Additional RELAP5 Analysis of Thermal-Hydraulic Stability in Parallel Channels of the RBMK Primary Circuit Model

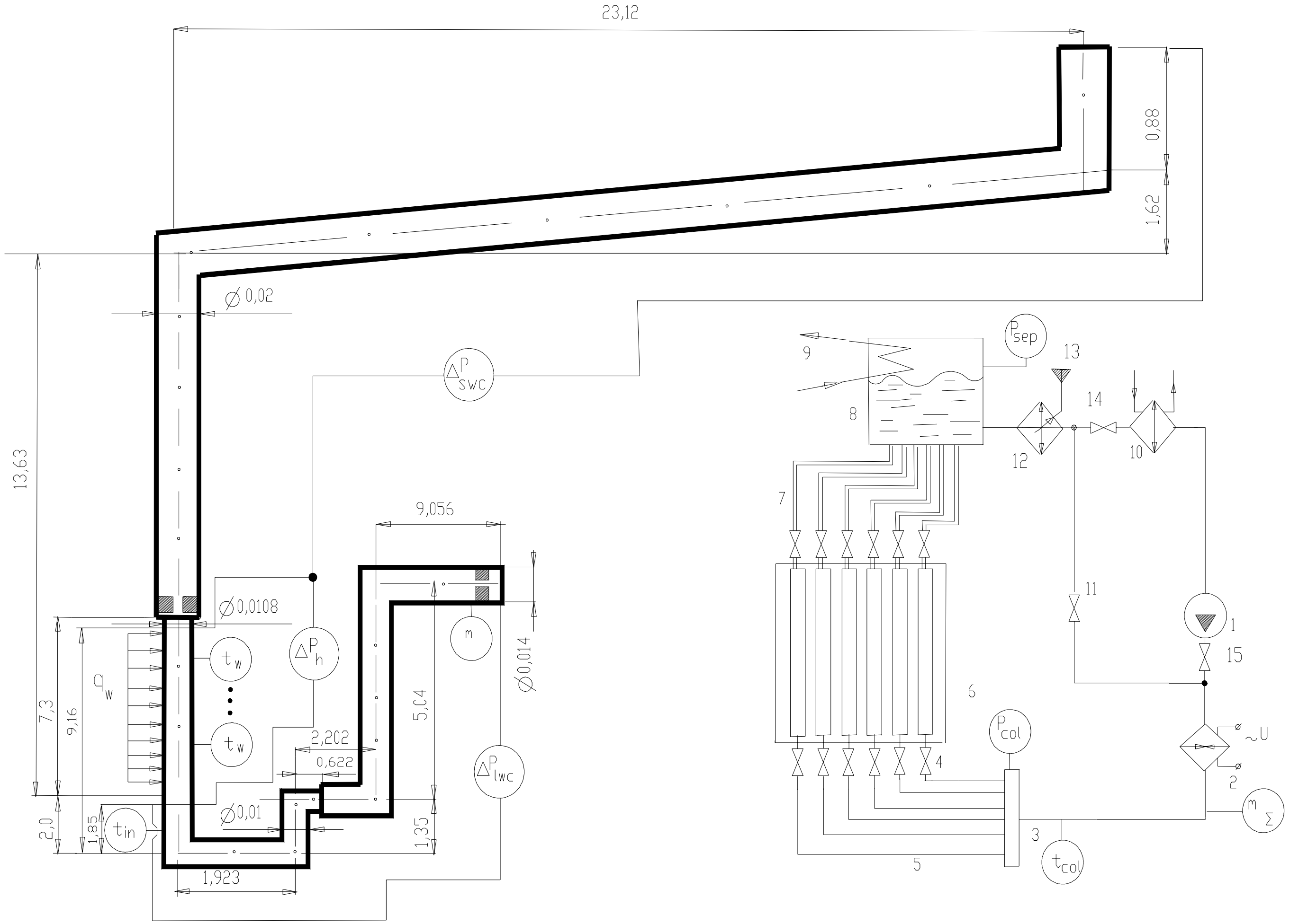
by
Brus N.A. and Ioussoupov O.E.

Electrogorsk Research and Engineering Center on NPP Safety

Presented by Ioussoupov O.E.

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

EREC 108 Experimental Test Facility



1-Circulation Pump;
2-Electrical Heater;
3-Pressure Header;
4-Throttling Valves;
5-Low Water Communications;
6-Heated Channels;
7-Steam Water Communications;
8-Separator;
9-Condenser;
10-Cooler;
11-Bypass Throttle;
12-Mixing Unit;
13-Feed Water Injection;
14,15-Pump Cut-off Throttles.

EREC 108 Experimental Test Facility (cont'd)

- model of multiple forced circulation circuit of RBMK including assembly of six identical parallel heated channels with full pressure in the separator columns (7.0 MPa);
- maximum power 1MW; channel walls were heated directly with electrical current;
- elevations scale 1:1;
- volume scale of one test facility channel relatively to one RBMK channel is 1:27.

As heated channels were used smooth tubes ∅12×1 mm (Channel 1) or tubes ∅12×0.6 mm with corrugations of 0.5 mm in depth knurled on the inner surface (such that the inner diameter of the tube varies from 10.8 to 9.8 mm) with distance 25 mm (Channel 2).

The electrical heating scheme allows to model uniform heat generation along height as well as cosine one typical for RBMK. If the case is smooth tubes, uniform power generation is modeled. Corrugated heated tubes modeled actual cosine power generation with gradations.

Boundaries of stability

The stability boundary is formed by regime parameters, which correspond to the beginning of flow rate auto-oscillations with minimal magnitude in any of parallel channels.
In tests flow rate or coolant temperature in the inlet were varied.

For each of series of test the boundaries of thermal hydraulic stability were drawn using coordinates:

$$\Delta X_{sub} = \frac{i_{l,sat} - i_{col}}{l}$$

as function of

$$\Delta X_h = \frac{Q_\Sigma}{m_\Sigma \cdot l}$$

where:

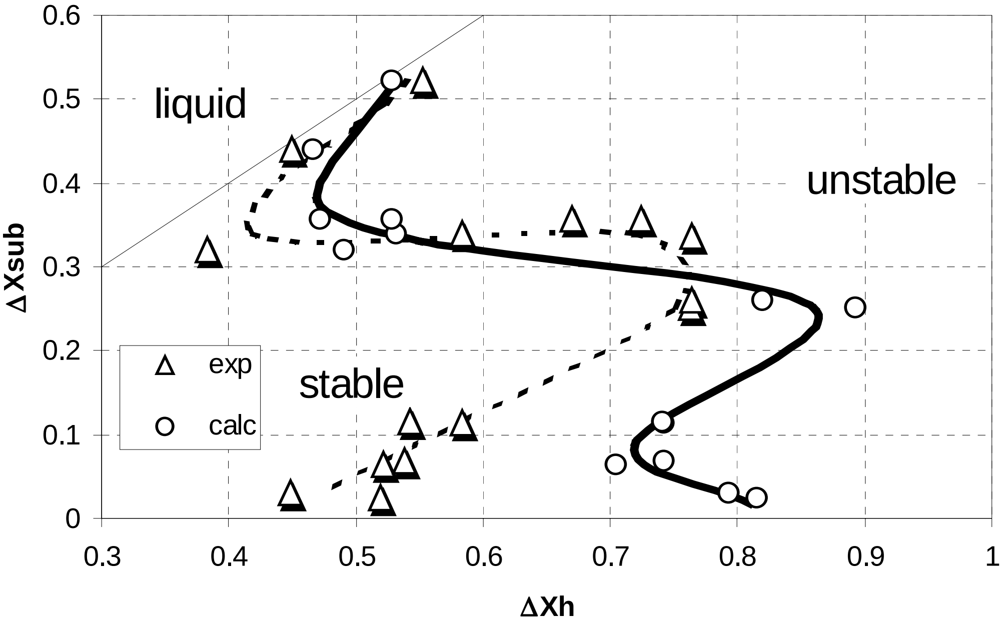
$i_{l,sat}$ enthalpy of saturated liquid under pressure in the heated channel inlet, J/kg

i_{col} enthalpy of subcooled liquid in the header, J/kg

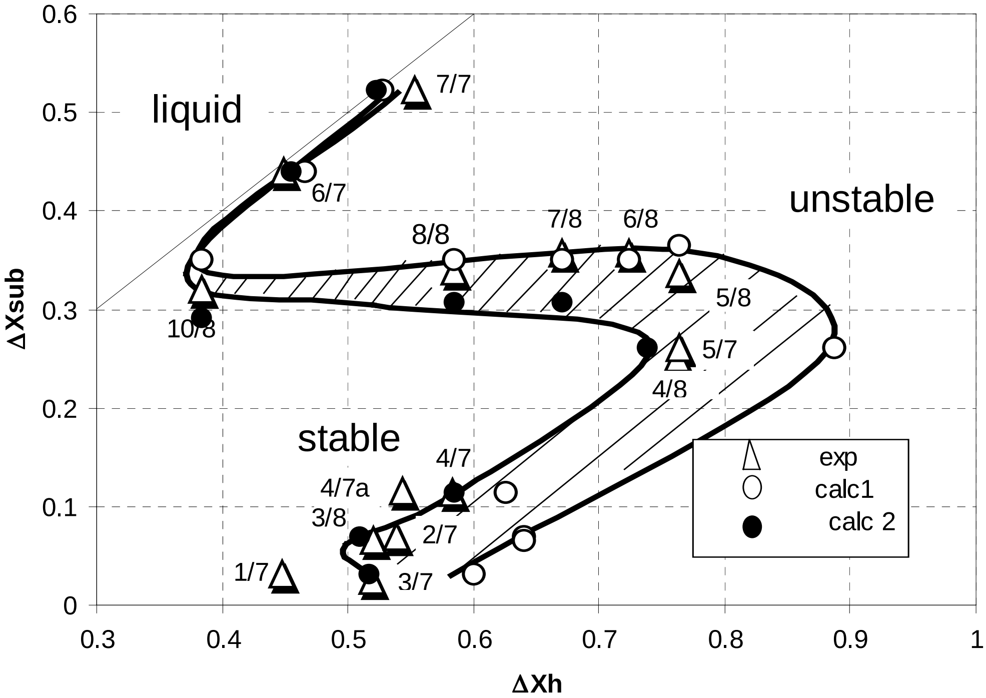
l latent heat, J/kg

m_Σ total mass flow rate through all the channels, kg/s

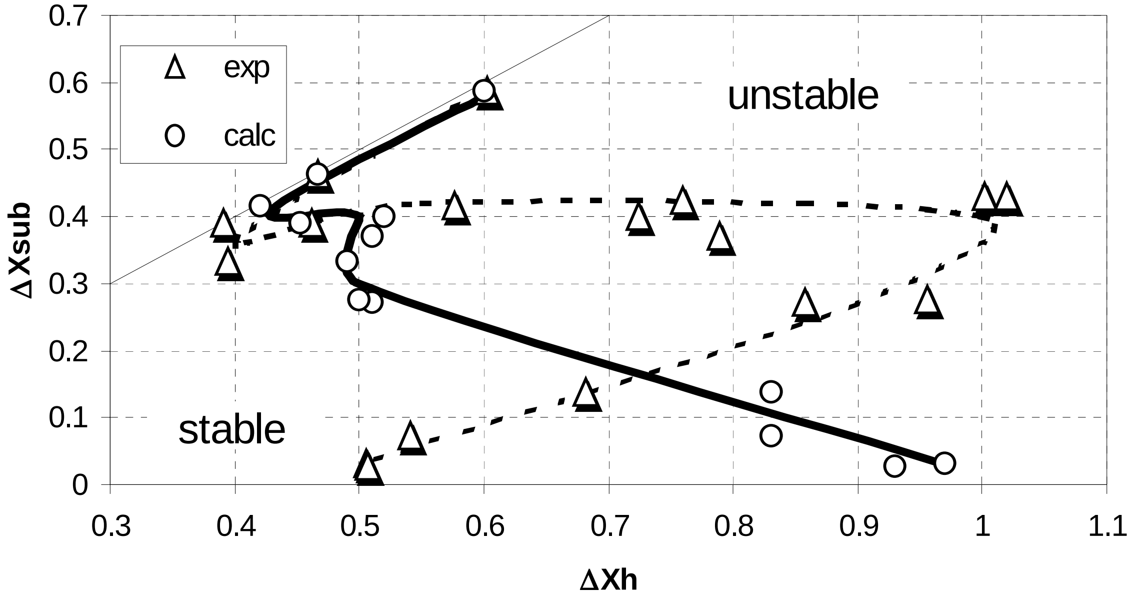
Q_{Σ} total heat load of all the channels, W



RELAP5 calculated and measured stability boundaries for Task 2b
(Obtained with single channel inlet pressure drop approach)

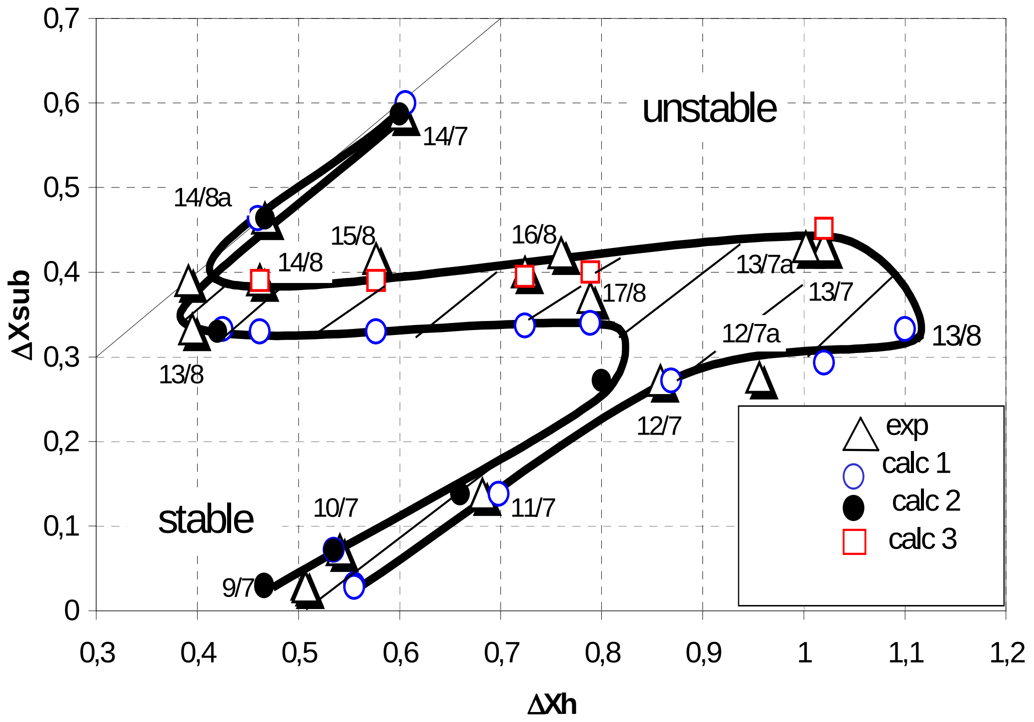


RELAP5 calculated and measured stability boundaries for Task 2b
(calc1 and calc2 differ by hydraulic resistances; Obtained with two parallel channels approach)



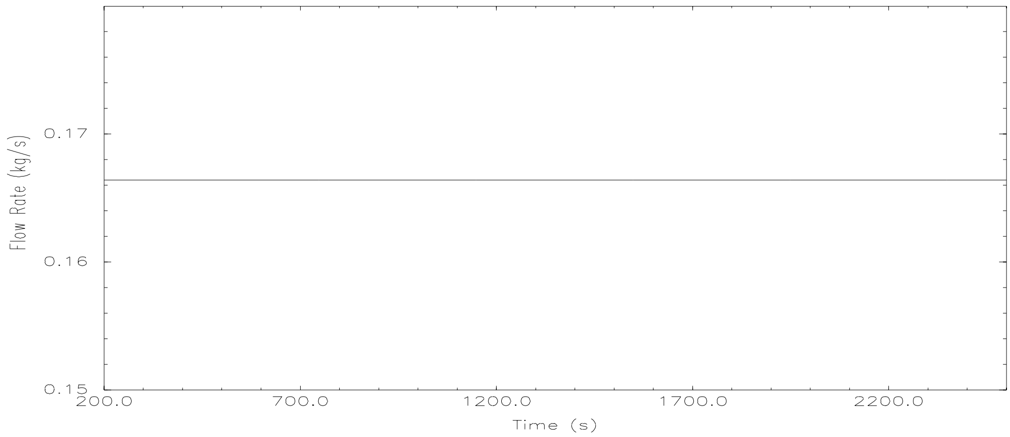
RELAP5 calculated and measured stability boundaries for Task 2d

(Obtained with single channel inlet pressure drop approach)

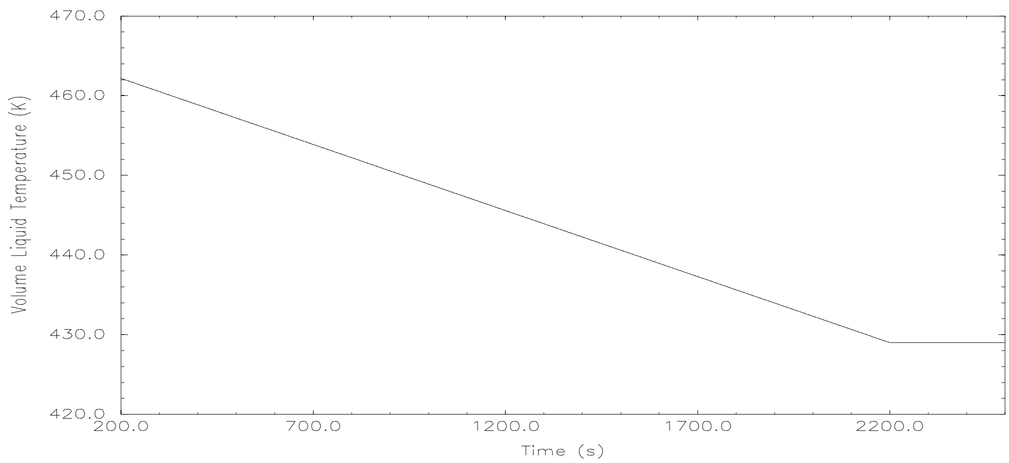


RELAP5 calculated and measured stability boundaries for Task 2d

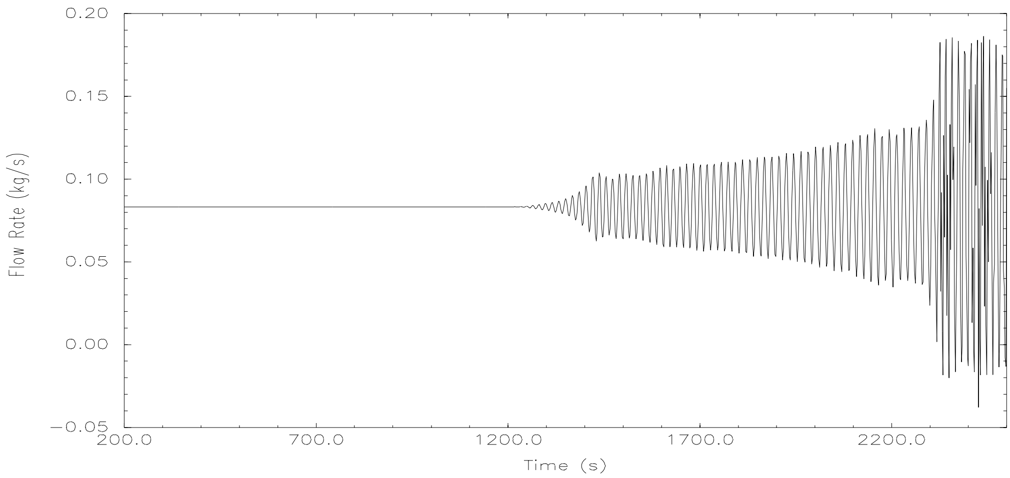
(calc1, 3 and calc2, 1 differ by hydraulic resistances; Obtained with two parallel channels approach)



a) Flow rate in the inlet of the pressure header

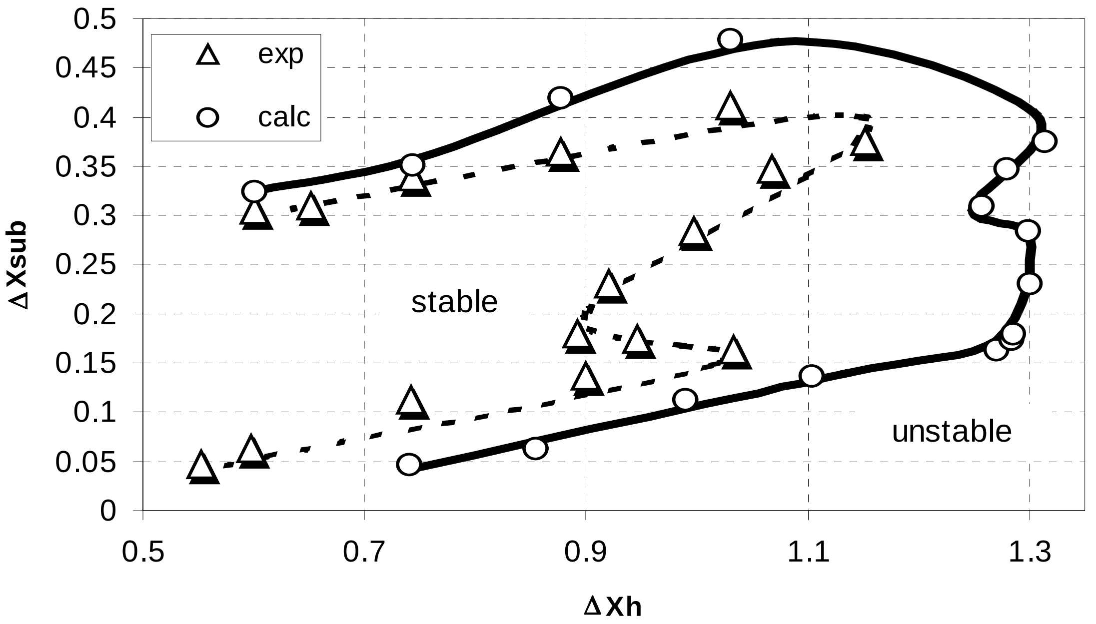


b) Flow temperature in the inlet of the pressure header



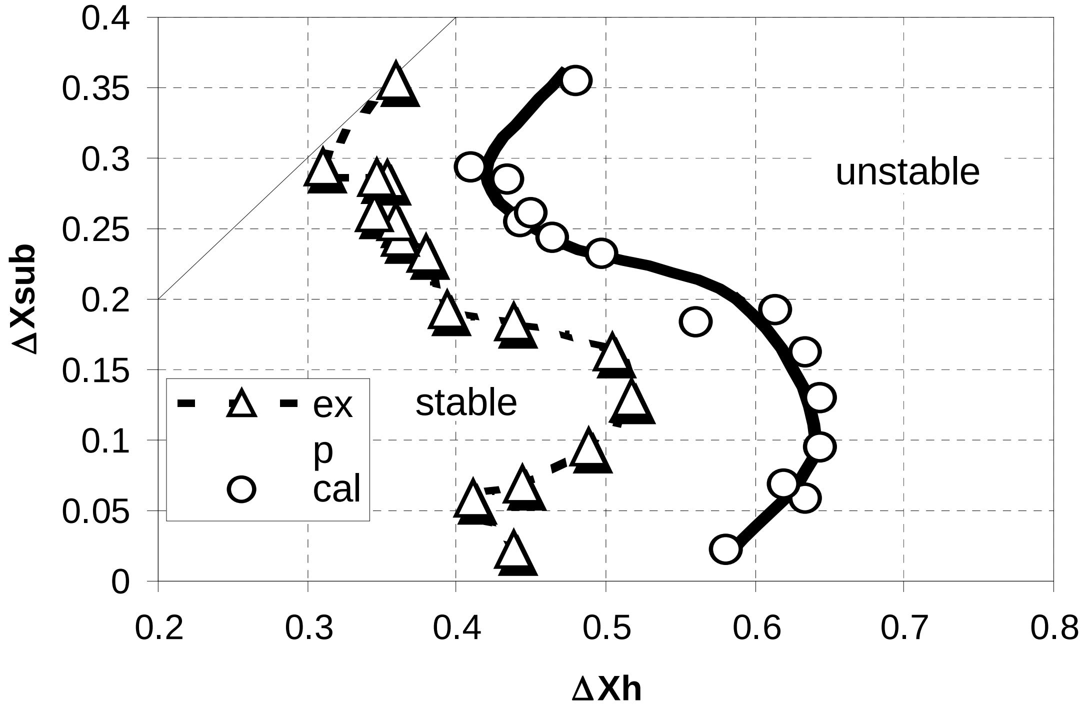
c) Flow rate in the inlet of the channel

Thermal-hydraulic instability onset due to reduction of inlet flow temperature. Experiment 16/8



RELAP5 calculated and measured stability boundaries for Task 2e

(Obtained with two parallel channels approach)



RELAP5 calculated and measured stability boundaries for Task 2f

(Obtained with two parallel channels approach)

Conclusions

This is additional analysis performed with RELAP5/Mod3.2 computer code of 4 experimental runs for thermal hydraulic instability performed at 108 EREC test facility. The main objective of experiments and computer modelling was to determine boundary of thermal hydraulic instability.

The agreement between experimental and calculated results could be judged to be between reasonable and minimal.

Drag and local resistances pressure drop measurement error has significant impact to measurement error of thermal hydraulic boundaries determination. RELAP5/Mod3.2 algorithms and correlations for calculation of friction pressure drop for different regimes of two phase and single phase flow should be checked closer then it is possible with current Standard Problem and refined if necessary in order to improve agreement between experiment and calculation. In addition to oscillations of flow rate m_i oscillations of pressure drop DP of specific sections of experimental channel should be recorded in case of new experiments for investigation of thermal hydraulic instability are to be performed.

No more specific code modification related recommendations can be made as result of the analysis performed.