III International Scientific Conference **“Sustainable and efficient use of energy, water and natural resources – SEWAN-2021”**

# Numerical simulation of processes in the latent-heat thermal energy storage tank

**Authors: Rafael Faizullin, Victoria Zakharova, Alexander Baranenko**

**Affiliations: ITMO University, Saint Petersburg**

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***Keywords:***
thermal energy storage, LHTES, PCM, mathematical modeling

## Research Objective:

Development and verification of a mathematical model of thermal processes in the latent-heat thermal energy storage tank.

## Relevance of the problem:

The increase in energy consumption requires the introduction of innovative energy-saving technologies. One of these technologies is thermal energy storage. However, the selection of the optimal design parameters for the heat accumulator is a complex engineering problem. Current mathematical models and methods of their implementation do not have the necessary qualities (speed, accuracy) for carrying out design calculations.

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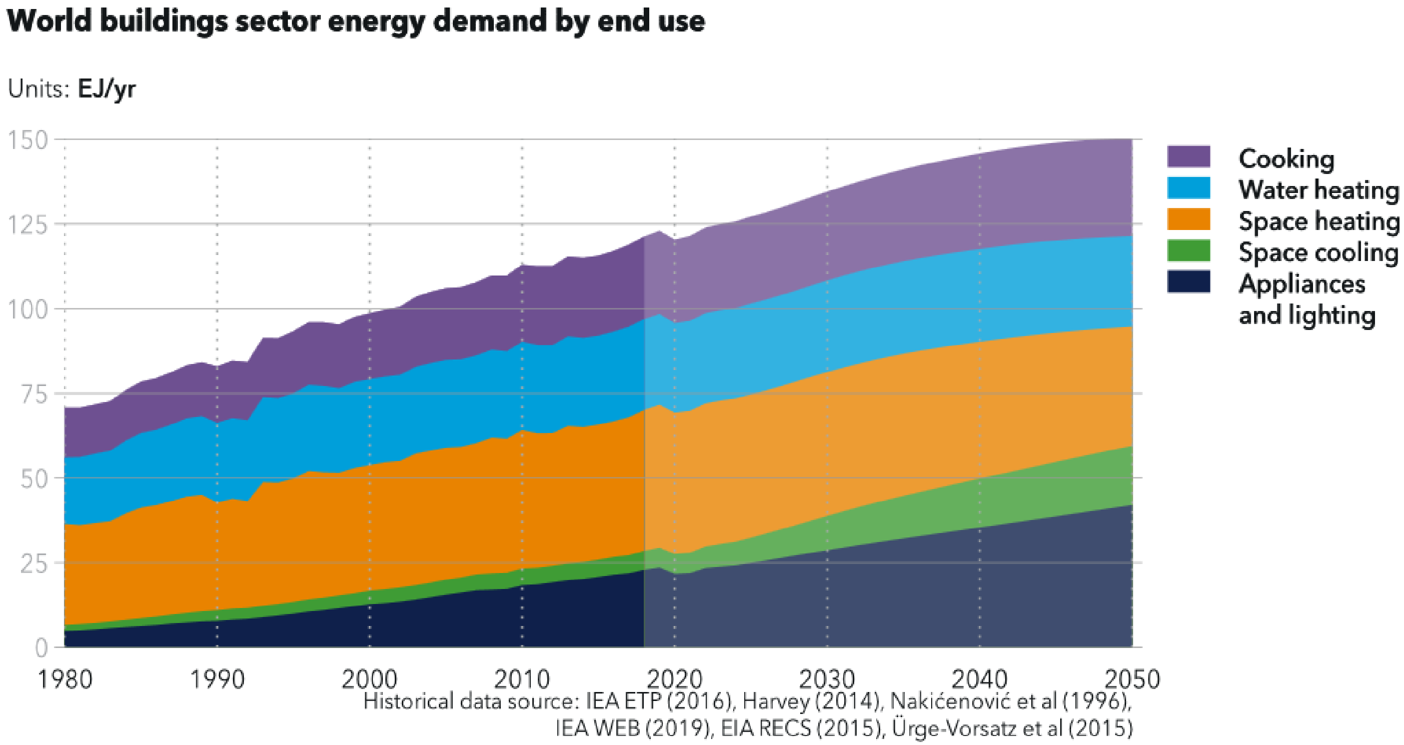


**In the near future, a significant increase in the number of air conditioning systems and an increase in their total electricity consumption are predicted.**

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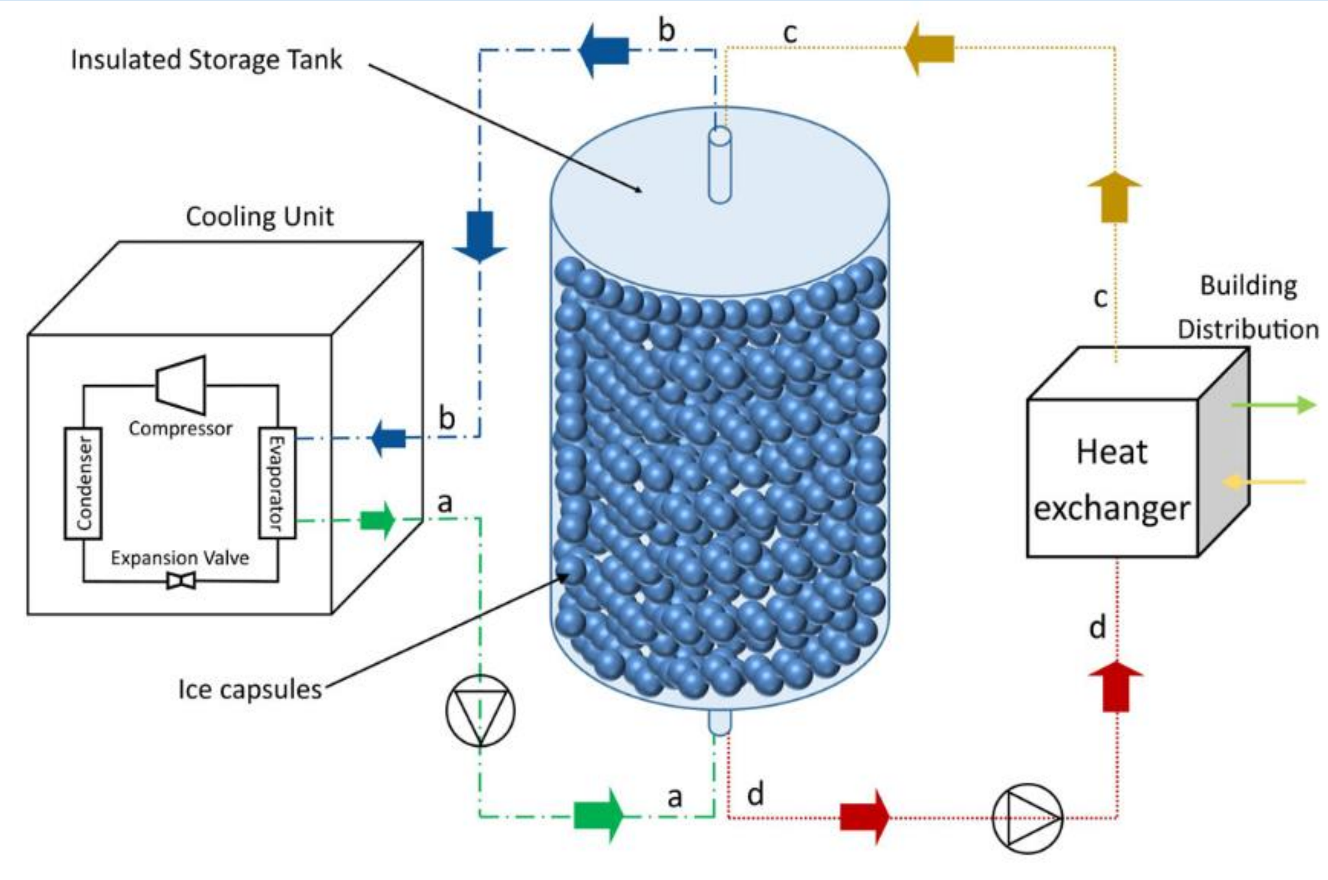


**The use of latent-heat thermal energy storage (LHTES) in air conditioning systems will reduce the peak load on equipment. This will enable to establish systems of lower power and reduce energy costs in the presence of a double tariff rate.**

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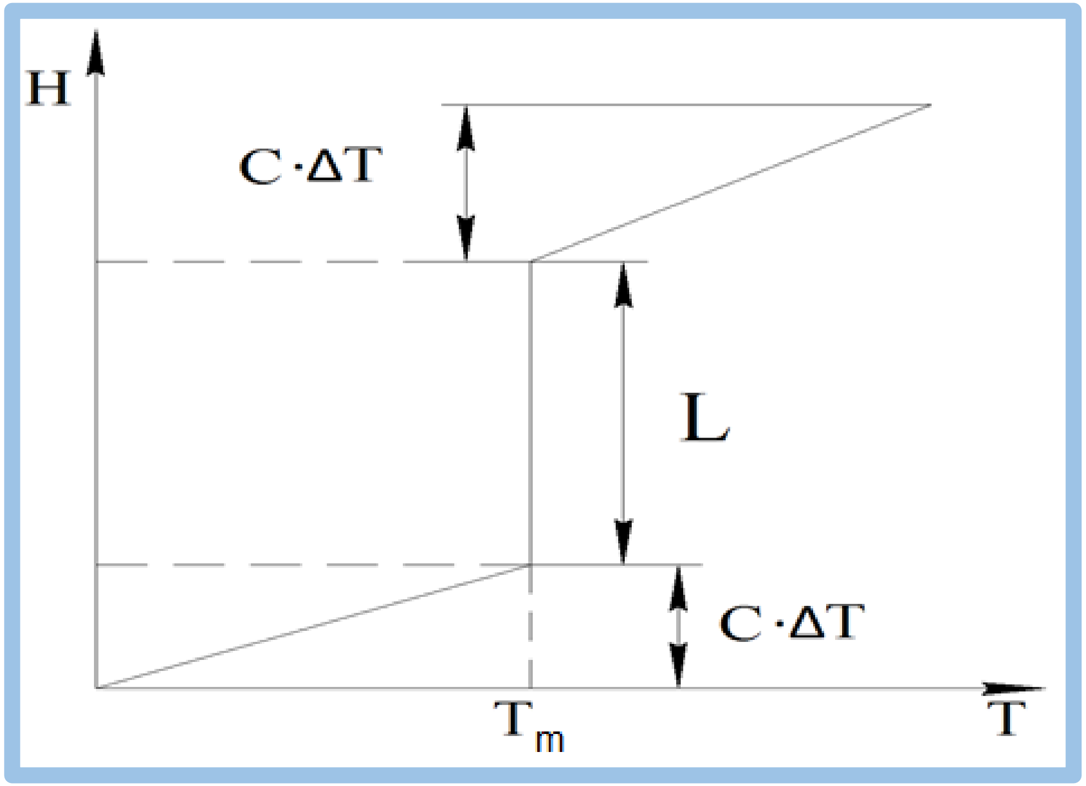


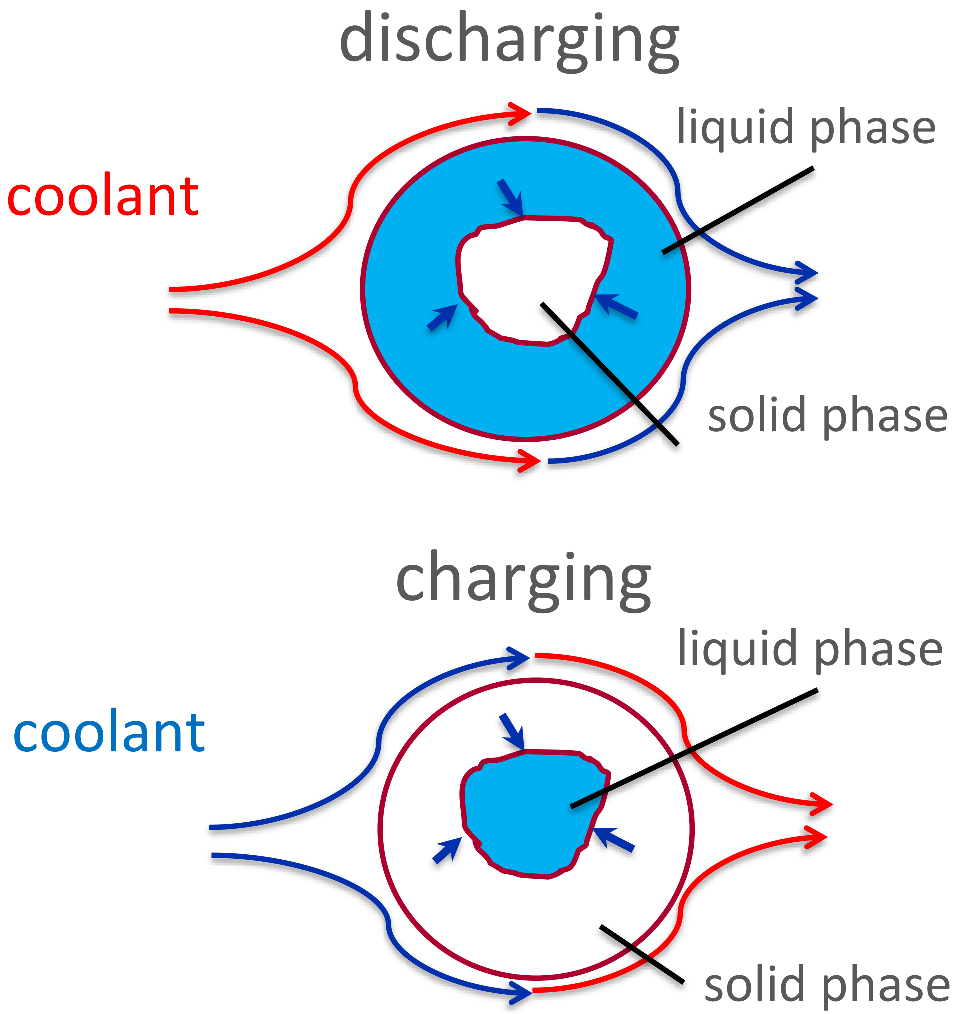

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**For the creation and effective operation of the LHTES, it is necessary to calculate the key parameters of the system, like the charging-discharging time and the power of the storage. Because of the high nonlinearity of thermophysical parameters of phase change materials (PCM), such a calculation presents a complex computational problem for CFD programs.**

**An alternative is to calculate using simplified mathematical models. This calculation significantly requires fewer computing resources, time and does not require the purchase of expensive licenses.**

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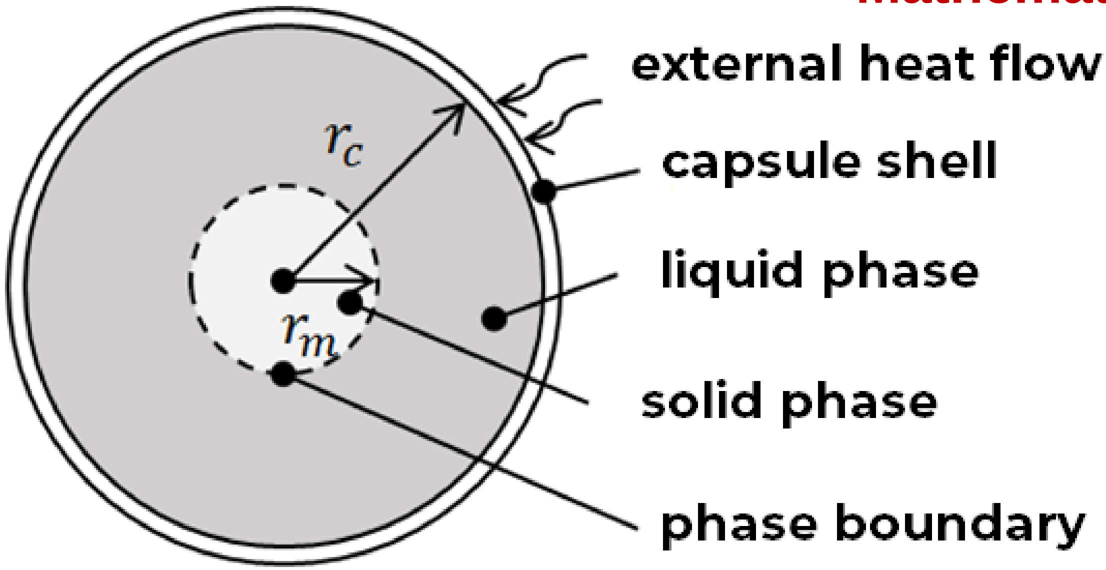
## Mathematical model




$$\frac{dr_m(t)}{dt} = -\frac{T_c(t) - T_m}{R(t)} \frac{1}{\rho_f A_m(t)\left[L + c_f\left(T_c(t) - T_m\right)\right]} \quad (1)$$

$$C\frac{dT_c(t)}{dt} + \frac{T_c(t) - T_m}{R(t)} + \sigma\left(T_c(t) - T_a\right) = 0 \quad (2)$$

$$R(t) = \frac{r_c - r_m(t)}{4\pi r_c r_m(t) k_{ef}} \quad (3)$$

$$k_{ef} = \begin{cases} k_{f,} \ \mathrm{Pr} < 1000 \\ 0,18 \cdot k_f \cdot (\mathrm{Gr} \cdot Pr)^{0,25} \end{cases} \quad (4)$$

$$\mathrm{Gr} = b_f \cdot g\left(r_c - r_m(t)\right)^3 \frac{T_c - T_m}{\nu^2} \quad (5)$$

$$\mathrm{Nu} = 0,825 Re^{0,62} = \frac{\alpha * l}{\lambda_{fl}} \quad (6)$$

$$\mathrm{Re} = \frac{D_{tub}\nu\rho}{\eta} \quad (7)$$

$$T_i = T_{(i-1)} - \frac{q_{lay}}{Q_m c_a} \quad (8)$$

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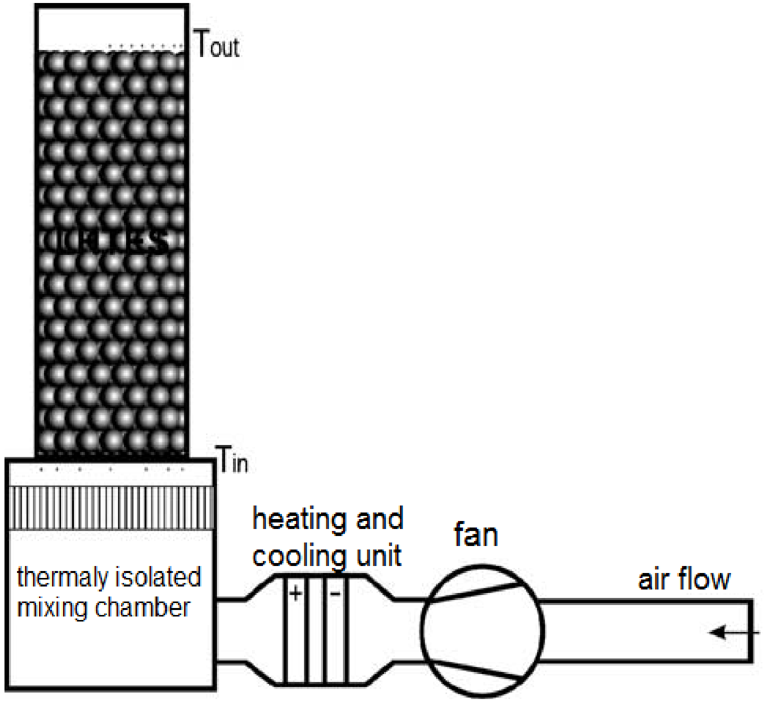
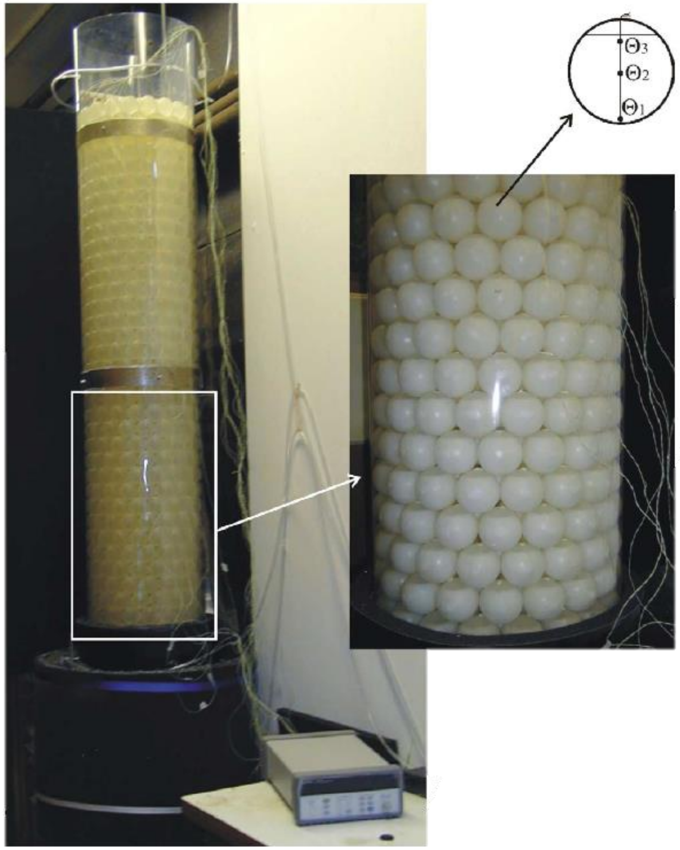
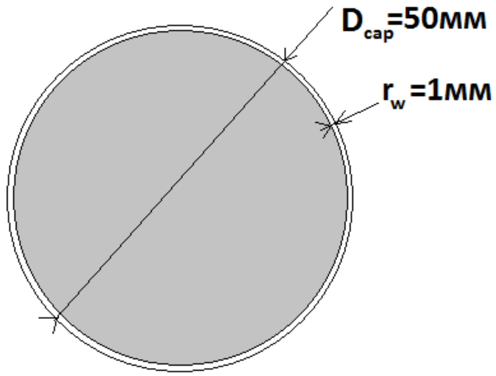
## Experimental data




$$D_{cyl} = 0{,}34\text{м}$$

$$Q_v = 215\text{м}^3/\text{ч}$$

$$T_{in} = 35°C$$

Influence of accuracy of thermal property data of a phase change material on the result of a numerical model of a packed bed latent heat storage with spheres. C. Arkar S. Medved

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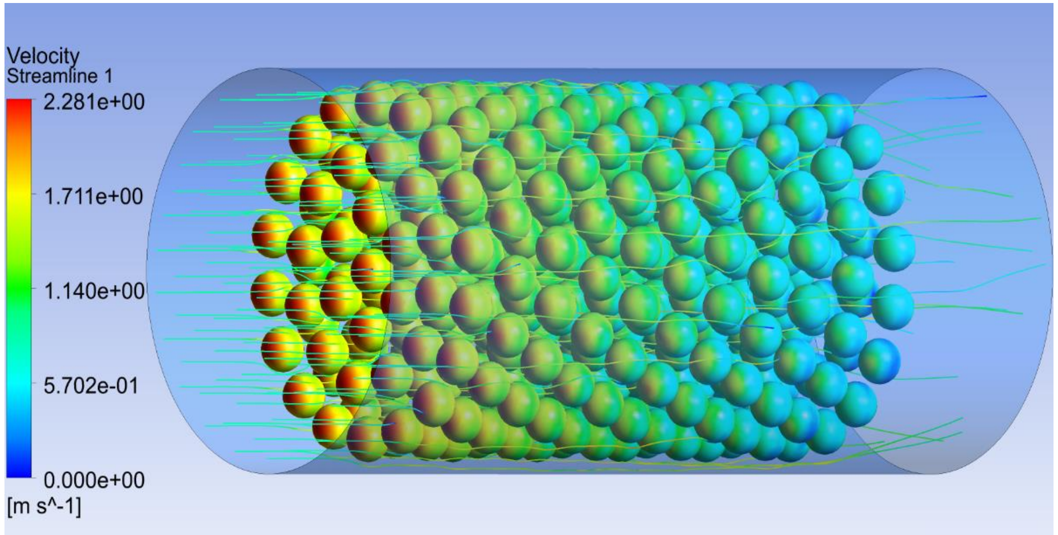
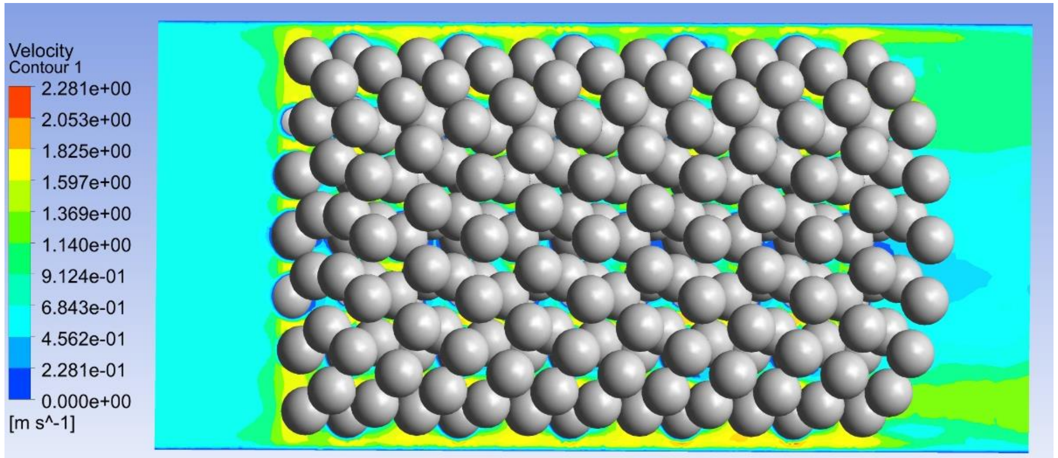



$$Nu = 0,825 Re^{0,62} \quad (6)$$




**To describe the conditions of heat transfer between the coolant and the wall of the capsule, an experimental dependence was used (6). The calculation is reduced to obtaining the temperature of the coolant after passing one layer of the packed bed. The resulting temperature represents an input parameter for calculating the subsequent layer. This operation is rehearsed until the calculation is made for all layers of the packed bed. The numerical calculation was carried out in the mathematical software Scilab.**

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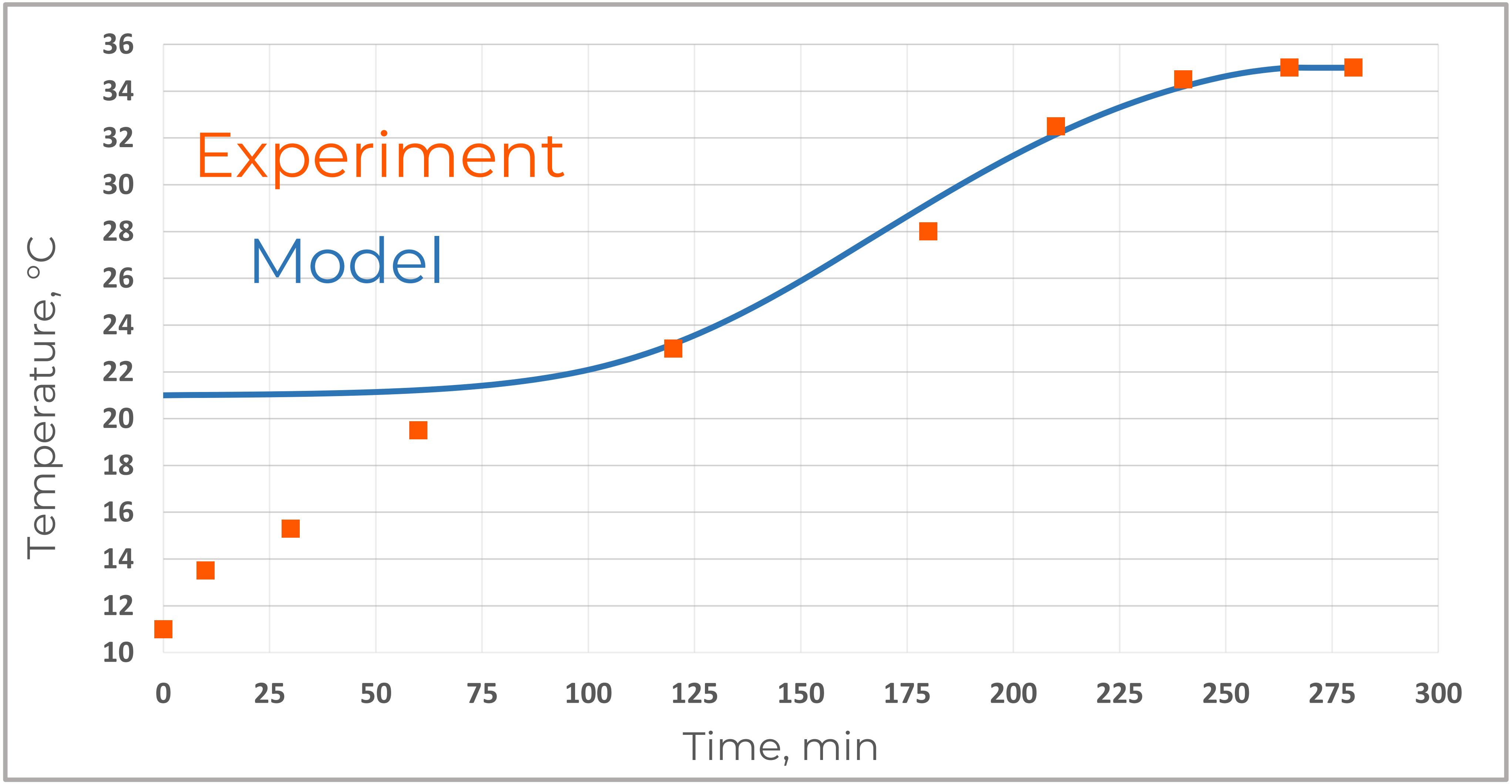
# Results



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## Conclusions

- The article presents a technique (mathematical model) for numerical calculations of solid-liquid phase transitions in packed bed;
- The model has a high accuracy in calculating the LHTES discharge time;
- The calculation time for the proposed model was 5 minutes;
- The duration of the calculation and its accuracy allow the use of a mathematical model for the design calculation of air conditioning and cooling systems.

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# Thank you for your attention!

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