Project #3194

"Fuel Assembly Tests under Severe Accident Conditions"

Information letter on the test
PARAMETER-SF1
(done 15 April 2006)

The PARAMETER-SF1 test conditions simulated a severe LOCA sequence in which the overheated up to 2000°C core would be re-flooded from the top in occasion of ECCS recovery. The test was conducted at the SRI SIA "LUCH" 15 April 2006 and was the first of two experiments to be performed in the frame of the ISTC 3194 Project.

Technological systems of PARAMETER facility had been assembled in accordance with the functional scheme (Fig.1) on the SF1 test.

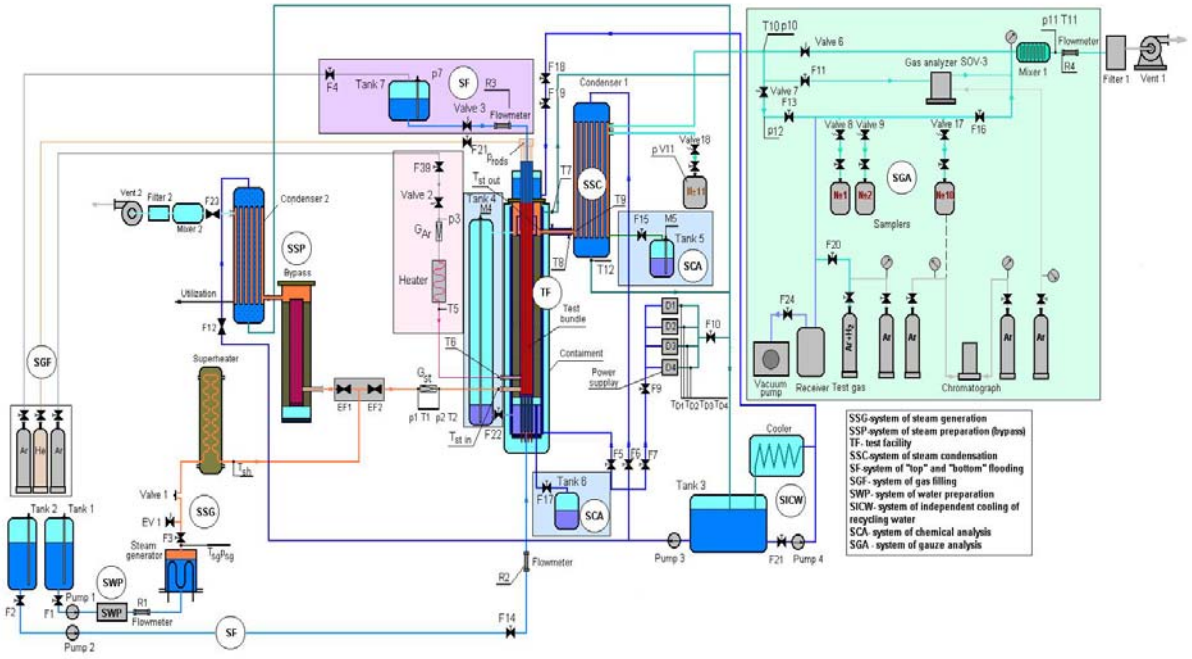


Fig.1. Functional scheme.

Object for investigation was the bundle of VVER-1000 type, which is made up of 19 fuel rod simulators. Residual heat of bundle was simulated by electrical power supply. Overall test scenario was accomplished by water quenching from the top.

The determination of the test scenario has based on numerous calculations by RATEG/SVECHA, SCDAPSIM, MELCOR, MAAP-4, ATHLET and PARAM-TG codes.

The SF1 test scenario consisted of the preliminary phase with duration about 7000 s, cladding oxidation phase (7000 – 14900 s) and quench phase. At the preliminary phase the test bundle was heated up step-by-step in argon atmosphere from room temperature up to 500°C, initially under low argon flow rate,

later under designed argon flow rate 2.0 g/s accompanied by steam injection after 5400 s with steam flow rate about 3.3 g/s.

Up to ~10400 s the PARAMETER-SF1 test was executed in accordance with pre-calculated test protocol. All measuring and technological systems were operated in order.

From ~ 11000 s it was observed that behavior of some bundle parameters deviate from anticipated values. In particular the increase of electrical power (from 4.6 to 6.4 KW) resulted in higher temperatures than it could be expected under specified convective heat transfer to steam flux (3.3 g/s). From this point to keep the designed temperature behavior the electrical supply was handled by operator only on the basis of thermocouples indications. This decision allowed keeping the pre-oxidation stage and maintaining the bundle temperatures at the designed value (about 1200°C) up to start of transient. Post test preliminary data analysis allowed us to suppose that the course of observed temperature behavior is heat imbalance appeared possibly due to accidental steam bypass of the upper heated elevations.

Transient stage was initiated at 14450 sec. At this stage the bundle was overheated from 1200°C up to 2000°C with heat up rate about 2 K/s. At 14900 s the quench water injection was initiated, water flow rate was ~ 41 g/s. Bundle quenching was prolonged ~500 s.

Electrical power history is presented in Fig.2. Argon and steam flow rates and inlet temperatures, top flooding water flow rate are plotted in Fig.3. The test section pressure versus time is shown in Fig.4. From this figure one can conclude that over-pressurization during quenching was small. Thermocouples indications at hottest zone (1100, 1250 and 1300 mm), at upper (1400, 1500 mm) and lower (800, 900, 1000 mm) elevations are presented in Fig.5 (a, b, c).

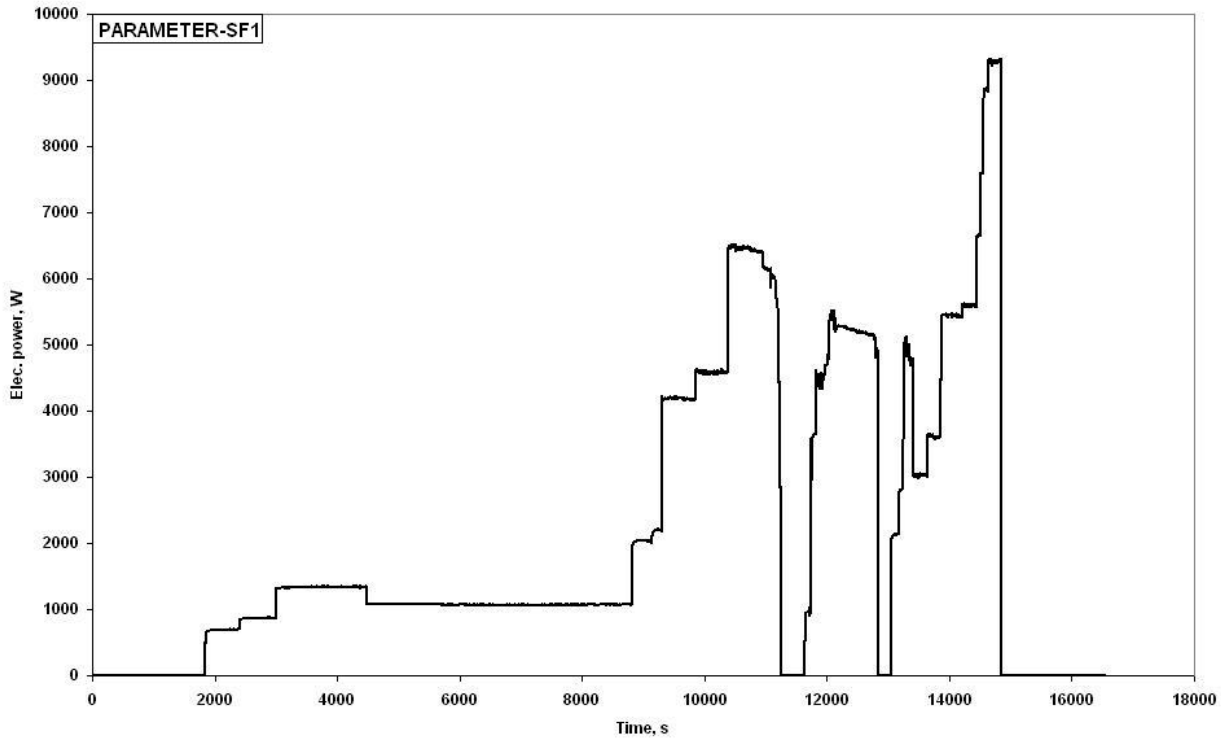


Fig.2. Input electrical power.

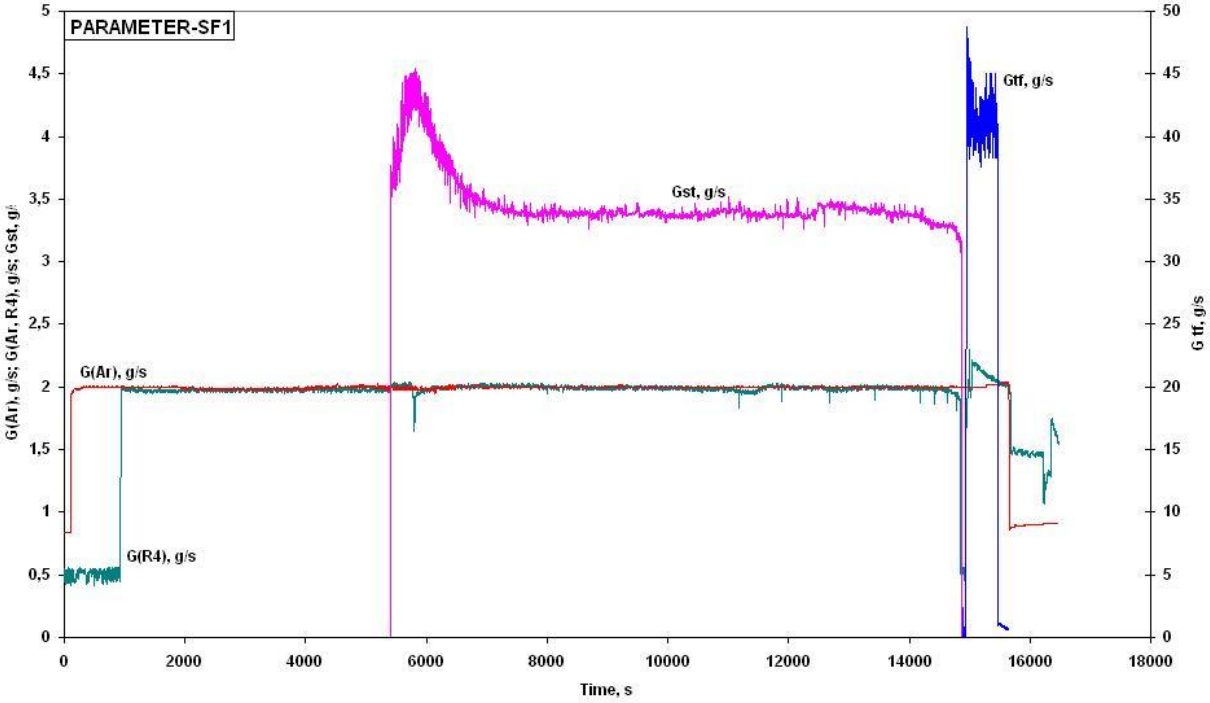


Fig.3. Steam flow rate Gst, argon flow rate G(Ar) and top flooding water rate Gtf measurements.

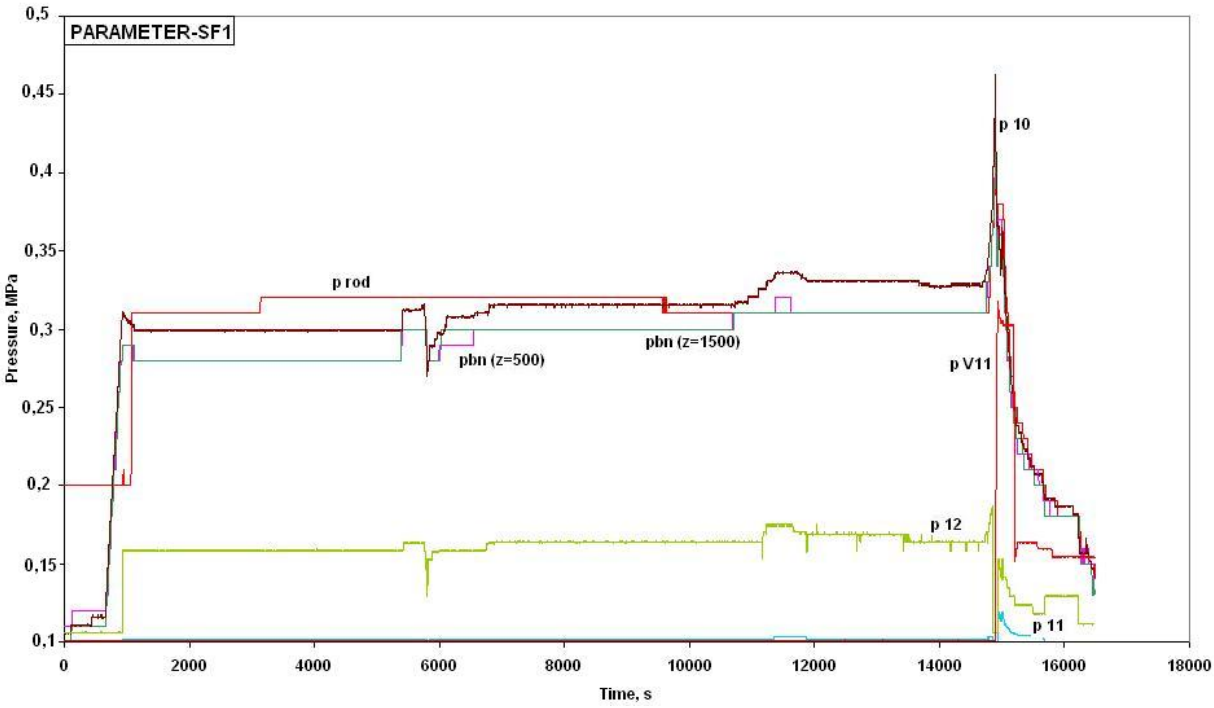
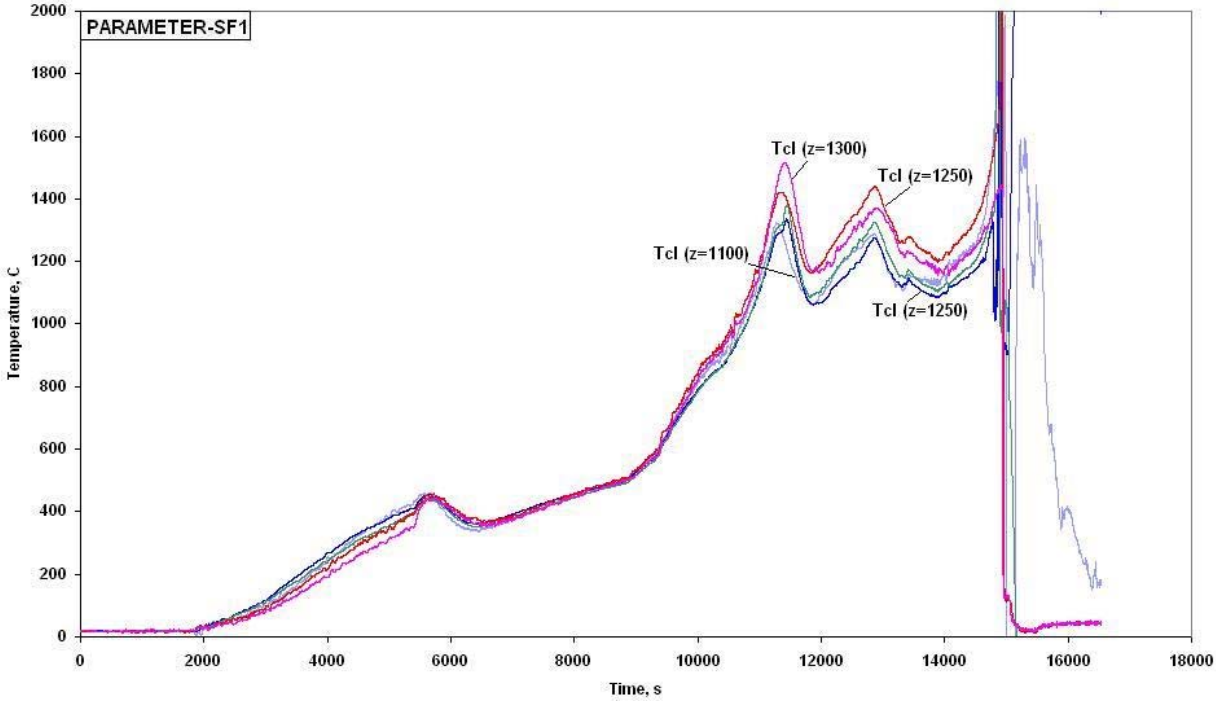
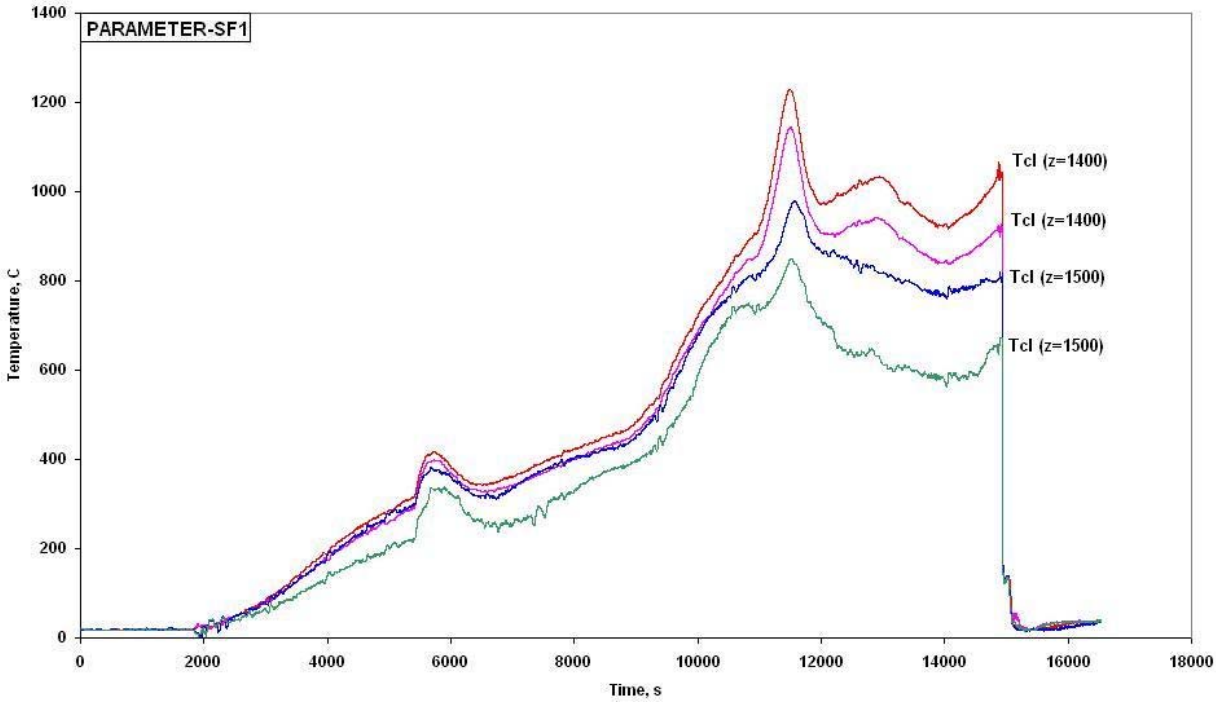


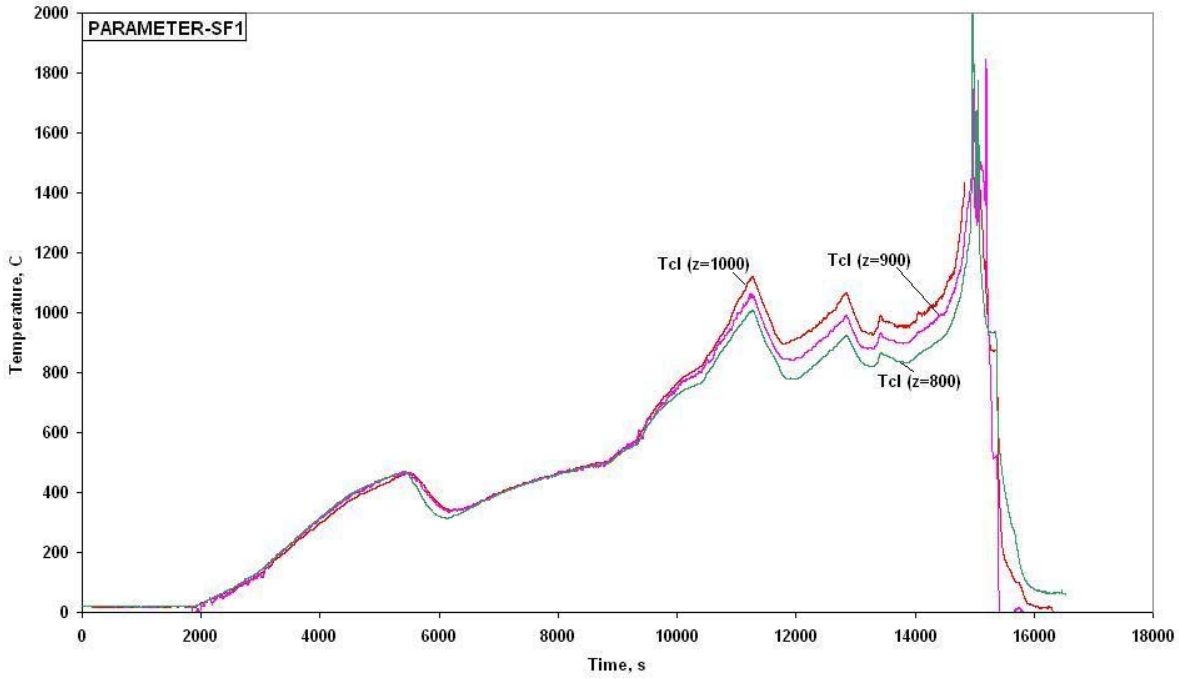
Fig.4. Pressure measurements in the rods (prod), the bundle test section (pbn) and in the off-gas pipe tubes (p10, p11, p12, pV11).


PARAMETER-SF1
Tcl (z=1300)
Tcl (z=1250)
Tcl (z=1100)
Tcl (z=1250)
Temperature, C
Time, s
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000

a)


PARAMETER-SF1
Tcl (z=1400)
Tcl (z=1400)
Tcl (z=1500)
Tcl (z=1500)
Temperature, C
Time, s
0
200
400
600
800
1000
1200
1400
0
2000
4000
6000
8000
10000
12000
14000
16000
18000

b)



c)

Fig.5. Temperatures measured by rod cladding outer surface thermocouples.

During quench period the re-flooding of the bundle top (region from 1300 to 1500 mm) was quickly (2-3 s) achieved (see Fig.6). At the same time the considerable time delay was observed (400-500 s) in the re-flooding of lower part of test bundle (0…600 mm). At these elevations the cooling front was slowly propagated upwards from the bottom to higher elevations (see Fig.7). At elevation 800 mm the bundle was quenched practically at the end of test.

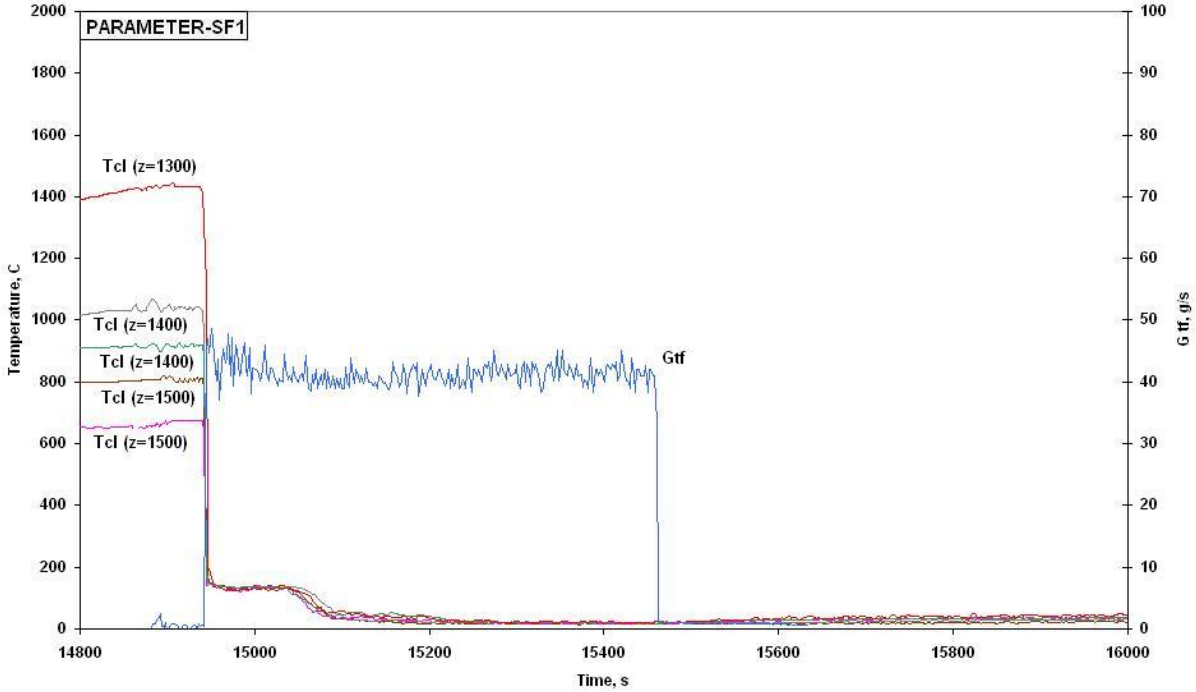


Fig.6. Temperature response of the rod cladding outer surface thermocouples at 1300-1500 mm elevations during the quenching phase.

Hydrogen concentration measurements were performed by SOV-3 system for all test stages. Hydrogen concentration measurements are depicted in Fig.8 with correction on inertia of the SOV. Results of gas sampling measurements are presented in Fig.8 as well. The analysis of results has shown that SOV and sampling measurements are in the close agreement.

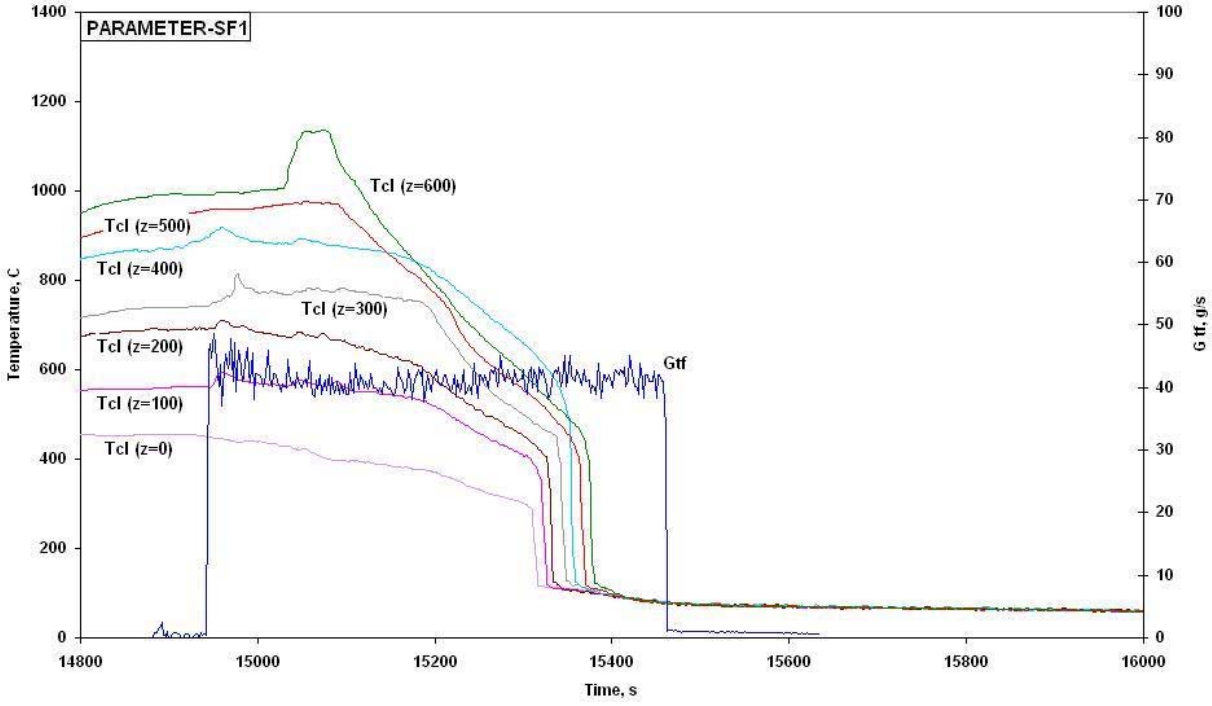


Fig.7. Temperature response of the rod cladding outer surface thermocouples up to 600 mm elevation during the quenching phase.

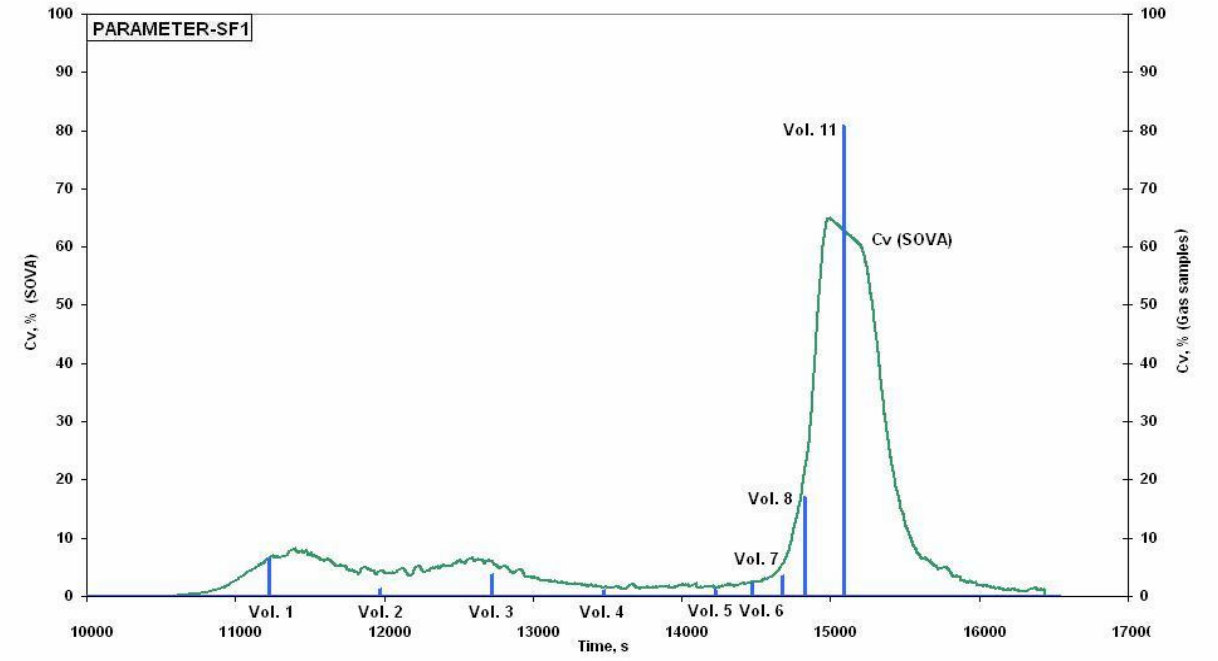


Fig.8. Hydrogen volume concentration vs. time.
(Vol.1,…, Vol.8 - gas sampling times (duration 8 s), Vol.11 – 300 s).

Maximum hydrogen production rate was ~ 0,19 g/s. The total generation of hydrogen was about 91g, of which about 60% was produced during the re-flooding phase (Fig.9).

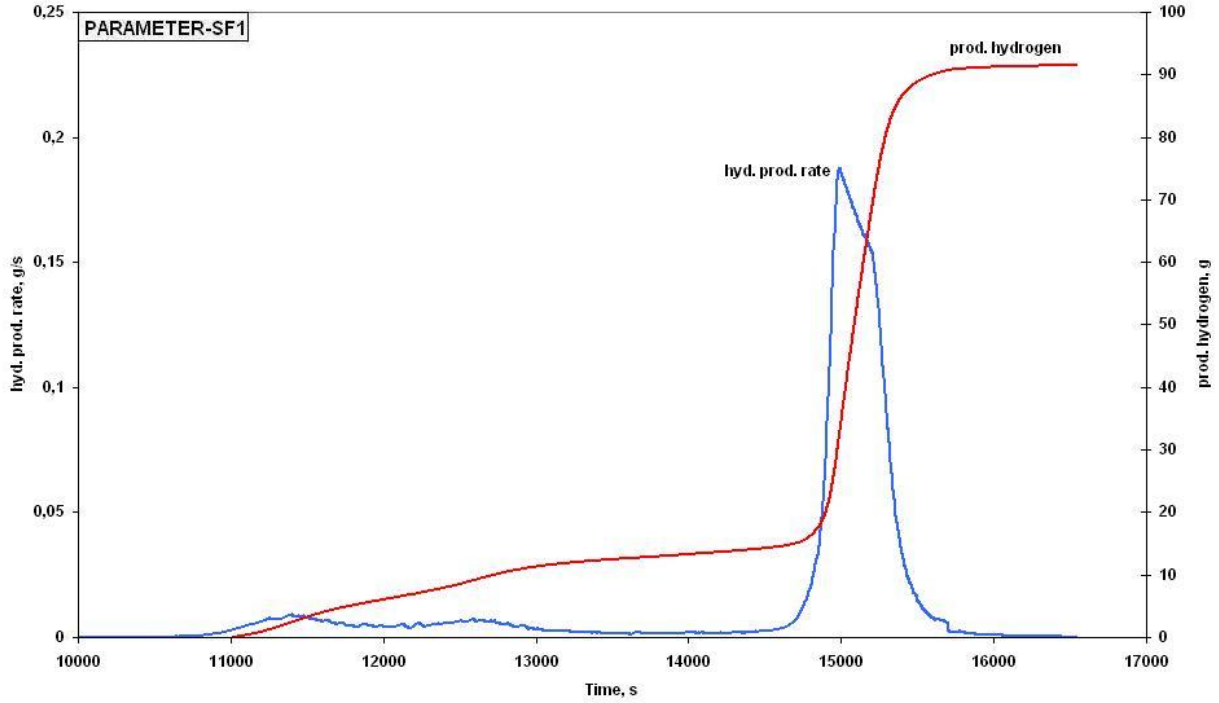


Fig. 9. Integral hydrogen release and hydrogen release rate (not corrected on hydrogen transport delay to SOV system).

After analysis of measured data and post test metallographic examinations the more detailed information about results of PARAMETER-SF1 experiment will be presented.

Moscow, May 2006