Analysis with RELAP5 Computer Code of Experiments for Investigation of Void Fraction Distribution in RBMK Fuel Channel Model

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The work was done in frame of RINSC-USINSC Joint Project #6

The work is part of an effort to validate computer code RELAP5/Mod3.2 in application to RBMK. Such validation is needed due to features of RBMK reactor design and thermal-hydraulics in comparison with PWR reactor for which this code was developed and validated.

The work was performed in frame of Joint Project #6 « Computer code validation for transient analysis of VVER and RBMK reactors» between US and Russian INSC.

Standard Problem for investigation of void fraction distribution in RBMK fuel channel for steady states was regarded as one of most important tasks to be performed within the project. To define the Standard Problem experimental data from BM test facility (NIKIET) were used.

Conclusions

RELAP5/MOD3.2 adequately models void fraction distribution along RBMK Fuel Channel.

Calculated results agree well with test data for saturated boiling.

Some disagreement between calculated and test data is observed for subcooled liquid boiling. This may be explained with following:

a) RELAP5 models and correlations inaccuracies;

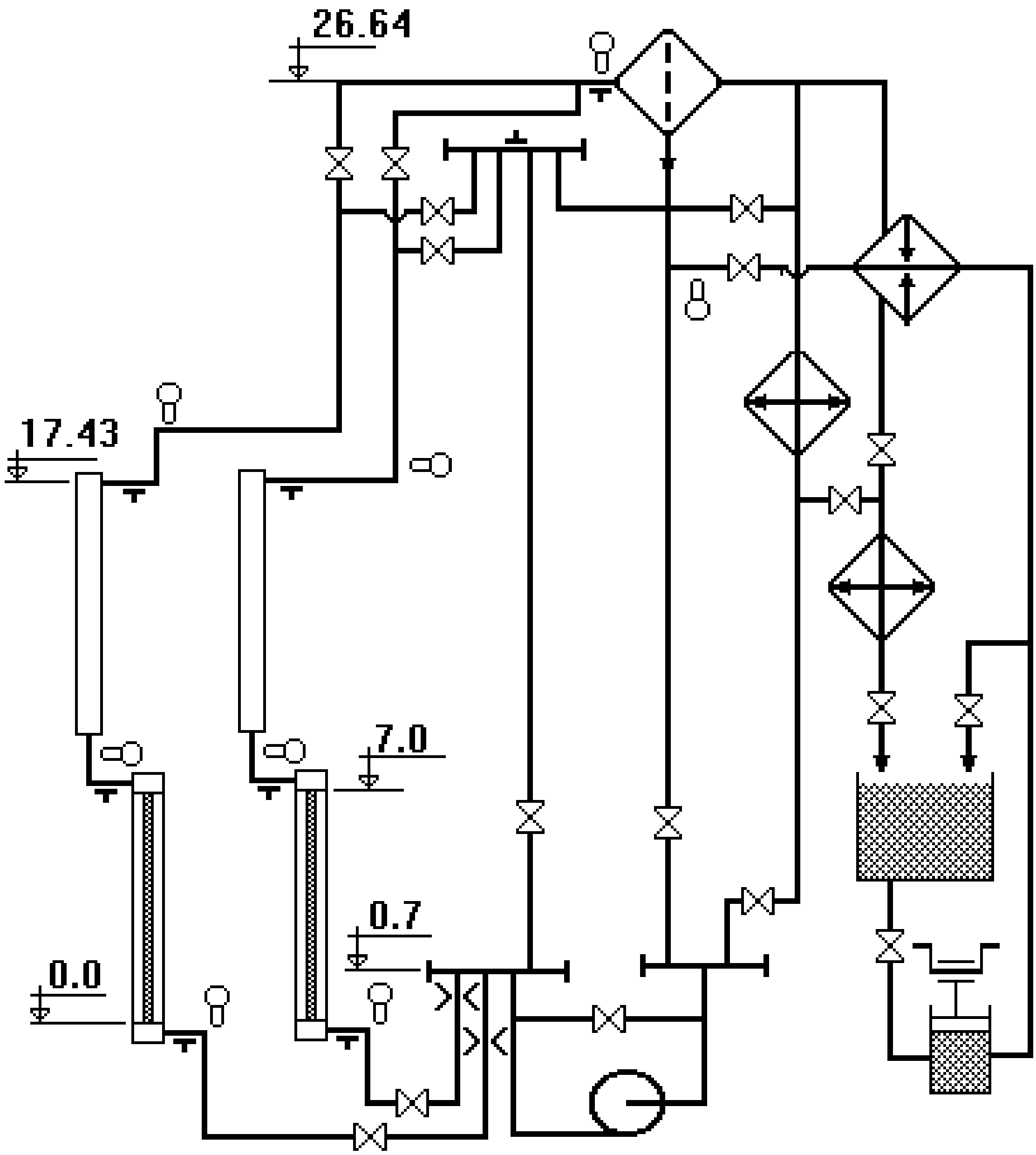
b) Non uniform heating of coolant in cross section;

c) Experimental inaccuracies.

To draw the final conclusion data on coolant and experimental channel wall temperature in specific cross sections are needed.

It is of interest to validate RELAP5 versus test data for higher values of relative enthalpy (X>0.5).

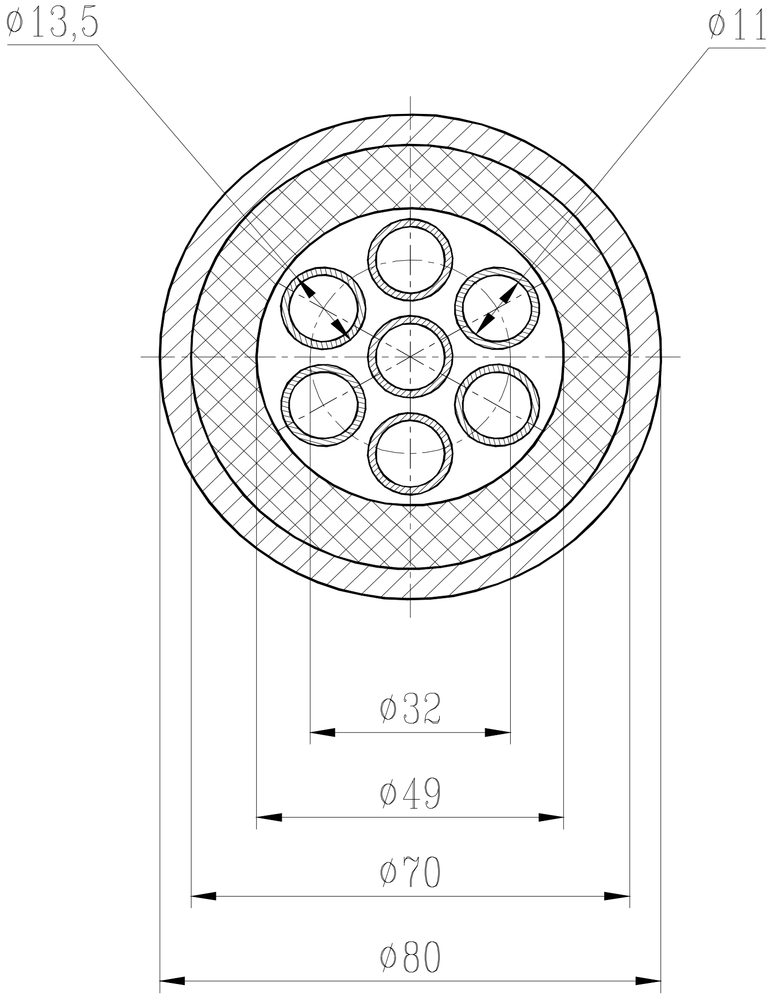
BM Test Facility



Elevation scale 1:1

Volume scale of one facility channel relatively to one RBMK channel: 1:2.57

Cross-section of the heated segment of the experimental channel



- The equivalent diameter of the facility channel is 7.84mm, the equivalent diameter of the reactor channel is 8.56mm;
- The relative coolant volumes accounted for one fuel rod are 0.045 m^3 for the test facility and 0.044 m^3 for the reactor channel.

MEASUREMENT SYSTEM

Coolant flow density averaged over the cross section was measured using one contactless sensor.

Operation of this sensor is based on the method of measurement of detection rate of neutrons issued from Plutonium-Beryllium source of fast neutrons after their moderation in the hydric medium.

For every steady state, void fraction was determined in ten locations along the heated channel:

0.385, 0.948, 1.573, 2.322, 2.947, 4.010, 4.823, 5.448, 6.135, and 6.760,

with total length of the core model of 7m.

MEASUREMENT SYSTEM

(cont'd)

The void fraction was calculated according to the following expression:

$$\nu = \frac{\rho_l - \rho_m}{\rho_l - \rho_v}$$

where:

ρ_l - is the liquid phase coolant density in the cross section under control (it was determined analytically with using water thermal properties with the coolant pressure and temperature been measured during the experiment);

ρ_m - is the measured coolant density;

ρv - is the steam phase coolant density at saturation (it was determined analytically with using water thermal properties at saturation with the coolant pressure measured during the experiment).

Measurements Parameters:

- pressure at the outlet from the heat release zone;
- flow rate in the test section;
- coolant temperature at the inlet to the heated channel;
- coolant density;
- coolant density sensor location;
- FA simulator electrical power.

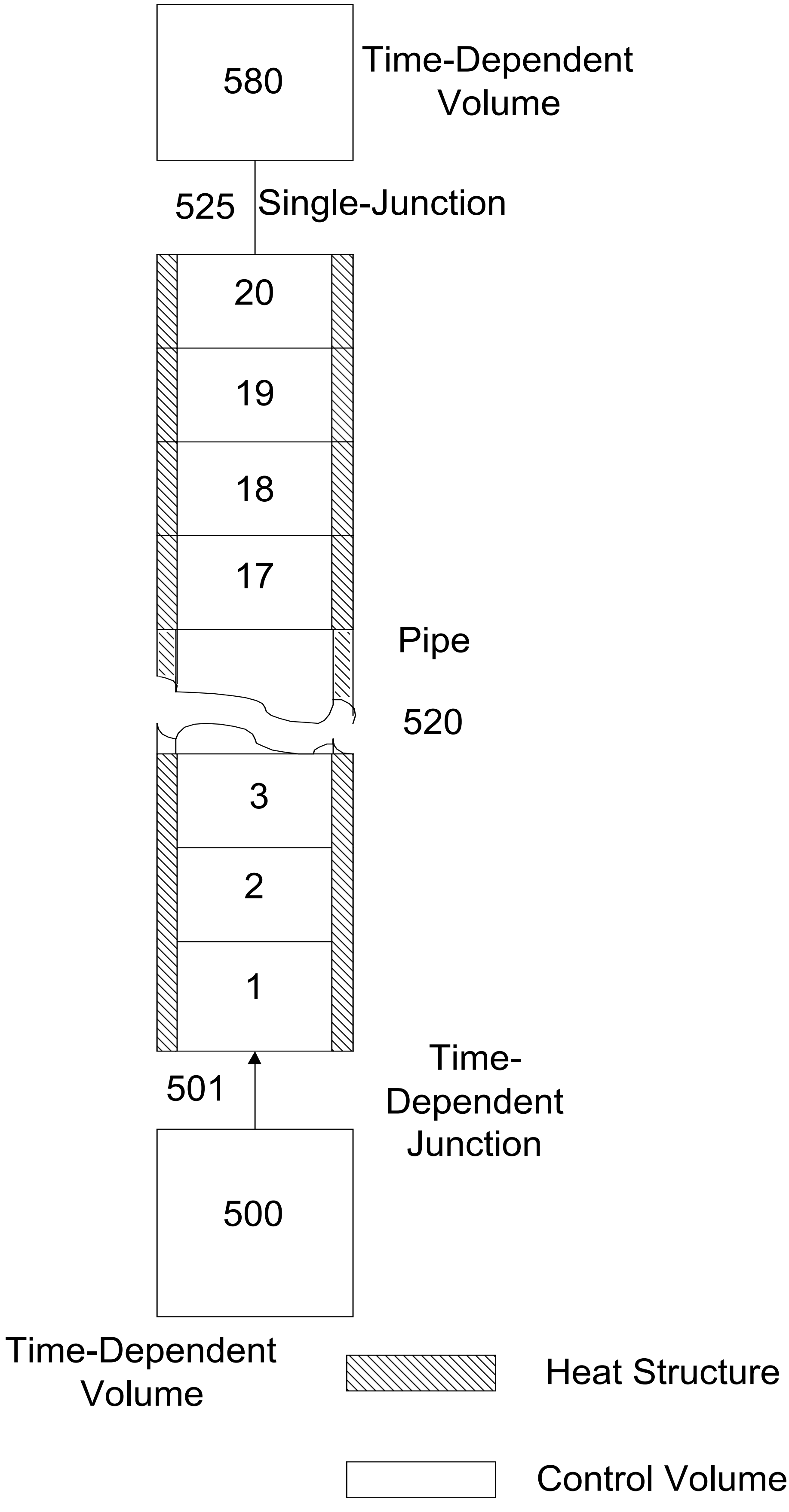
Range of the mode parameters is as follows:

- pressure – from 3 to 7 MPa;
- mass flow rate – from 500 to 2000 kg/(s·m^2);
- relative enthalpy of coolant – from – 0.64 to 0.5;
- heat flow density – from 0.15 to 0.4 MW/m^3.

Accuracies of values obtained were as follows:

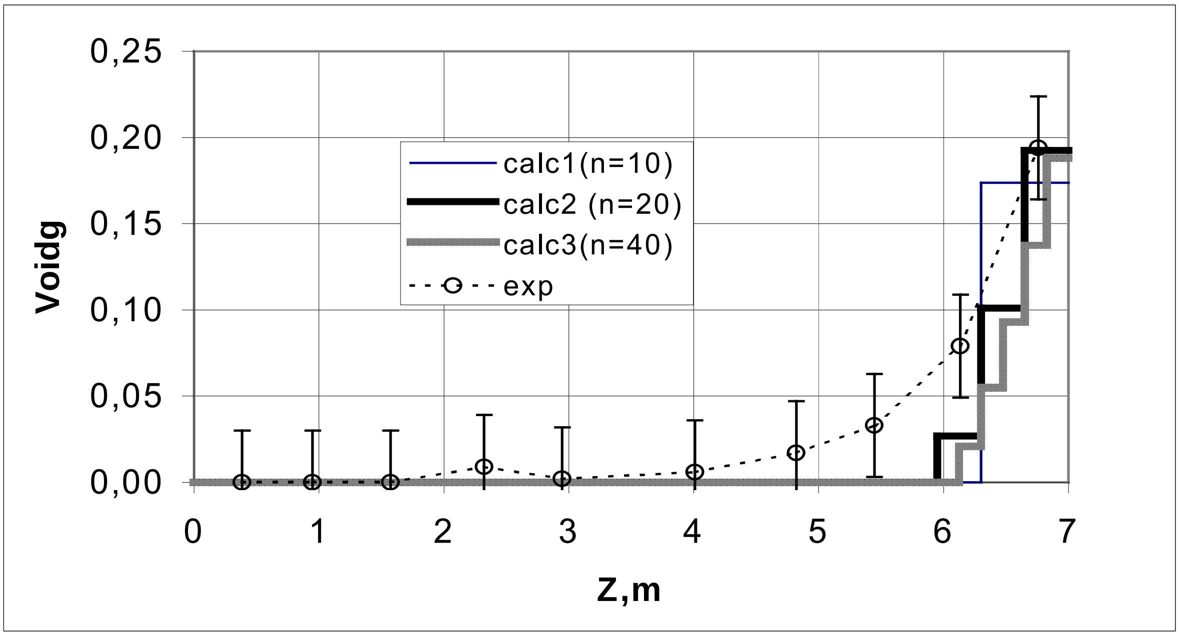
- mass flow rate – ±2.08 kg/(s·m^2);
- heat flux density – ±947 W/·m^2;
- void fraction – ±0.03;
- coolant density – ±8 kg/·m^2;

- **pressure – ±1.5%.**

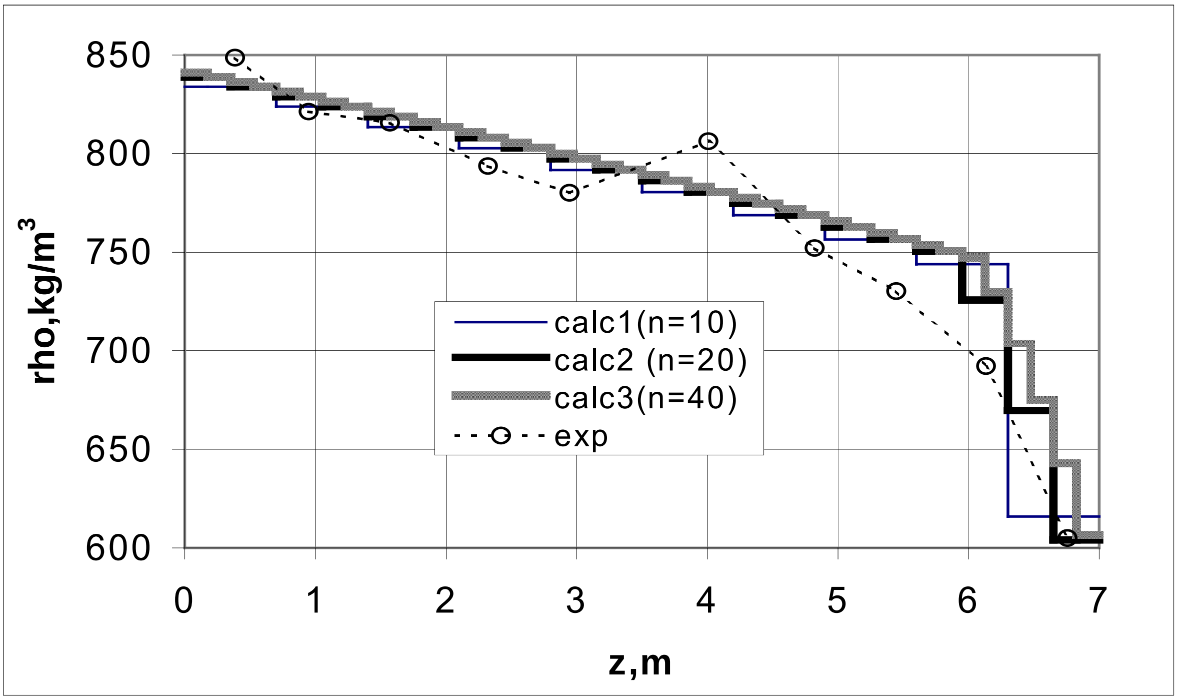


BM facility test section nodalization scheme in RELAP5 terms

Results for various noding of the heated section

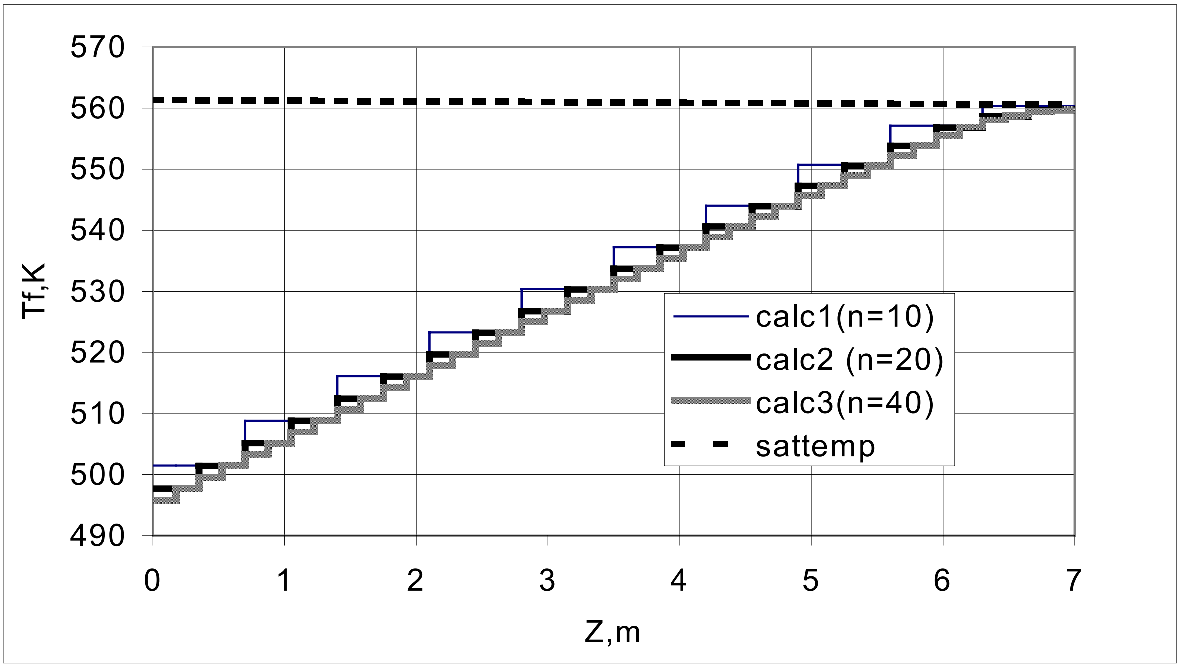


Cross section average void fraction distribution along experimental channel heated section

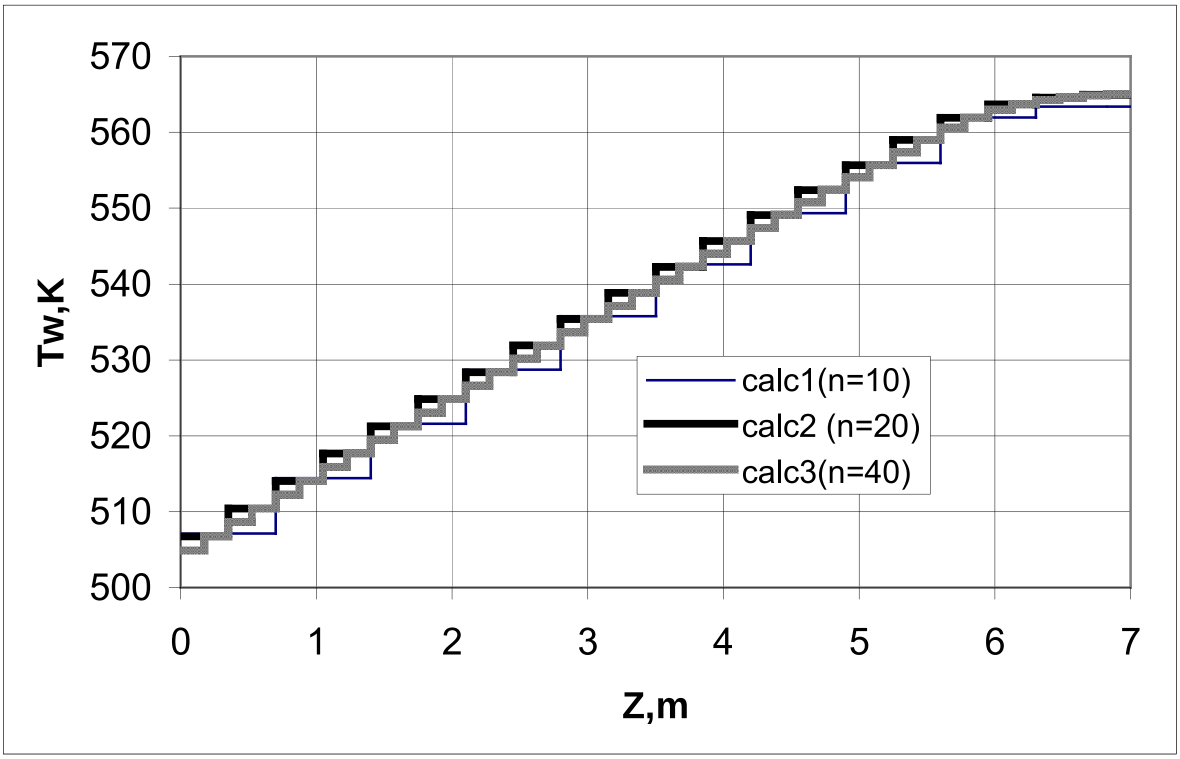


Cross section average coolant density distribution along experimental channel heated section

Results for various noding of the heated section

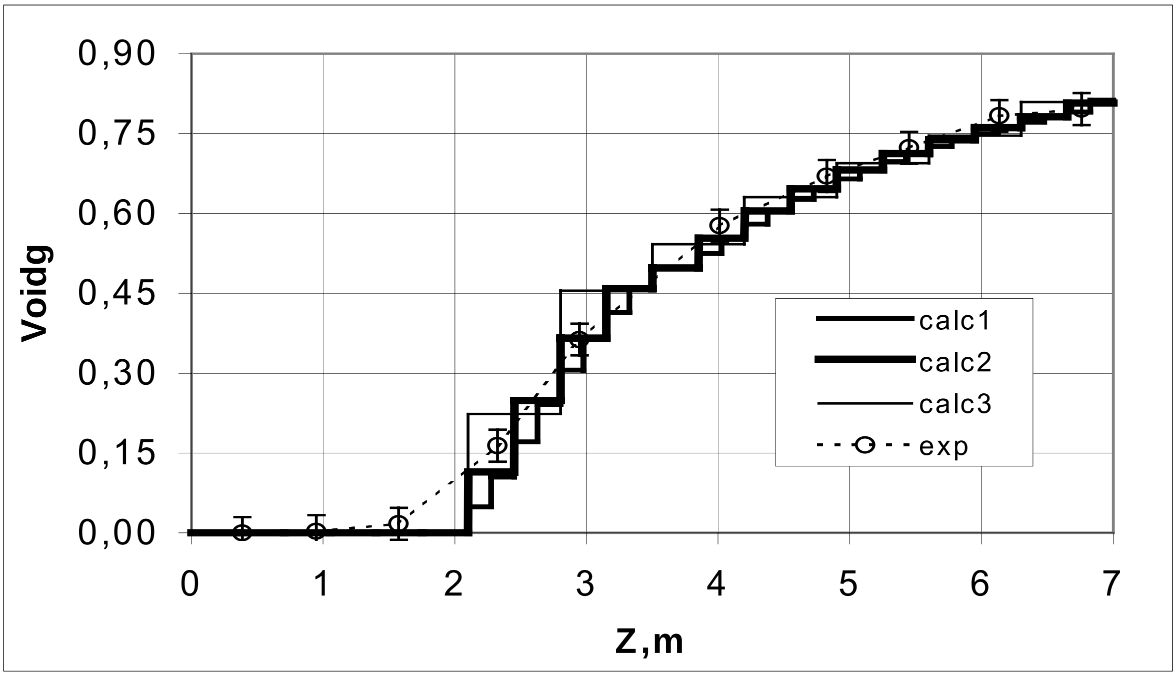


Coolant temperature distribution along experimental channel heated section



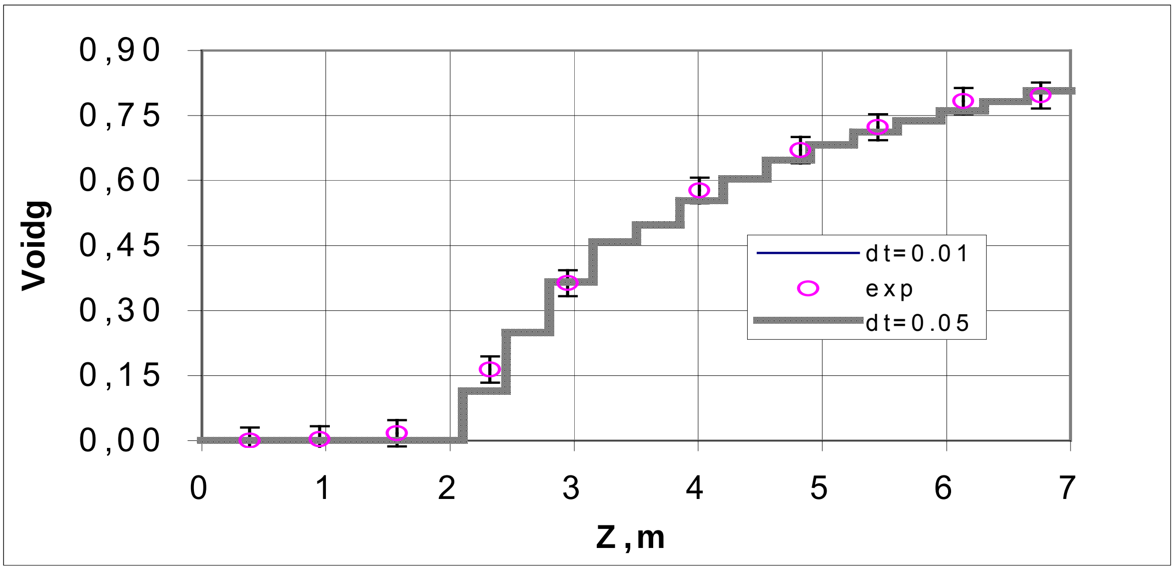
FE simulators wall temperature in different cross sections along experimental channel heated section

Results for various noding of the heated section



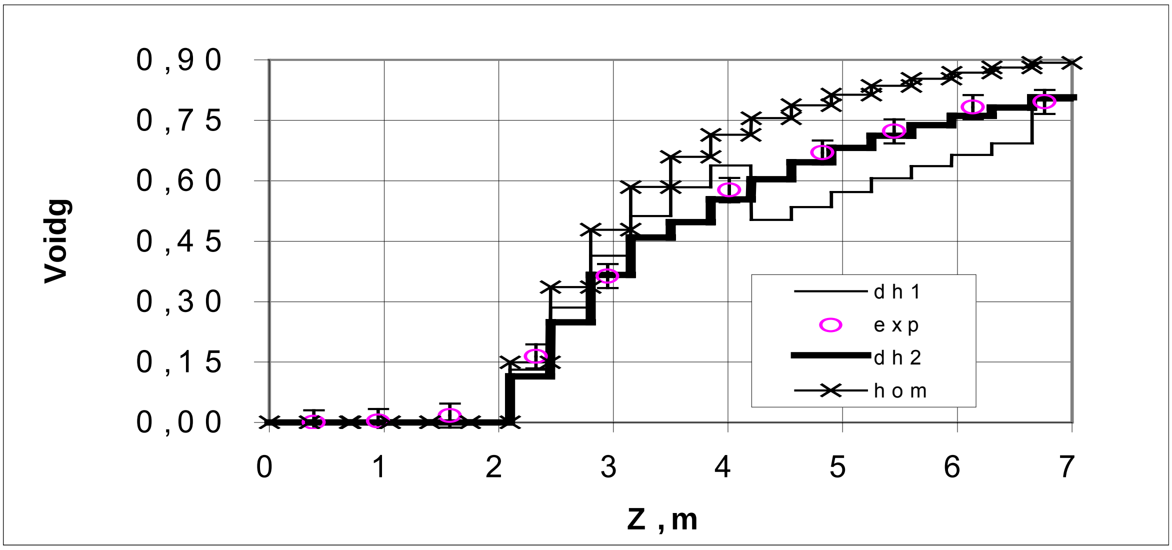
Cross section average void fraction distribution along experimental channel heated section (calc1- 40 control volumes, calc2- 20 control volumes; calc3-10 control volumes)

Studies of maximum time step dt influence to the void fraction distribution



Cross section average void fraction distribution along experimental channel heated section

Studies of interphase drag influence to the results



Cross section average void fraction distribution along experimental channel heated section

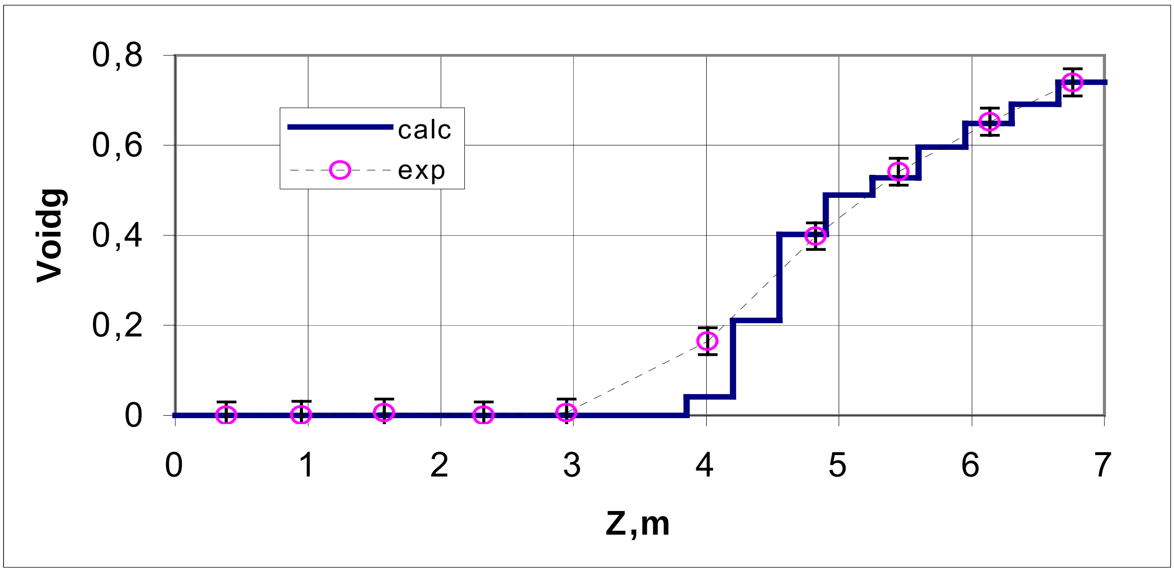
dh1- hydraulic diameter d_h for interphase drag was calculated from

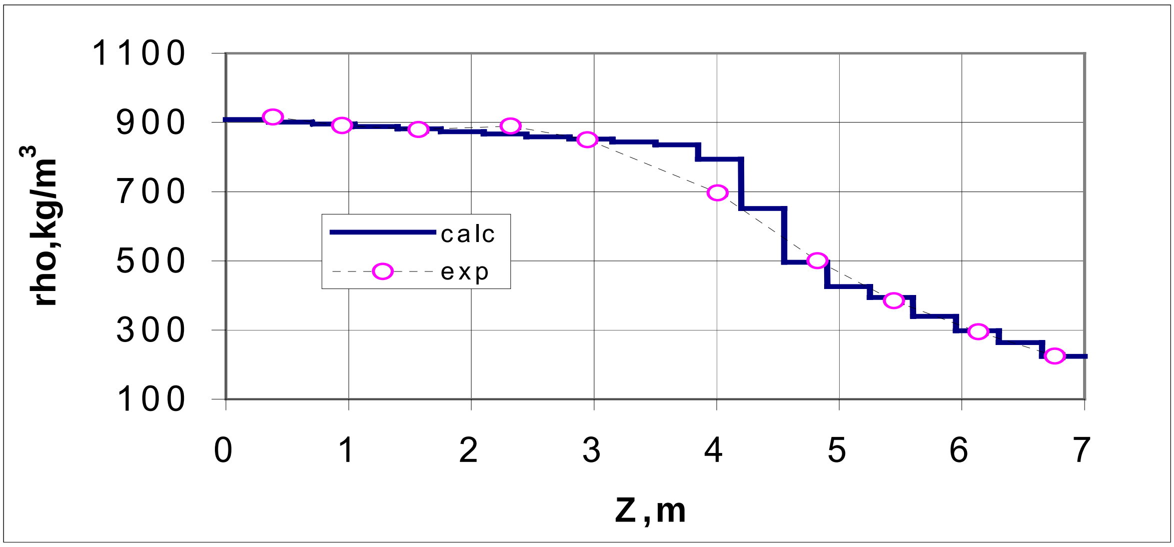
$dh = \sqrt{4 \bullet S / \pi}$ where S is channel cross section area;

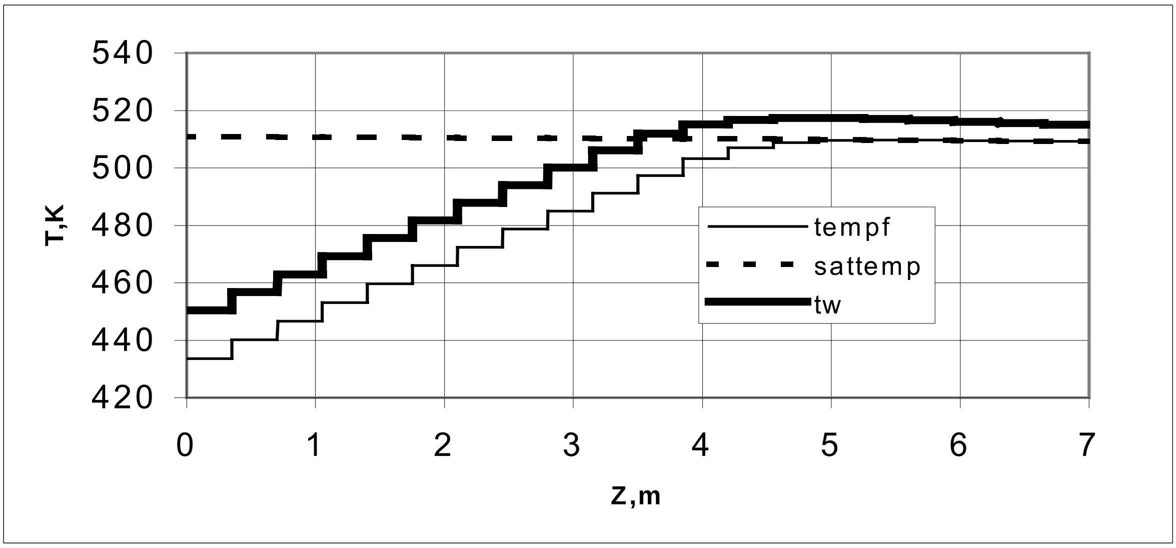
dh2- actual value of hydraulic diameter was used;

hom- homogeneous model was used for calculations.

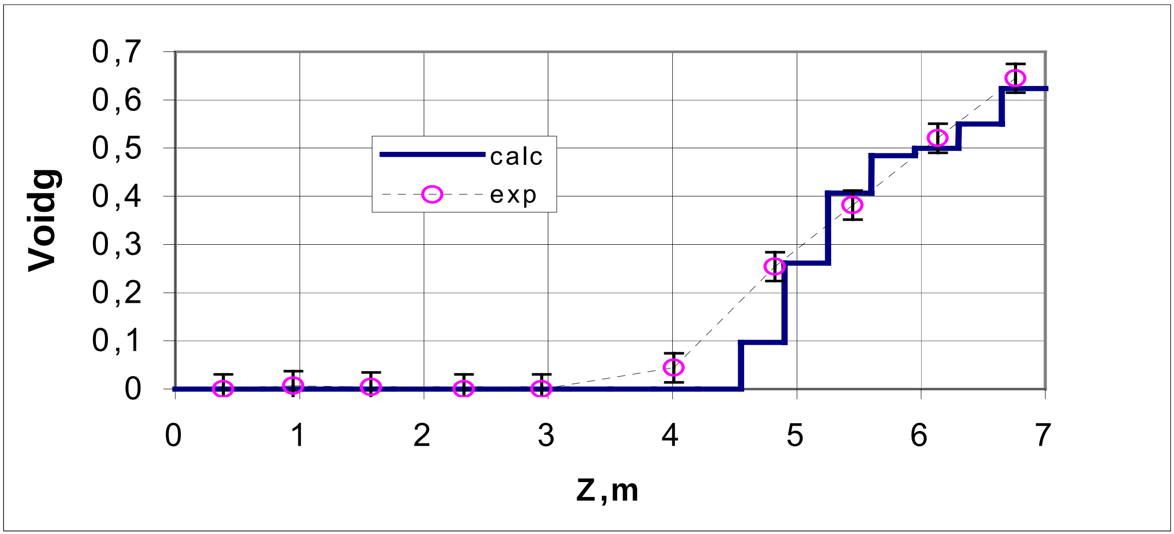
Comparison of calculated and experimental results (Tin=427 K, N=505 kW, m=0,886 kg/c, P=3,12 MPa, X=0.1)

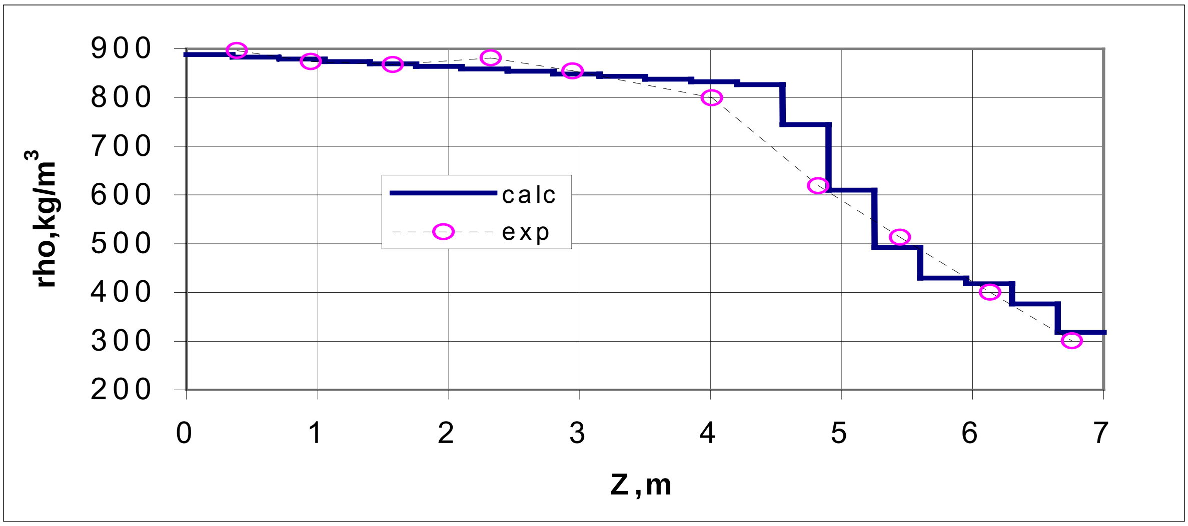


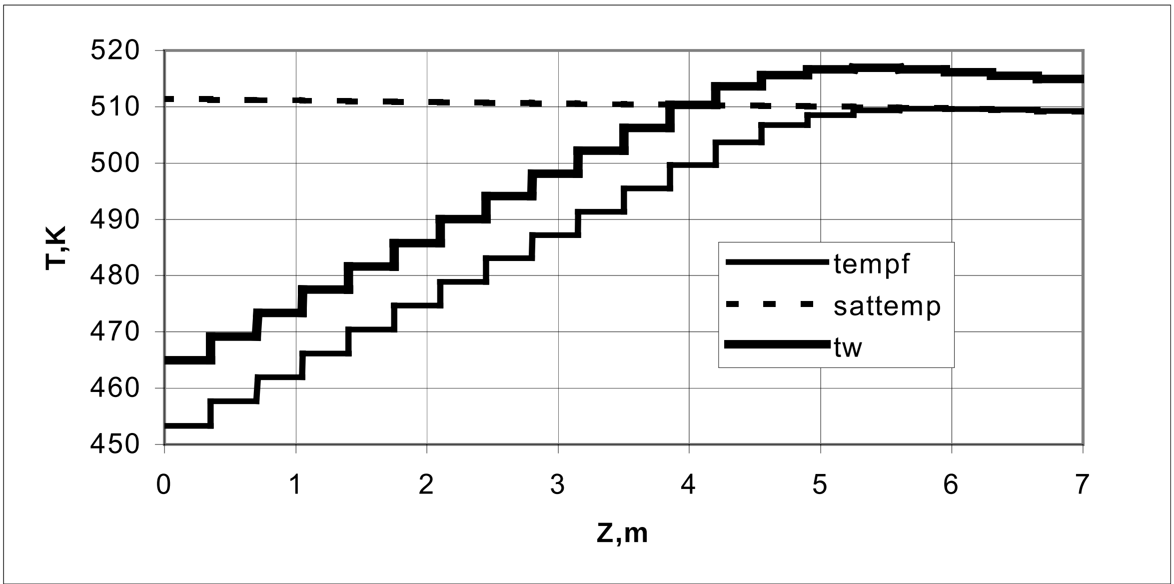




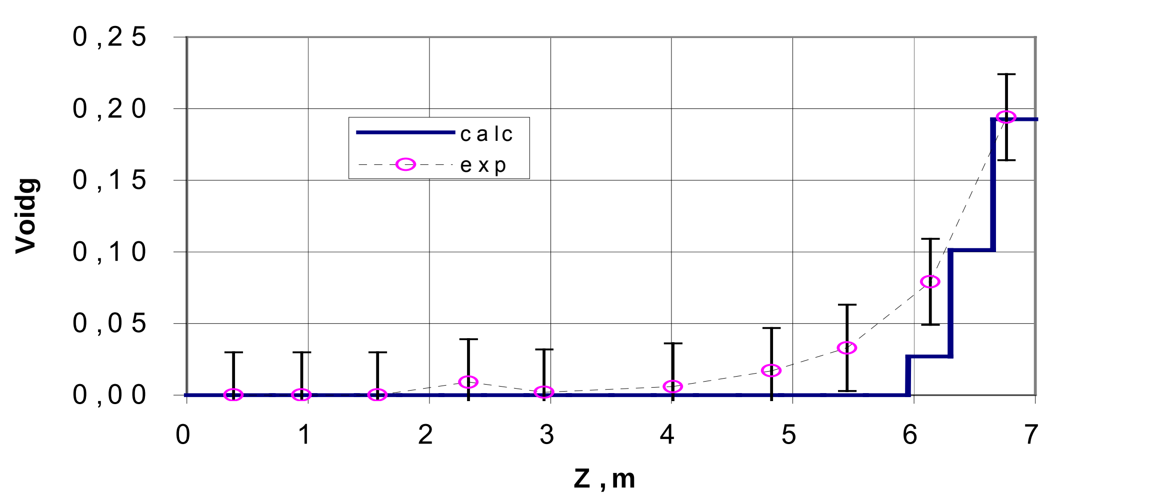
Comparison of calculated and experimental results (Tin=449K, N=504.8 kW, m=1,3278 kg/c, P=3,12 MPa, X=0.054)

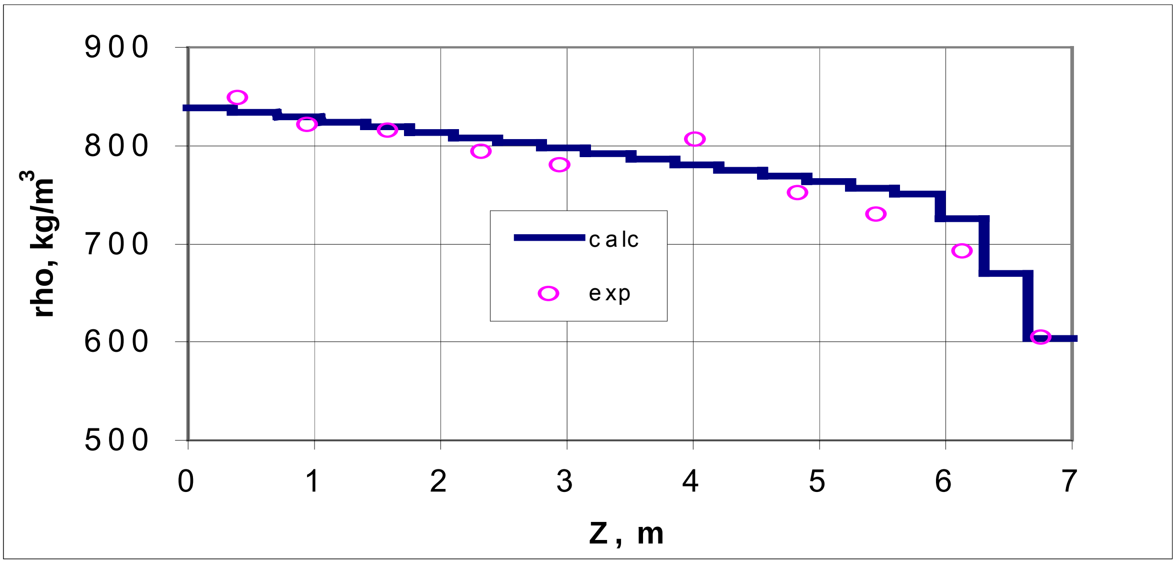


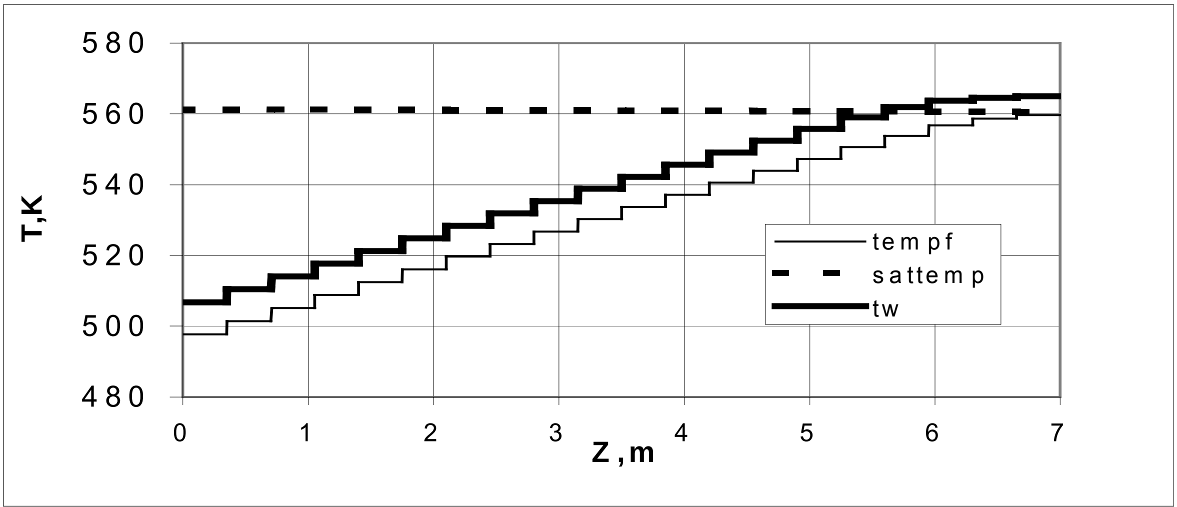




Comparison of calculated and experimental results (Tin=494K, N=303 kW, m=0,8825 kg/c, P=7,17 MPa, X=-0.001)







Comparison of calculated and experimental results (Tin=512 K, N=304 kW, m=0,44167 kg/c, P=7,14 MPa, X=0.258)