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Research of the efficiency of a heat storage system based on substances with a phase change materials for space technology

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Keywords: Energy efficiency, heat storage, phase change materials, space devices

Research Objective: Development of an energy-saving heat storage system for thermal stabilization of devices in the space environment

Relevance of the problem:

- Continuous growth of energy consumption

- Increasing the efficiency of energy consumption is possible by reducing the energy intensity of the technologies used, using alternative, renewable energy sources, equalizing the time differences between the produced and consumed energy due to accumulation.

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Introduction

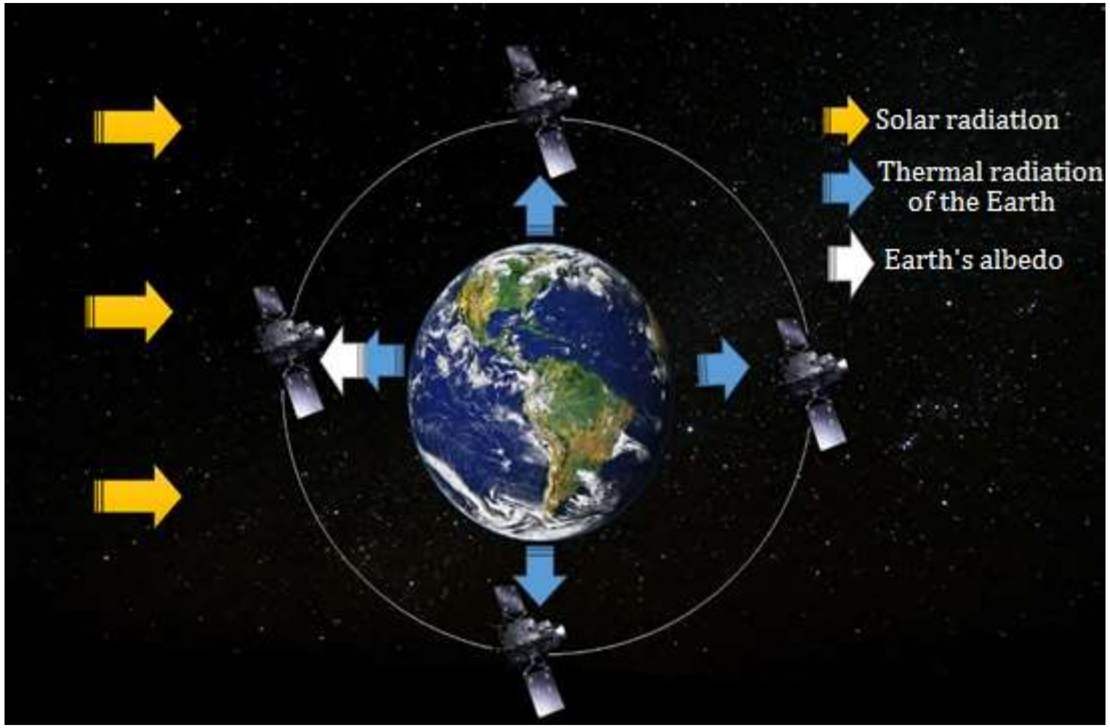

FIGURE 1. Influence of external heat flows on the space devices

Application of thermal energy storage using organic substances with high latent heat of melting

- ✓ The device for temperature stabilization
- ✓ Decrease of weight and size characteristics

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Thermal model

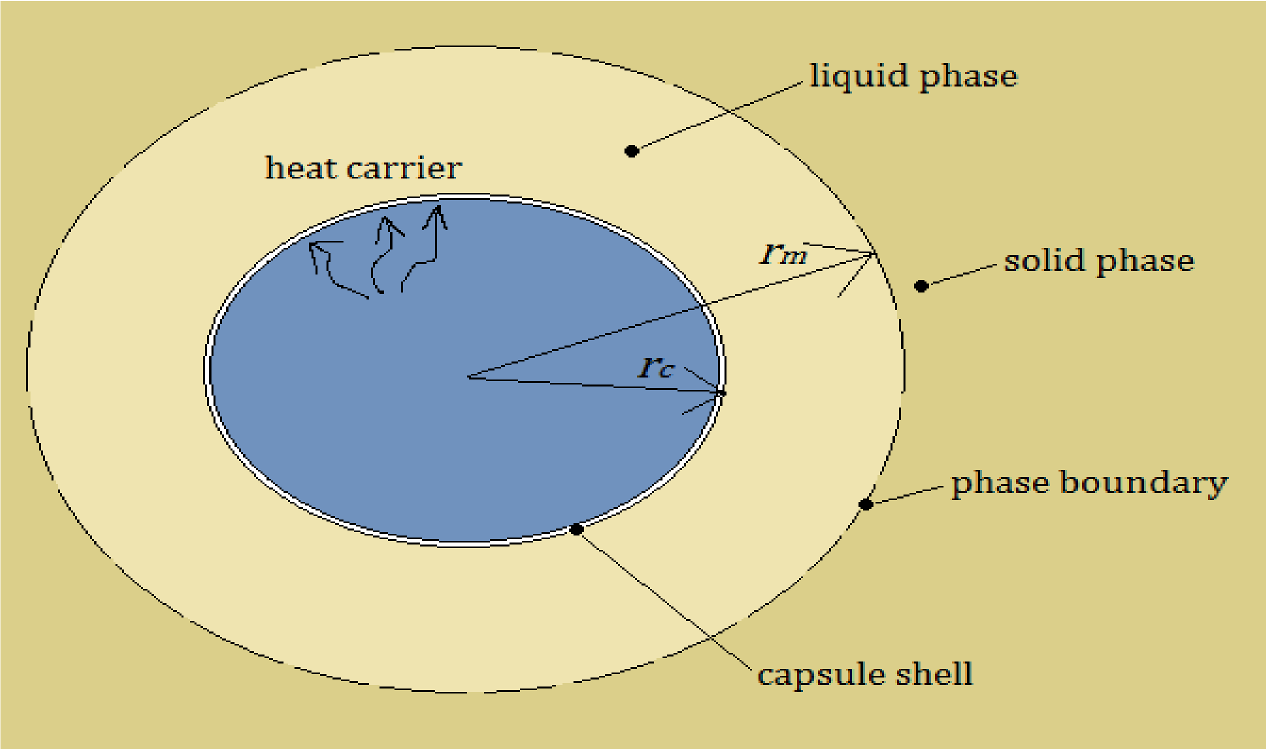

FIGURE 2. Thermal model of accumulator with phase change materials

$r_m, [m]$ - average radius of the position of the phase boundary

$r_c, [m]$ - inner radius of the shell

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Mathematical model

$$k_{ef} = \begin{cases} k_{ef}, Pr < 1000 \\ 0{,}18 * k_f * (Gr * Pr)^{0,25} \end{cases} \quad (1)$$

$$Gr = b_m * g\left(r_c - r_m(t)\right)^3 * \frac{T_c - T_m}{\vartheta^2} \quad (2)$$

$$R(t) = \frac{1}{2\pi k_{ef}} \ln \frac{r_m(t)}{r_c} \quad (3)$$

$$\frac{dr_m(t)}{dt} = \frac{T_c(t) - T_m}{R(t)} * \frac{1}{\rho_f * A_m(t)\left[L + c_f\left(T_c(t) - T_m\right)\right]} \quad (4)$$

$$C_s \frac{dT_c(t)}{dt} = \frac{T_c(t) - T_m}{R(t)} + \sigma\left(T_a(t) - T_c(t)\right) \quad (5)$$

$$\frac{dT_a(t)}{dt} = \frac{\left(Q_h - \frac{T_c(t) - T_m}{R(t)}\right) * h_s - \alpha_s * A_s * l_s * (T_a - T_{a0})}{(C_f * \rho_f * V_f)} \quad (6)$$

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Experimental stand

FIGURE 3. Experimental stand:
1 – Heat accumulator; 2 - device for measuring and controlling temperature; 3-heater; 4-expansion tank; 5-pump; 6-power supply

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Design of accumulator

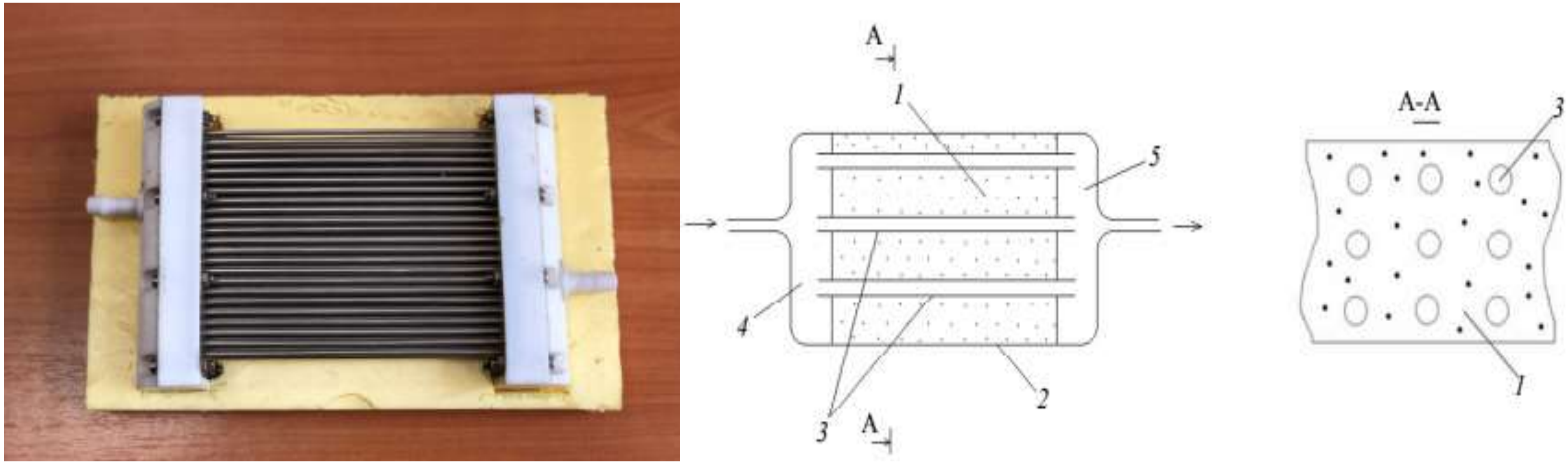

FIGURE 4. The design of the thermal energy storage:
1 – melting substance, 2 - body, 3 - tubes, 4 - input collector, 5 - output collector.

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FIGURE 5. Heater

FIGURE 6. Expansion tank and pump

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Characteristics of the phase change material

Characteristic ($C_{18}H_{36}O_2$)	Value
Temperature of phase transition	69,3°C
Heat of melting	192,1 kJ/kg
Liquid phase density	847 kg/m^3
Thermal conductivity of the liquid phase	0,166 W/m*K

TABLE 1. Characteristics of the stearic acid

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Radiator

FIGURE 7. Inclusion of the radiator in the circuit

FIGURE 8. Radiator view

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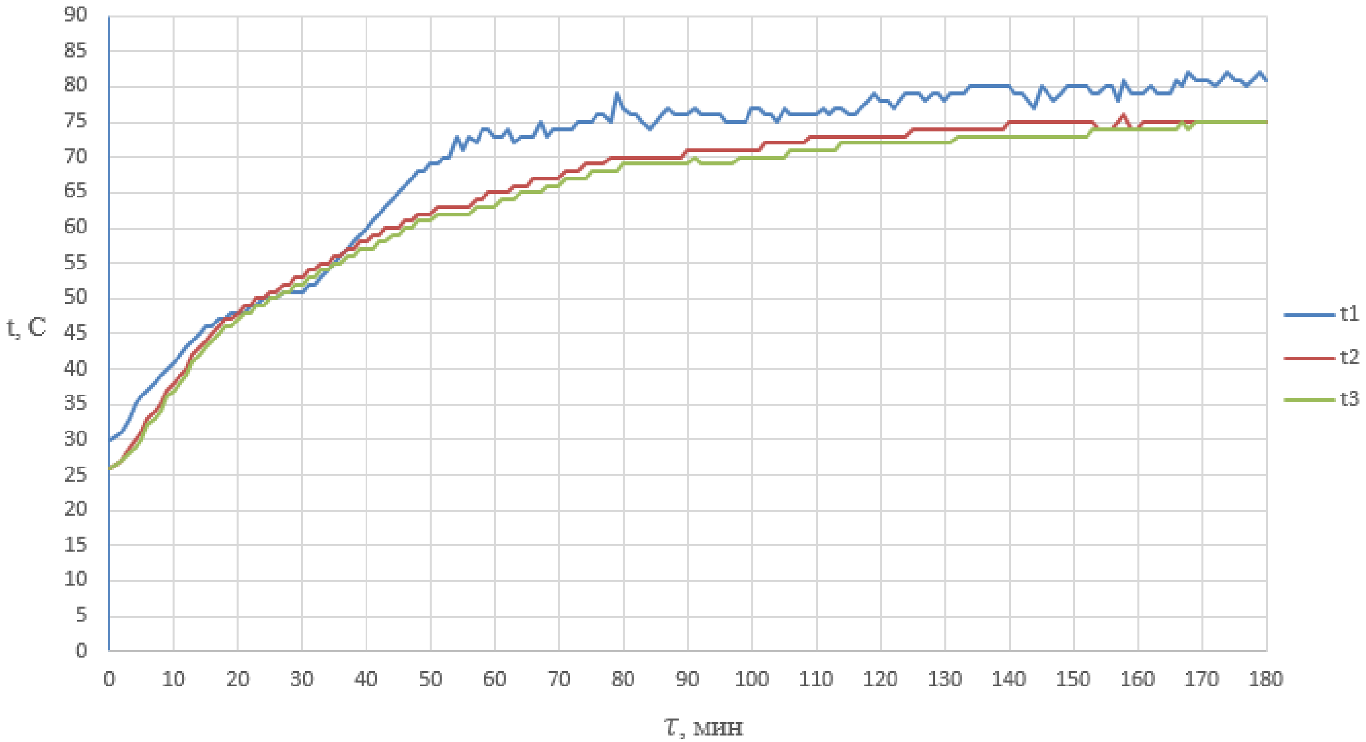
Experimental data results



GRAPH 1. Testing of the experimental stand

t1 – temperature of the heat carrier at the outlet of the heater;

t2 – the temperature of the heat carrier at the outlet of the accumulator;

t3 – the temperature of the heat carrier at the pump outlet.

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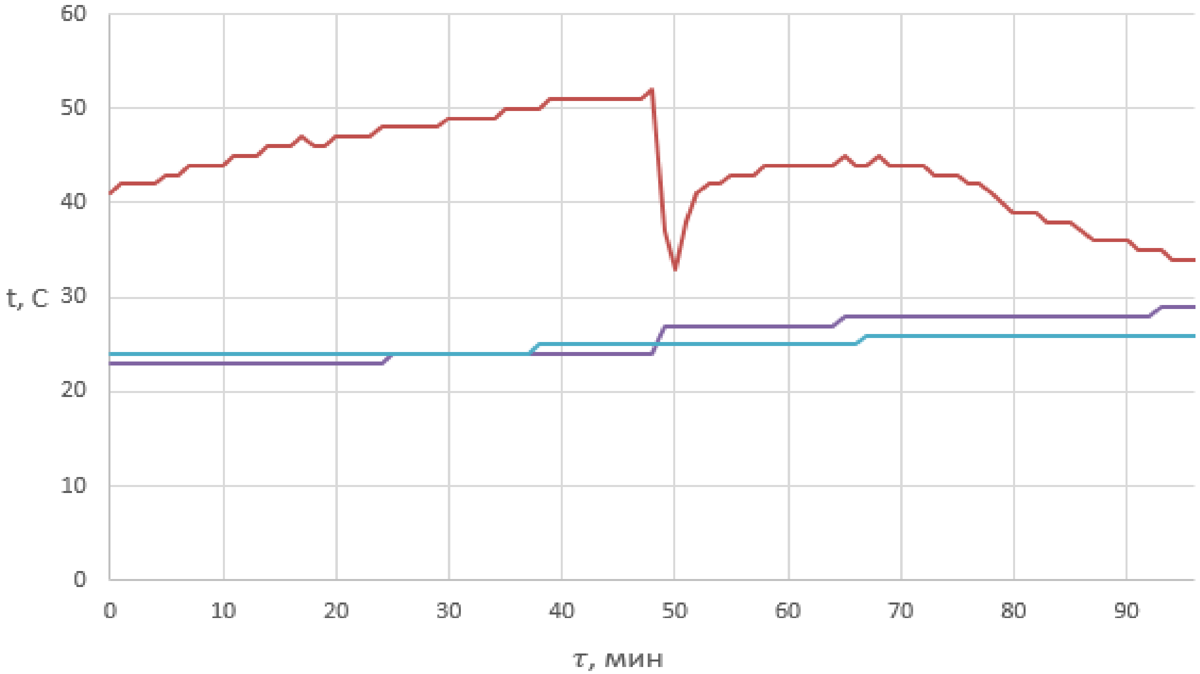
Connecting the radiator to the circuit



GRAPH 2. Connecting the radiator to the circuit
t1 – temperature of accumulator;
t2 – temperature of radiator;
t3 – temperature of environment

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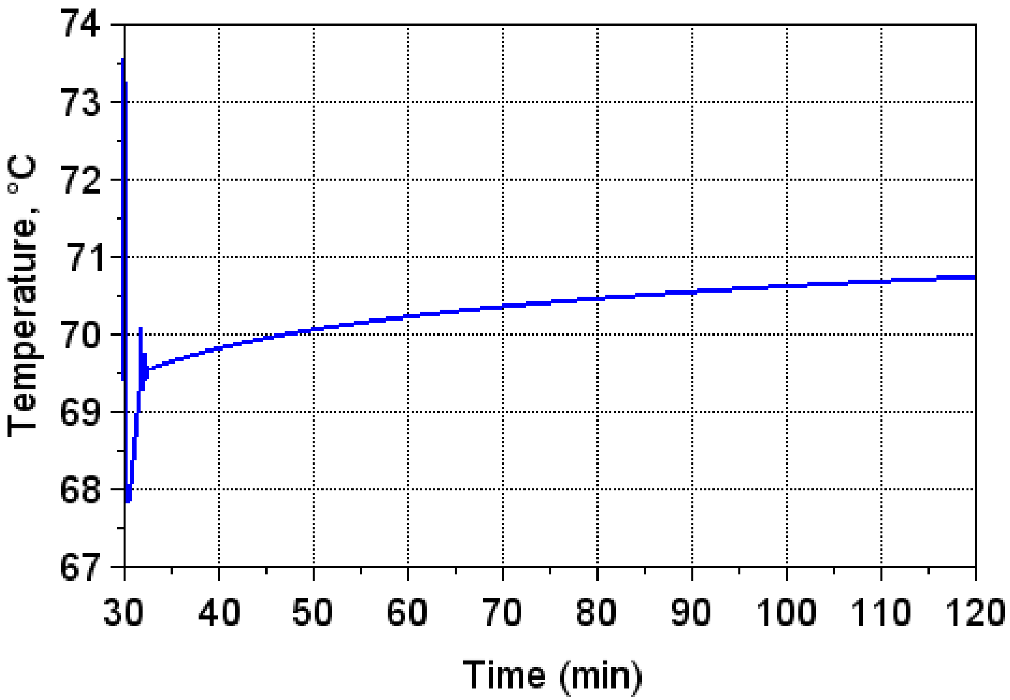
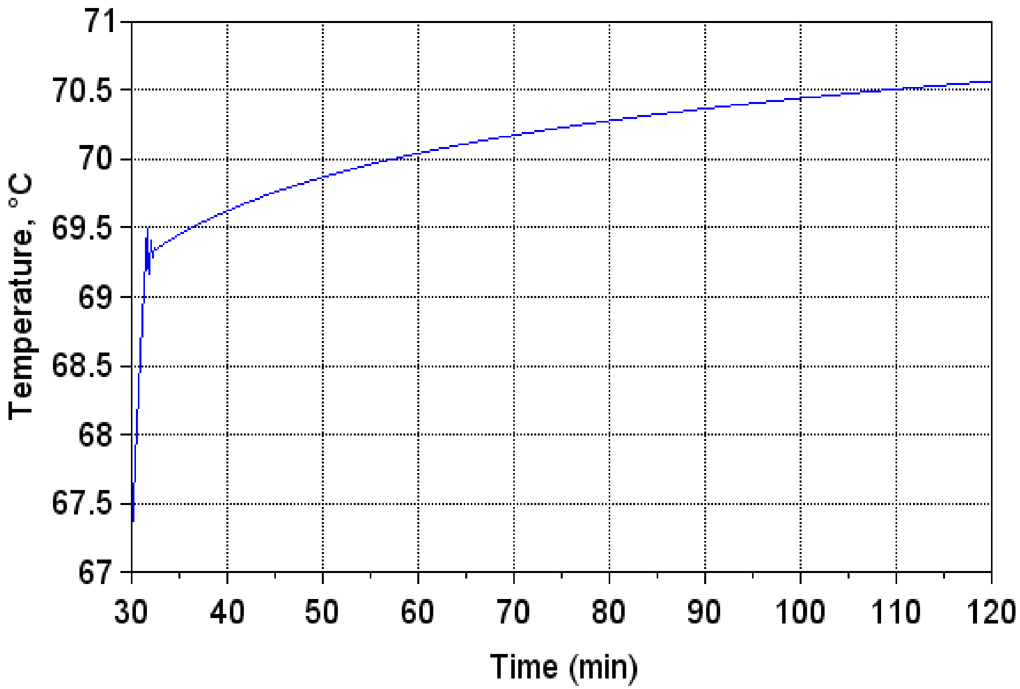
Results of numerical calculations



GRAPH 3. Case temperature



GRAPH 4. Water temperature

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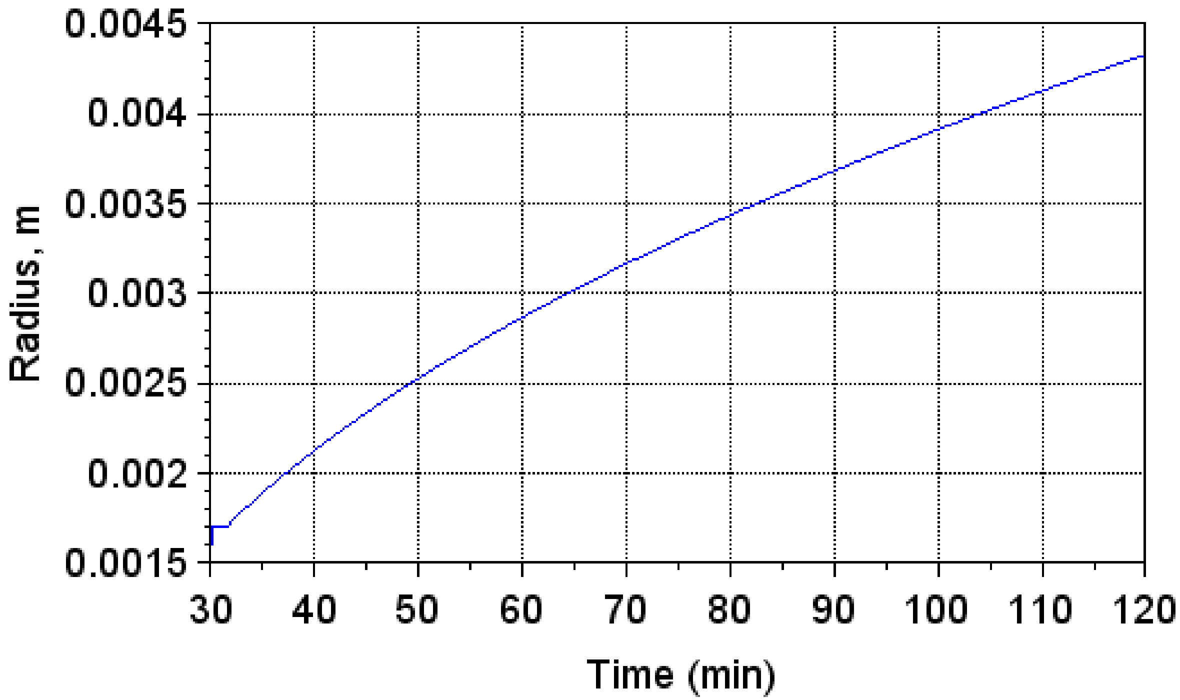

GRAPH 5. Increments of the radius of the molten substance

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Conclusions

- **The paper presents an improved technique (thermal and mathematical model) for numerical**
- **calculations of solid-liquid phase transitions;**
- **The paper presents the design of a heat storage system for thermal stabilization of a space device;**
- **The numerical implementation of the mathematical model is carried out in the Scilab package;**
- **The proposed method of using substances with a phase transition can be used as a means of ensuring the thermal regime of devices operating in difficult external conditions.**

References

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Thank you for your attention!

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