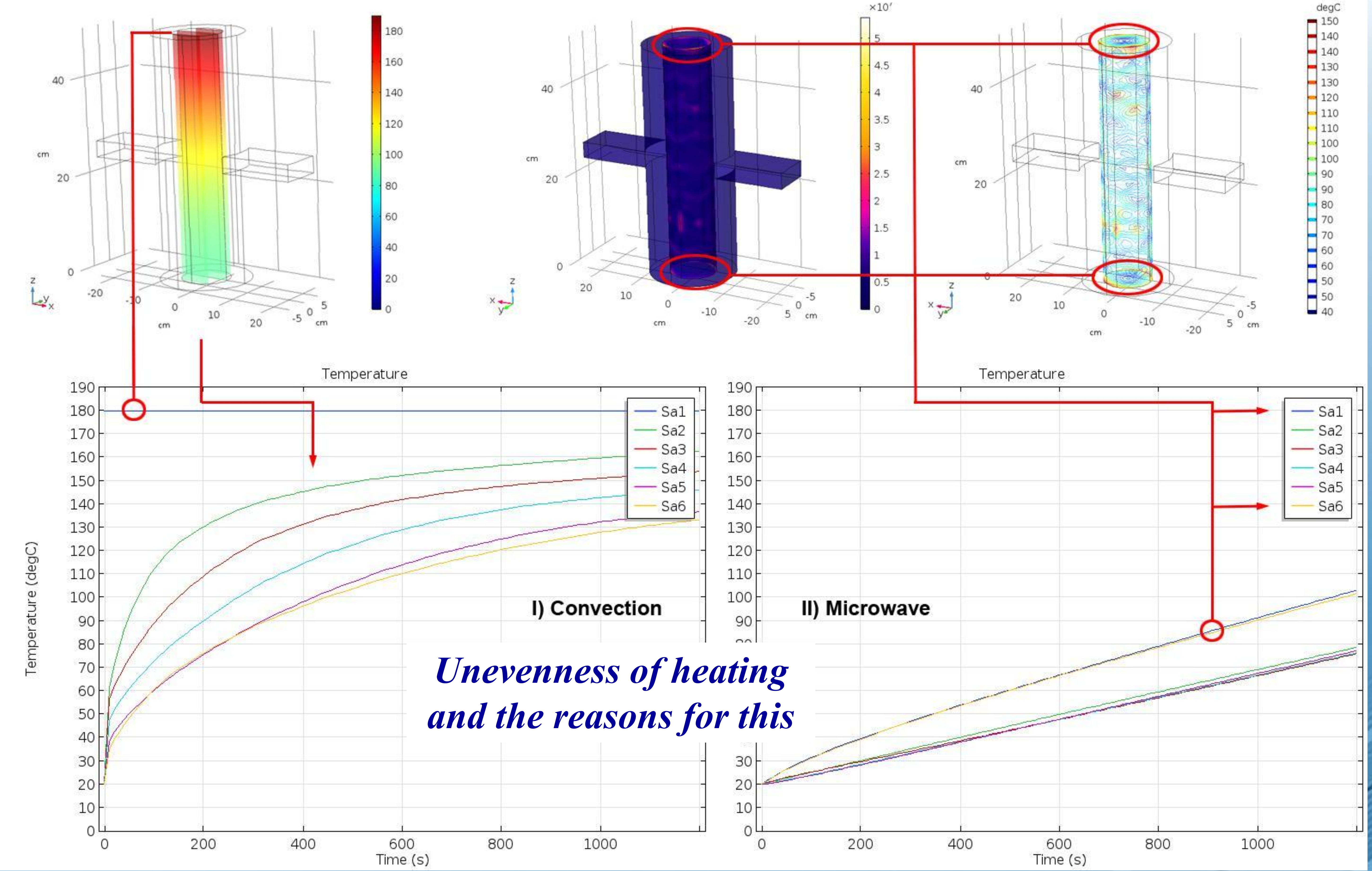
Microwave influence on the temperature od the adsorbent volume



In the process of microwave heating, data are obtained on the dynamics of temperature growth in the control layers Sa1, Sa2, Sa3, Sa4, Sa5 and Sa6 of the adsorbent volume.

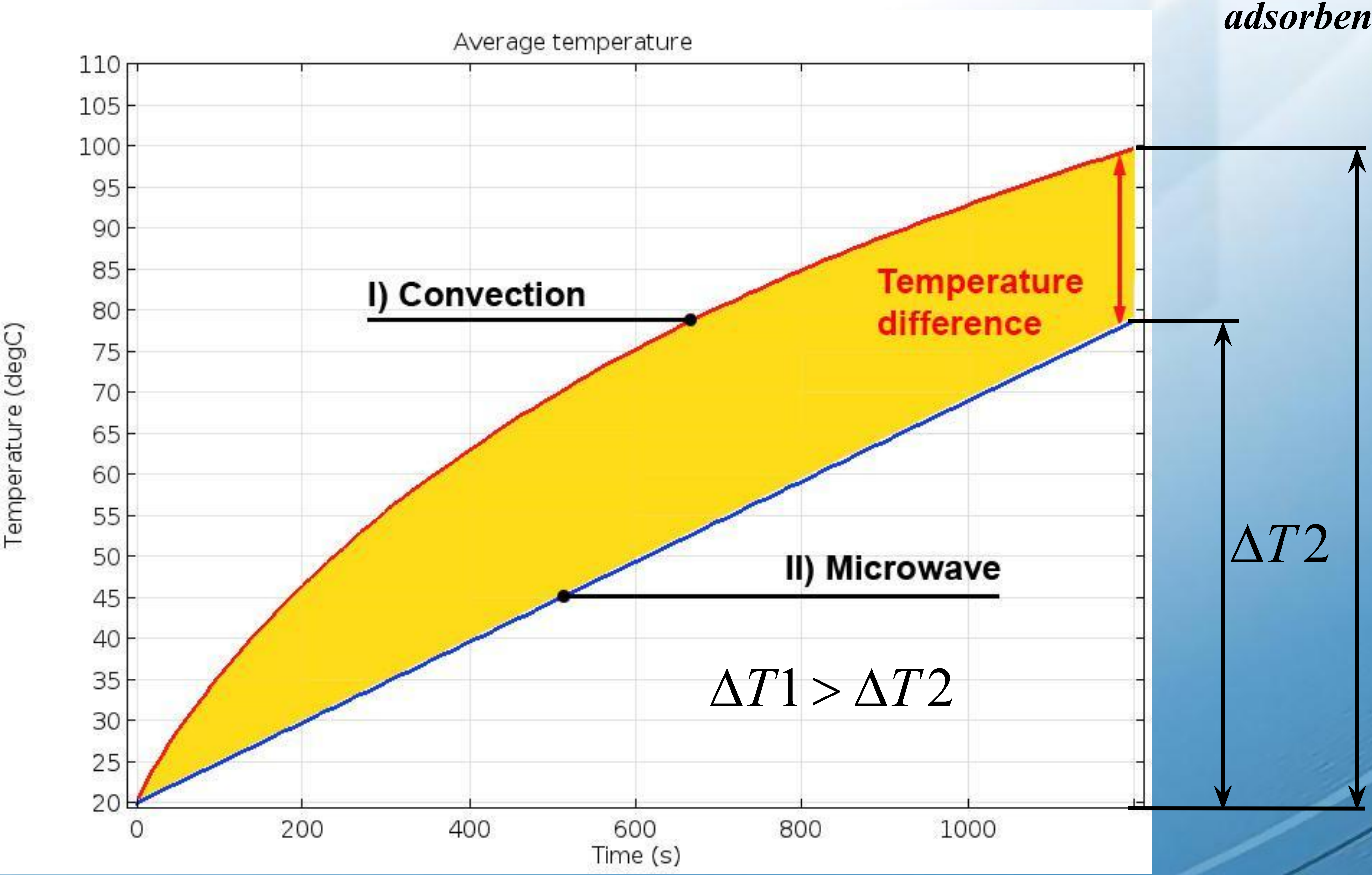
Unevenness of convection

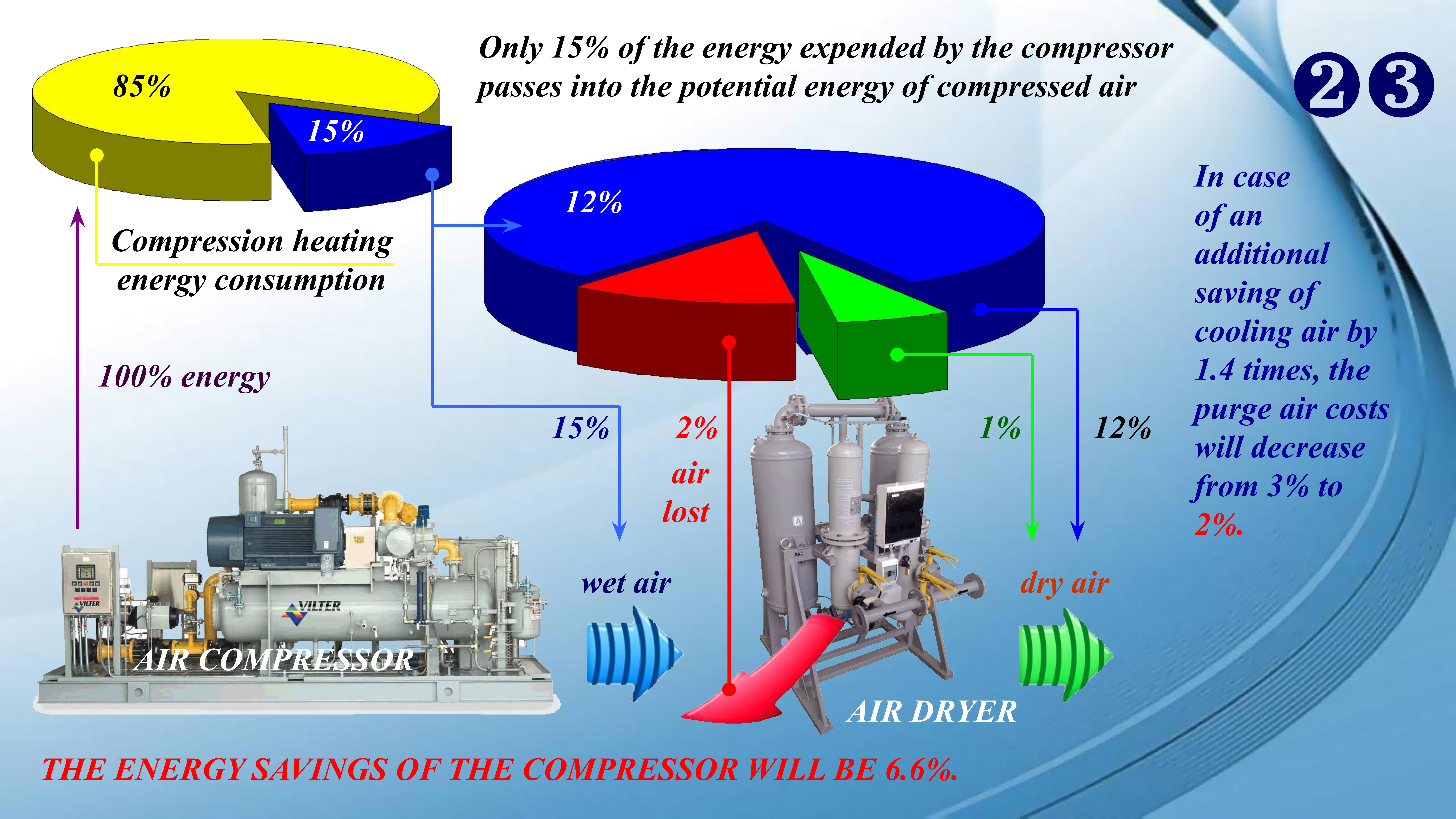
Unevenness of electromagnetic field strength



Unevenness of heating and the reasons for this

Also, data are obtained on the dynamics of average temperature growth of the adsorbent volume.




Only 15% of the energy expended by the compressor passes into the potential energy of compressed air
23
85%
15%
12%
Compression heating energy consumption
100% energy
15%
2%
air
lost
1%
12%
In case of an additional saving of cooling air by 1.4 times, the purge air costs will decrease from 3% to 2%.
wet air
dry air
VILTER
AIR COMPRESSOR
AIR DRYER
THE ENERGY SAVINGS OF THE COMPRESSOR WILL BE 6.6%.

THANK YOU FOR YOUR TIME AND ATTENTION!