CRITICAL HEAT FLUX INVESTIGATION AT HIGH WATER MASS FLOW RATE AND SHORT-TERM POWER EXCURSION FOR PIK REACTOR CONDITIONS

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Thermal processes under accidents in the PIK reactor were the common investigation subject of the CBTI and PNPI beginning from 1984. This work is devoted to an investigation of a fuel elements thermal state under the short-term power excursion. A single stainless tube directly heated by electrical current was used as an imitator of the hottest sub-channel of the core. An inner tube diameter (3 mm) was closed to the equivalent hydraulic diameter of the core sub-channel. A longitudinal heat generation was imitated by wall thickness shaping. An imitator of a rejecting "cold" part of the core was realized by connection of a big cross section non heating tube.

During the experiments the ratio of the flow rates through the heating tube and bypass was 0.16–0.19. It provided practically constant pressure drop on the heating tube independently of its thermohydraulic conditions.

The experiments were made as follows. After a water circulation in the test loop have reached a steady state heating from base transformer was feeded. A required steady state power was fixed by the power regulator . Then this transformer was switched off and in the same time another one was switched mounted beforehand on the required power surge. That operation was executed by a special commutation system. A duration of the transient process was 0.1–0.2 s. Simultaneously a timer picked up which switched off the power after a given time interval. Average flow mass temperature at the burnout cross section was determined from the heat balance taking into account a real longitudinal heat generation distribution included of electric resistance thermal dependence. A determination of inner tube surface temperature from the measured temperature values of outer surface was made with the help of Fourier equation solution for the cylindrical heat generating wall with constant physical properties.

The critical heat flux measurements were performed with step run-out power raisings at fixed values of flow rate, inlet water temperature and pressure. During these experiments some specialities of heat transfer worse process were observed. They consist in following. After the certain power level overshoot a continuous growth of wall temperature for a lower cross section of the tube middle part took place. A rate of that rise was not too rapid so it was possible to switch power supply off by hand.

The maximum heat flux density when such growth does not occurre can be regarded as CHF value.

An analysis of these results showed that the inner wall temperature in the crisis cross section met the condition

$$t = t + 0.8(t_{sp} - t_s)$$

where t_{sp} — saturation temperature, t_s — temperature of ultimate superheating.

The results of these tests are presented in Table 1.

Constant situation of the critical cross section in the middle part of the tube permitted to use a short tube with a lesser thickness of the wall. It provided the wall temperature drop smaller by a factor of 1.5 and more precise flow temperature modelling in the critical cross section.

The critical heat flux data for this channel are presented in Table 2.

Since the duration of a single experiment after the run-out power was 5–10 s, it was possible to observe the crisis development. The crisis occured as a hot shining spot that occupied at first a part of the tube perimeter only. Then the superheated hot spot widened and shining intensity increased.

Thus the high value of the heat transfer coefficient from the tube (0.6–0.7 of the initial one) kept during a long time (5–10 s and sometime more). This increasing must be related by a new structure of the boundary layers. One of the possibilities is velocity profile changing and velocity increasing over the hot part due to decreasing the friction coefficient connecting with the vapar film.

As the result of this investigation the critical heat flux densities are determined for different operating conditions.

The power excursions up to this volumes are not dangerous for the reactor. The particularies of the crisis in these conditions are a slow decrease of heat exchanging in spite of very high heat loads (till 25 MWt/m^2). This circumstance can essentially increase the limit power of short power excursions. The slow transients process before the crisis appearance show slight influence of boiling on the heat transfer and a prevalence of the convection.

Table 1

Experimental data of critical heat flux for channel 1

N№	P	N	q	W	t_{in}	t_{sub}
	atm	kWt	MWt/m^2	m/s	C	C
1	35	57	16.1	10.7	30	106
2	32	63	18.0	12.6	32	100
3	30	68	20.0	14.4	30	105
4	46	58.2	16.0	9.8	23	105
5	42.5	59.6	17.0	11.9	22	125

Table 2

Experimental data of critical heat flux for channel 2

$N^{\underline{o}}$	P	N	q	W	t_{in}	t_{sub}
	atm	kWt	MWt/m^2	m/s	C	C
1	29	62.3	24.5	16.0	25	110
2	29	59.6	23.0	14.8	25	115
3	30	61.4	24.0	13.6	25	100
4	30	52.8	21.0	11.5	25	95
5	50	60.5	23.5	15.0	26	130
6	50	55.2	21.5	12.5	25	130
7	50	49.0	19.0	10.0	25	110