Experimental Measurements for Plate Temperatures of MTR Fuel Elements at Sudden Loss-of Flow Accident and Comparison with Computed Results

Dr. Bülent SEVDIK

TR-2 Reactor Unit Head

Turkish Atomic Energy Authority, CNAEM, Istanbul, Turkey

The aim of this study:

- **To generate experimental data to be used for sensitivity analysis and assessment calculations on the thermal-hydraulic codes written for Loss of Flow Accident (LOFA) analysis of research reactor with MTR- type (plate type) fuel elements.**

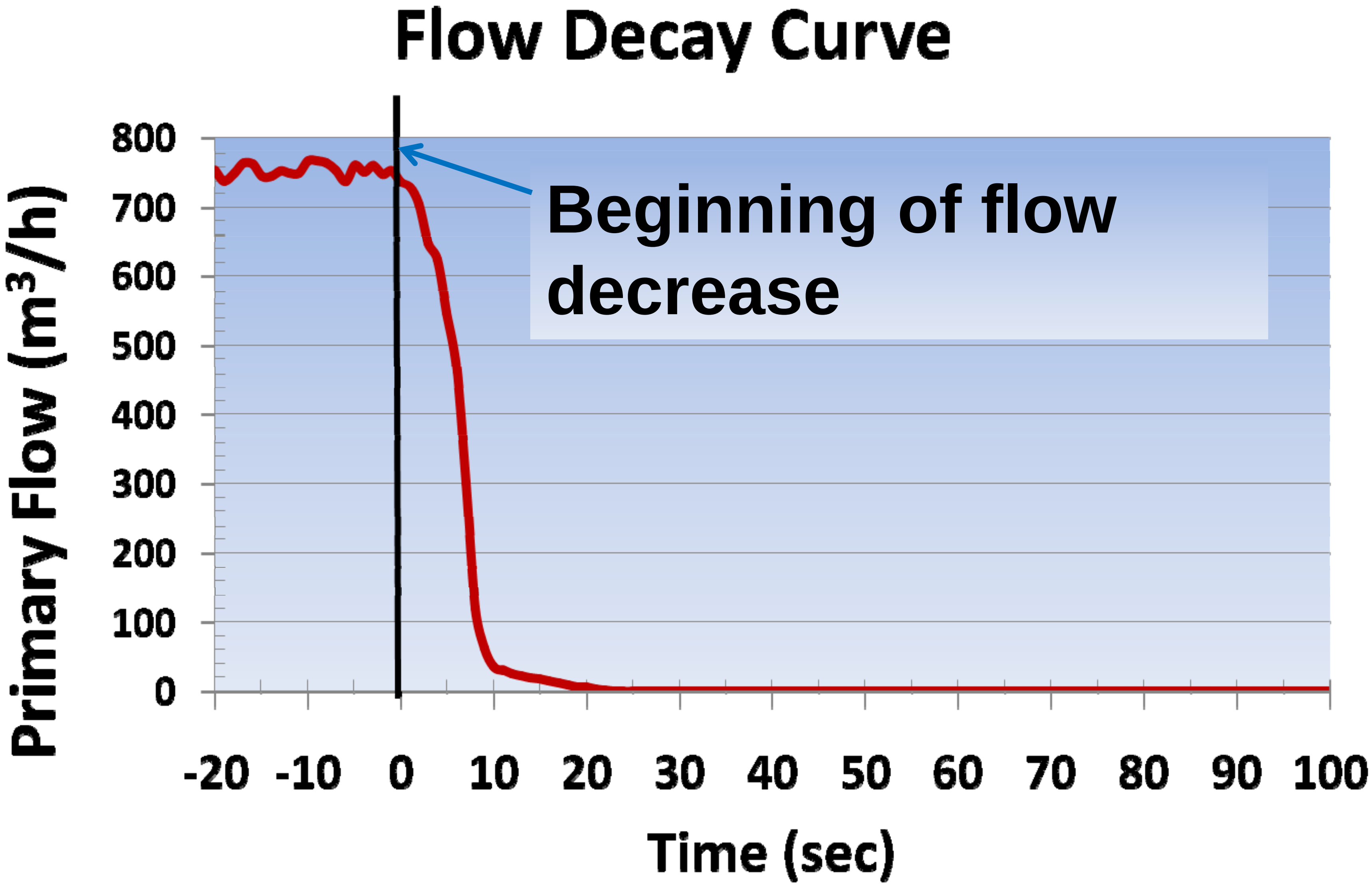
How does it Happen:

- In an open pool research reactor with downward coolant flow, an accident such as **shaft breaks between pump and flywheel** can lead to **sudden loss of flow.**

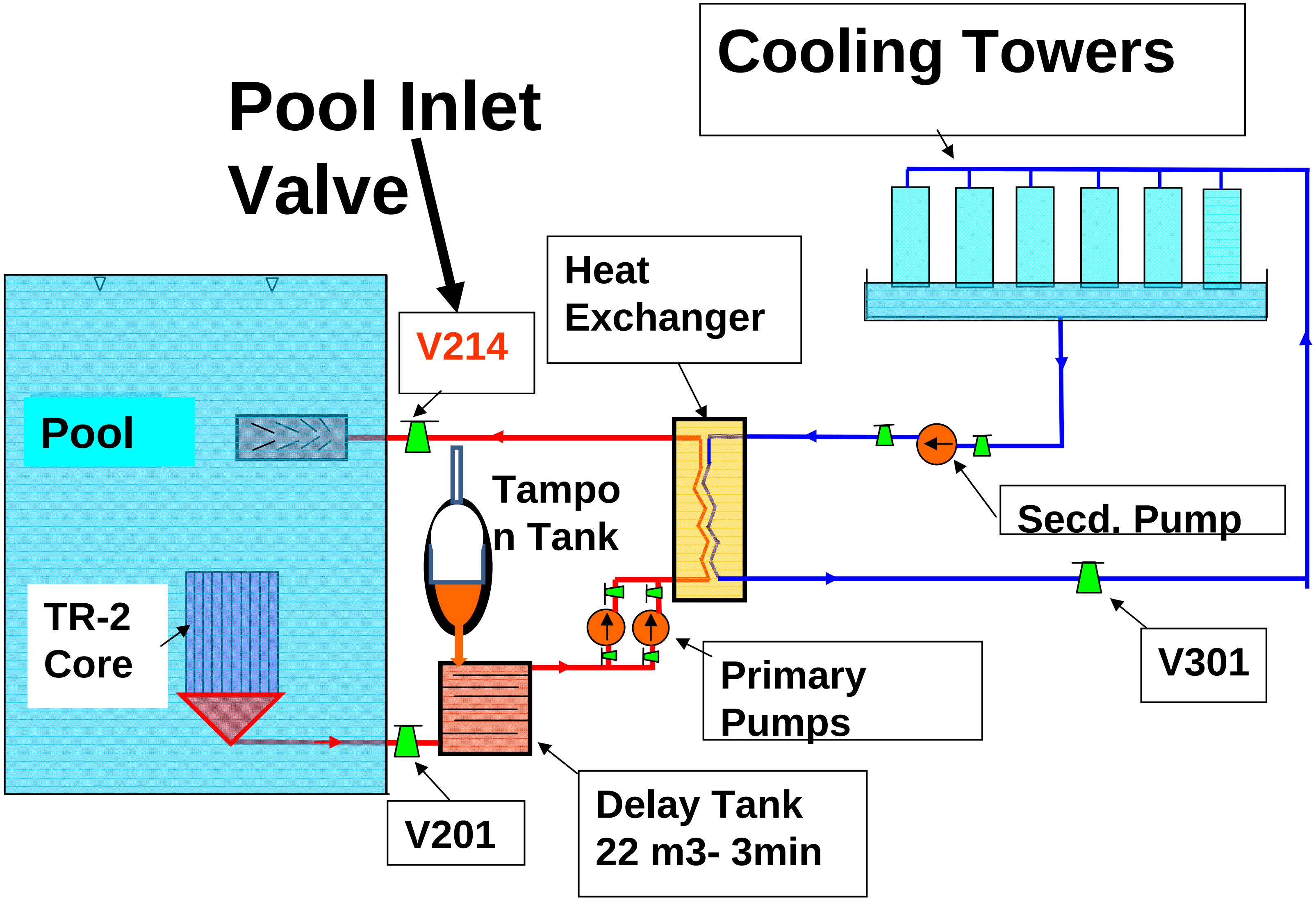
- **In the TR-2 Research Reactor;**
- **Sudden Loss of Flow Accident is *simulated by closing the pool inlet valve.***
- **It is a butterfly type valve and total closing time is about 30 seconds but**

effective flow decrease occurs in 10seconds.

- ***The beginning of the flow decrease by the closing of valve was accepted as zero time* and decrease curve of flow rate versus time was plotted.**



Flow Decay Curve
Beginning of flow decrease
Primary Flow (m3/h)
800
700
600
500
400
300
200
100
0
-20
-10
0
10
20
30
40
50
60
70
80
90
100
Time (sec)



TR-2 Reactor Cooling Systems

- **Power distributions** of the fuel elements in the reactor core were determined **experimentally** by using copper wire activation technique.
- **According to the existing core loading of the TR-2 Reactor;**
- **core positions**
- **power distributions** (U-235 weights, relative flux dist.)

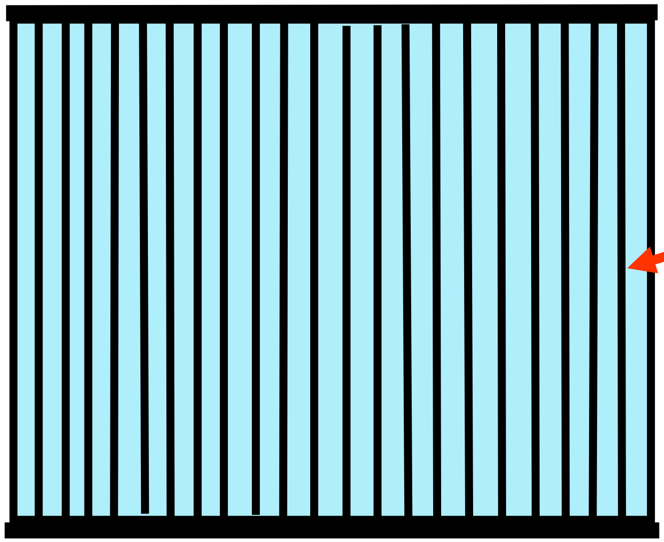
of the fuel elements were given for the inputs of the calculations to simulate the **LOFA** at the **(PARET)** computer codes.

Instrumented Fuel Element:

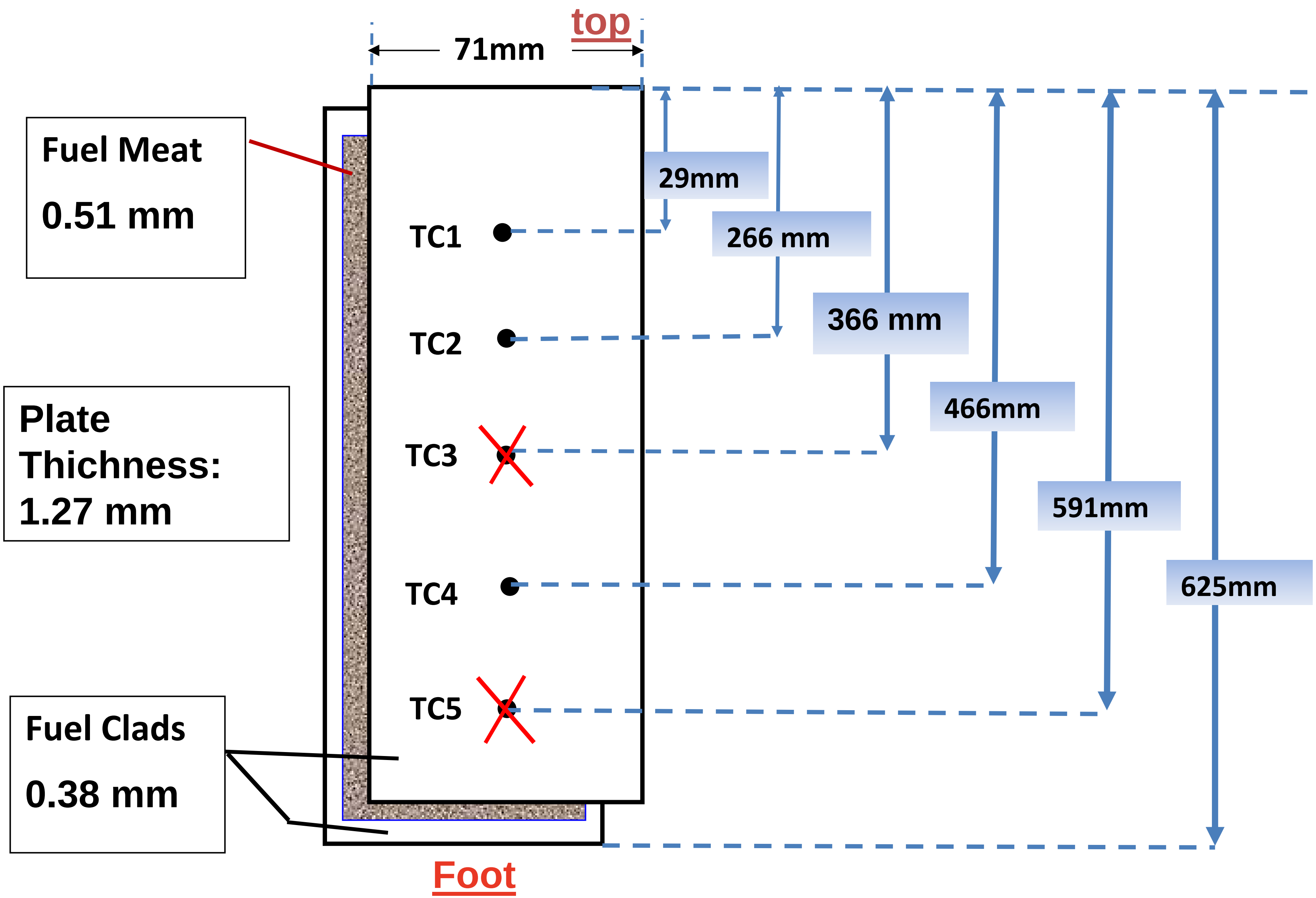
- **An instrumented fuel element, which has five thermocouples along the vertical direction of the fuel plate, was used for the experiments.**

Instrumented Fuel Element top view.

23 Fuel Plates



Thermo-couples are placed on second fuel plate (first cooling channel) (Cooling gap:2.1 mm)



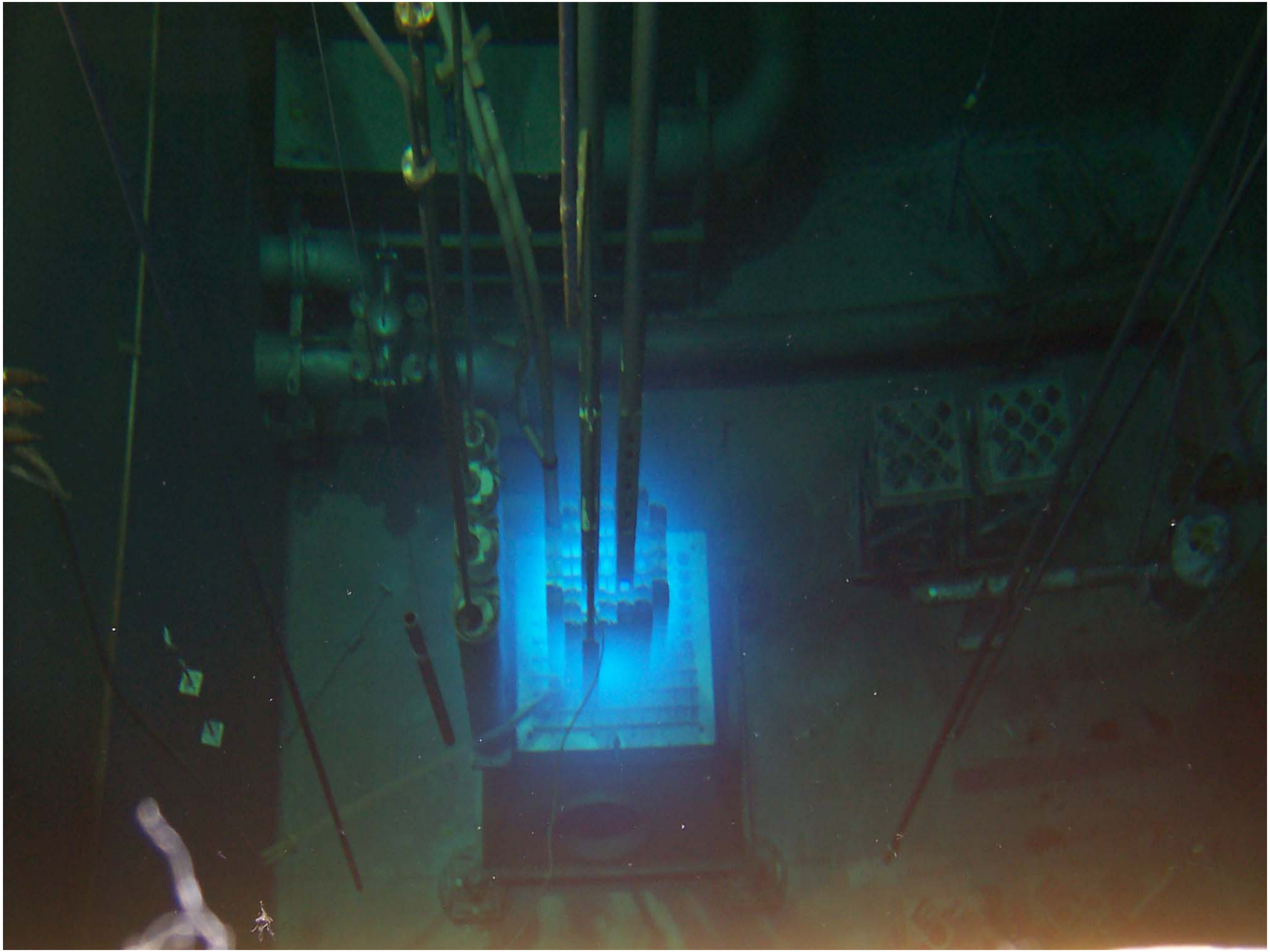
Location of the Chromel –Alumel Thermocouples on Fuel Plate of the Instrumented Fuel Element


W
Tx5

TR-2 Core Configuration

88	78 Grafit	68 BE	58 BE	48 BE	38 Grafit	28
87 Grafit	77 BE	67 S-107	57 I-003	47 S-106	37 BE	27 Grafit
86 Grafit	76 S-120	66 C-015	56 S-108	46 C-012	36 S-119	26 Grafit
85 WB	75 S-105	65 S-111	55 I-001	45 S-114	35 S-117	25 WB
84 BE	74 S-118	64 C-017	54 S-101	44 C-011	34 S-116	BE
83 WB	73 BE	63 S-115	53 SI-01	43 S-110	33 BE	23 WB
82	72 Punom atic	62 BE	52 BE	42 BE	32 Grafit	22

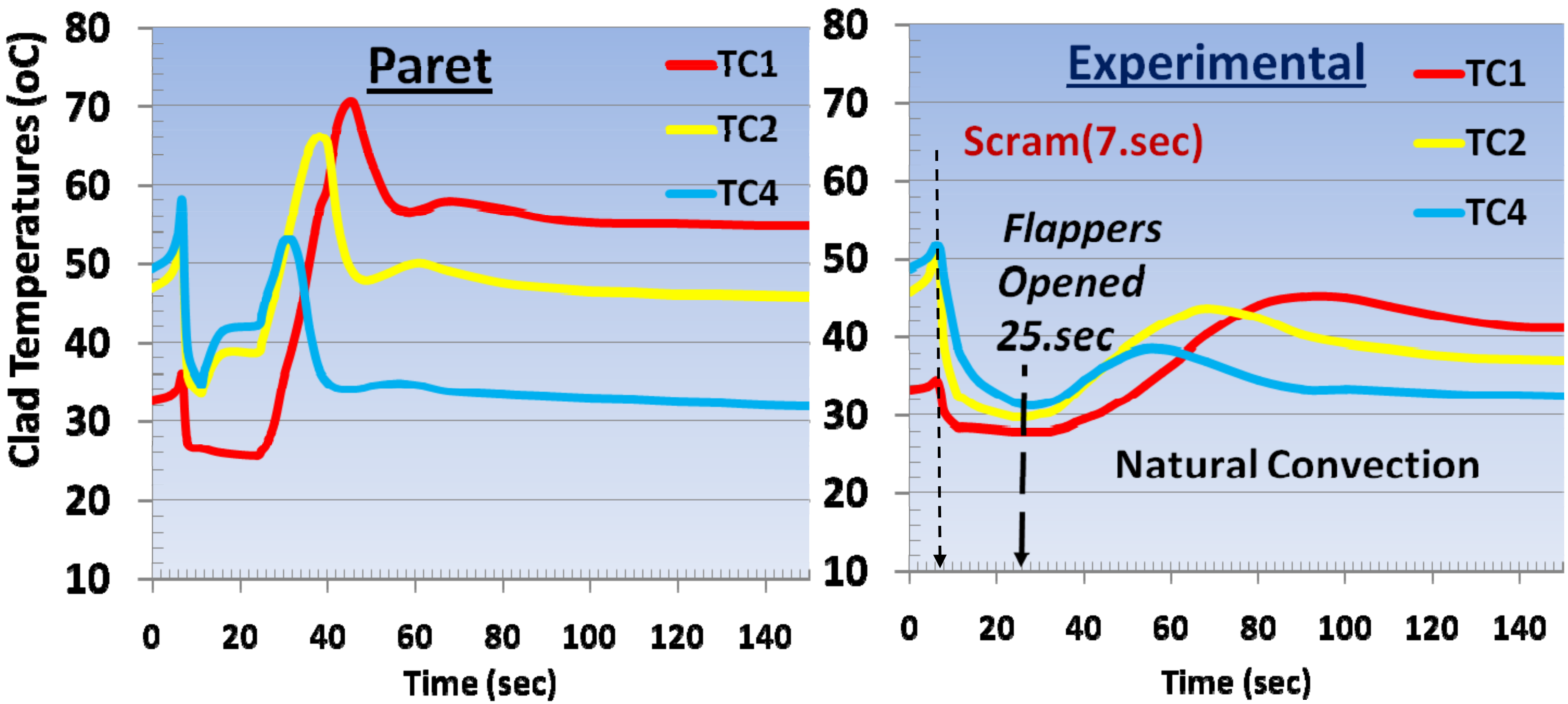
Instrumented Fuel Element was Placed .



Experiments:

- **Four experiments were performed for SLOFA.**
- **Three of these** experiments were repeated with ***different initial conditions*** such as **different core inlet temperatures** and ***different reactor operation times at 5 MW*** nominal power level and **750 m3/h** primary flow rate.
- ***The reactor was shutdown by flow scram at these three experiments.***
- Last Exp.was performed without scram. (Nötronic Power:50 kw)

1. Experiment

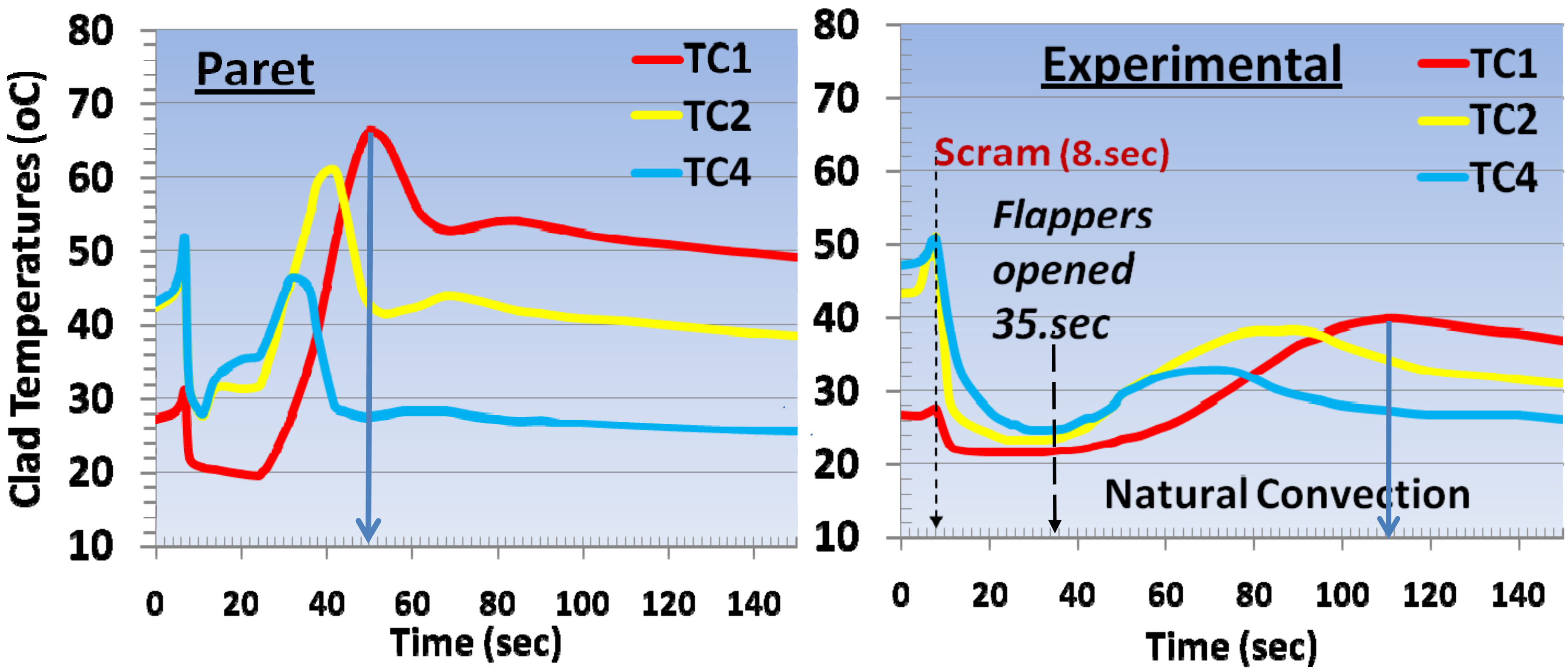


P=5 MW *Total reactor operation time is <u>5 minute</u> before scram*

Initial flow rate: 750 m^3/h (reverse flow)

Pool Water temperature : 23 ^oC (Core inlet)

2. Experiment

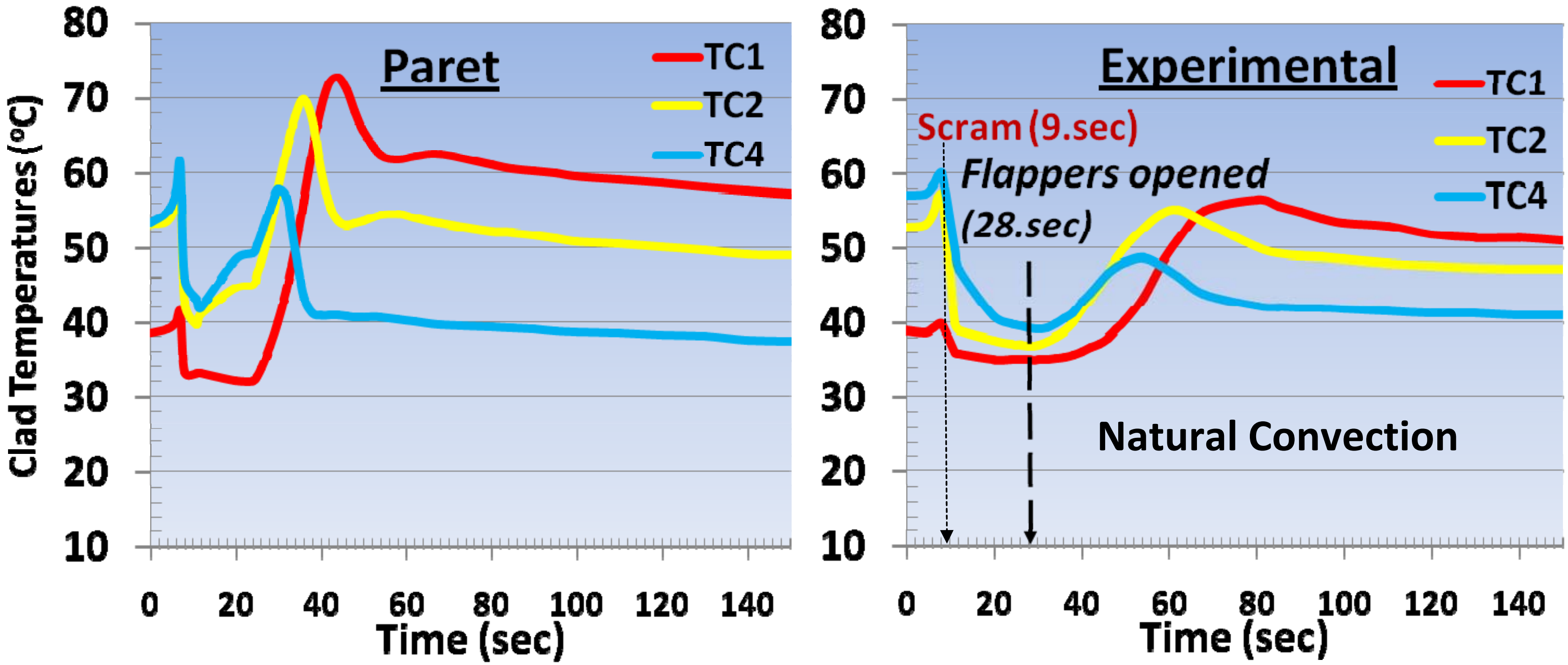


P=5 MW **Total reactor operation time is *5 minute* before scram**

Initial flow rate: 750 m³/h *(reverse flow)*

Pool Water temperature : 17 °C *(Core inlet)*

3. Experiment

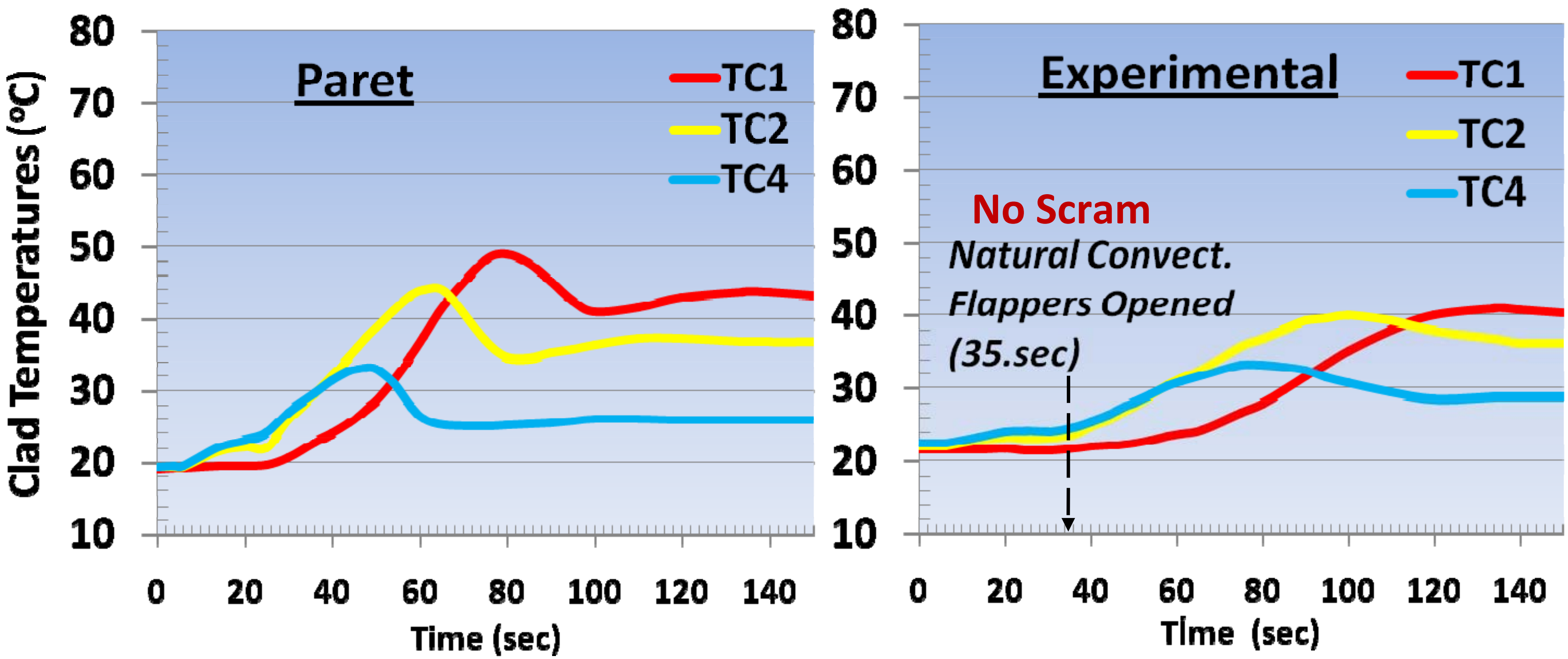


P=5 MW Total reactor operation time is *2 hours* before scram

Initial flow rate: 750 m^3/h *(reverse flow)*

Pool Water temperature : 29.5 °C *(Core inlet)*

4.Experiment

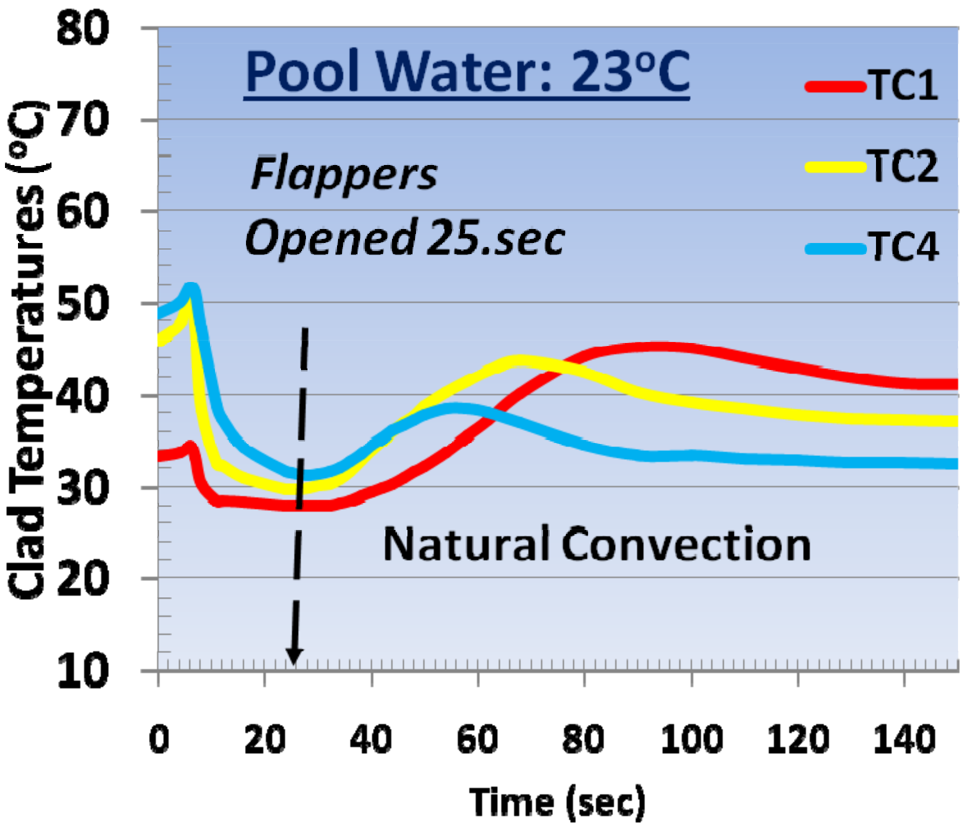


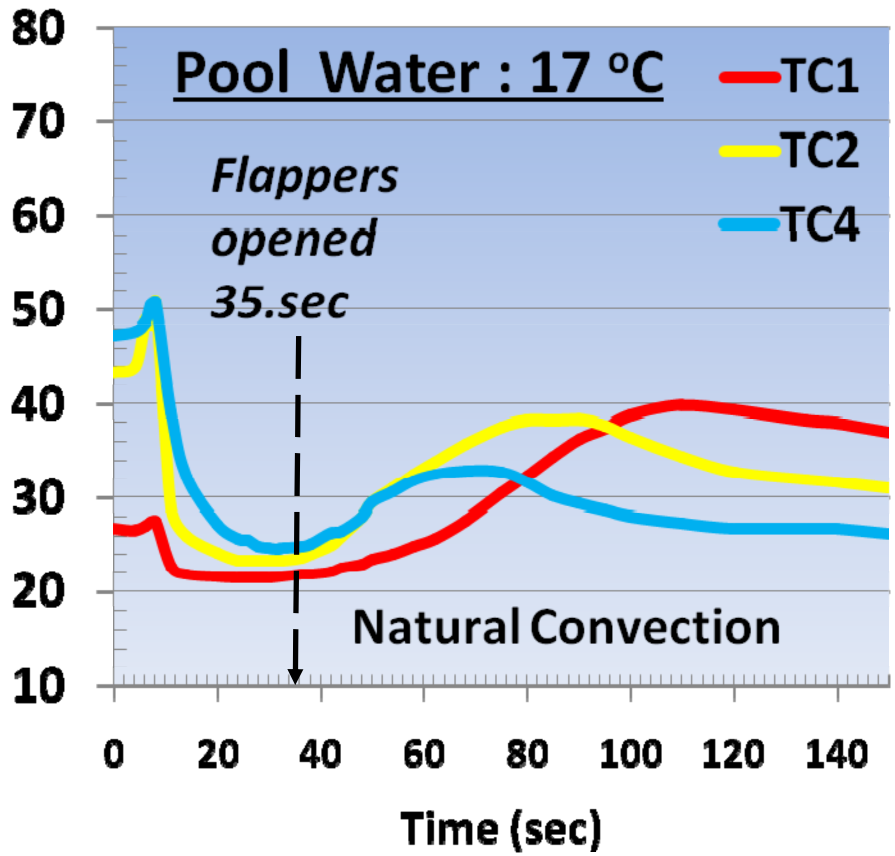
P= 50 KW Neutronic Power - Total reactor operation time is ***5 minutes***
before flow decrease **Without SCRAM**

Initial flow rate: 750 m^3/h *(reverse flow)*

Pool Water temperature : 19 °C *(Core inlet)*

1. & 2. EXPERIMENT



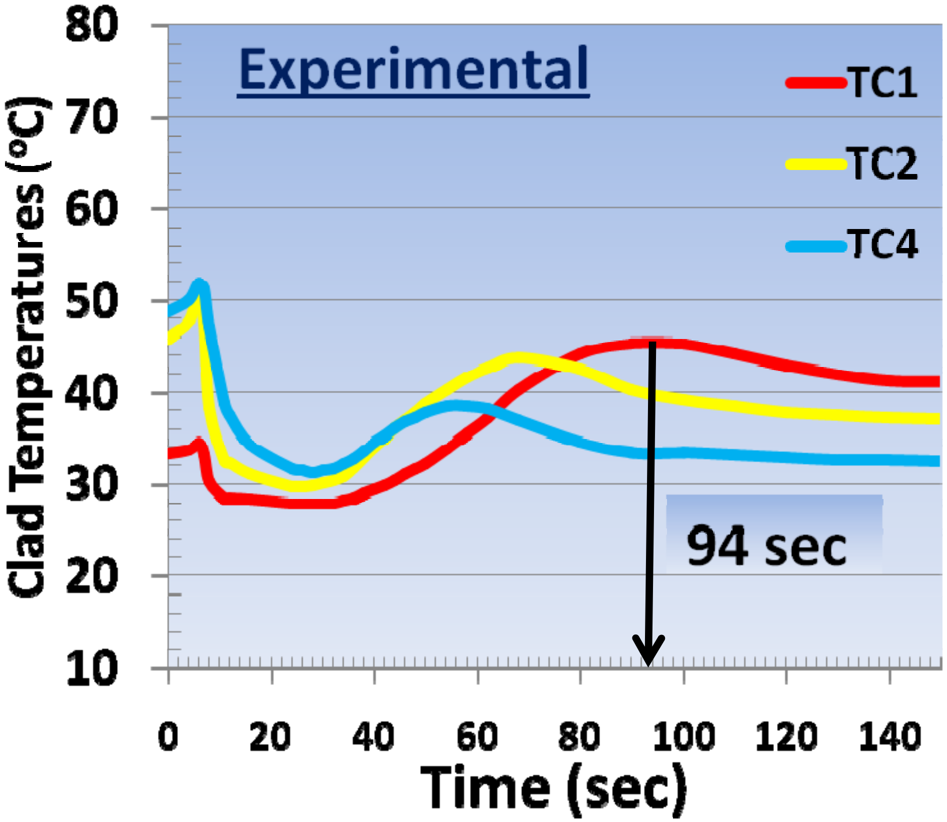


P=5 MW *Total reactor operation time is 5 minute before scram*

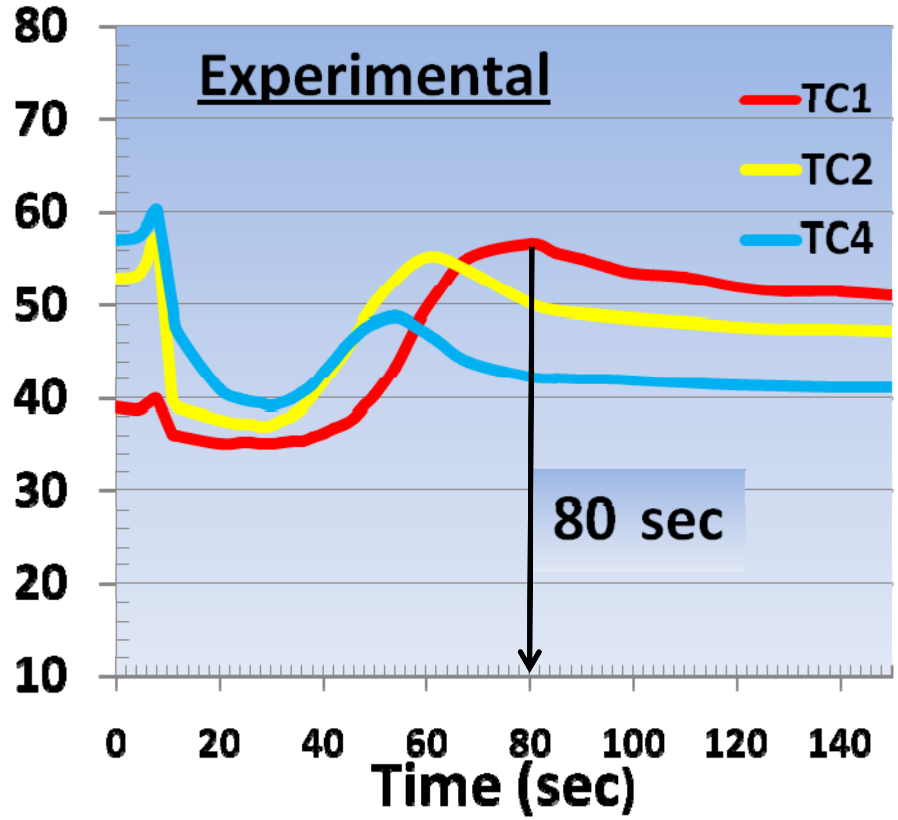
Initial flow rate: 750 m^3/h (reverse flow)

They are compatible

5 Minutes 5 MW Power Operation
Pool Water: 23 ^{o}C

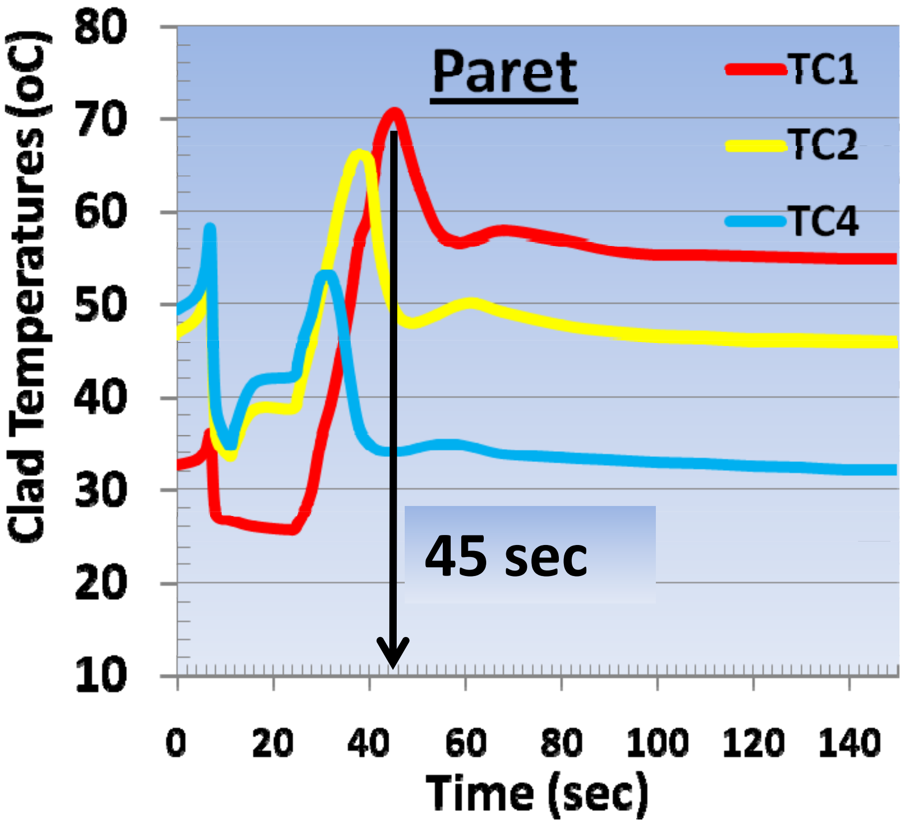


2 Hours 5 MW Power Operation
Pool Water: 29.5 ^{o}C



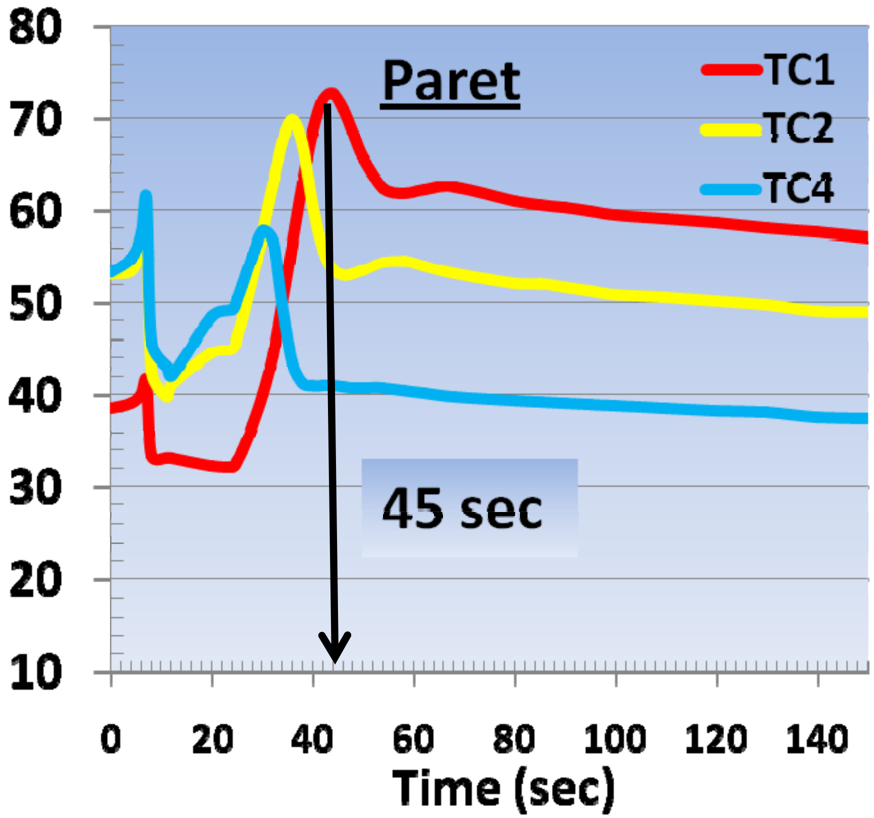
5 Minutes 5 MW Power Operation

Pool Water :23 °C

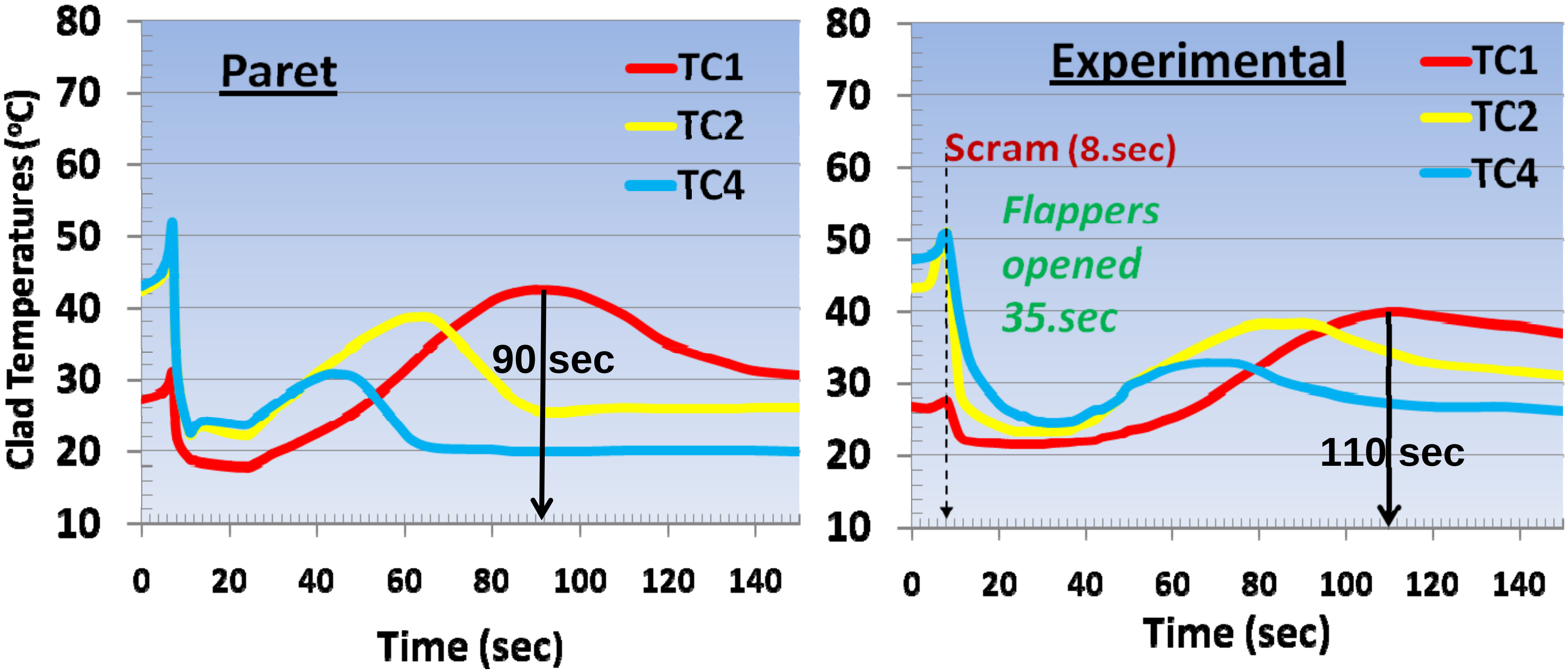


2 Hours 5 MW Power Operation

Pool Water :29.5 °C



Decreased Decay Heat

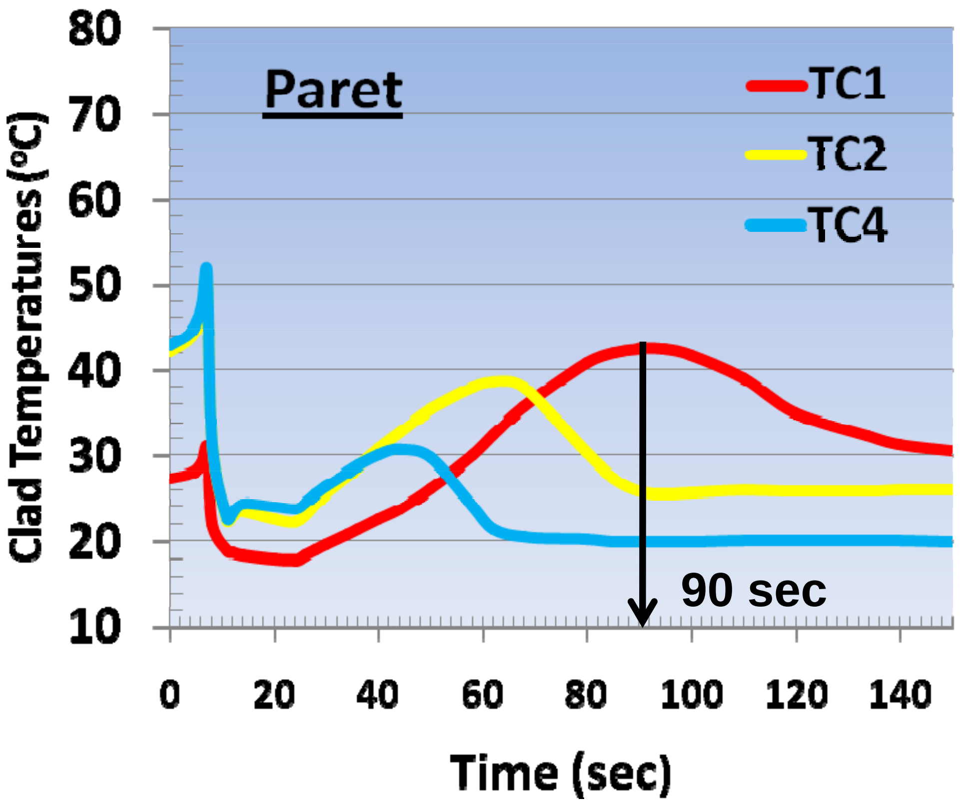


For Paret Calculations : P=5 MW , Reactor operation time before scram 5 minutes at **1 MW** , **(to decrease decay heat at the calculations)**

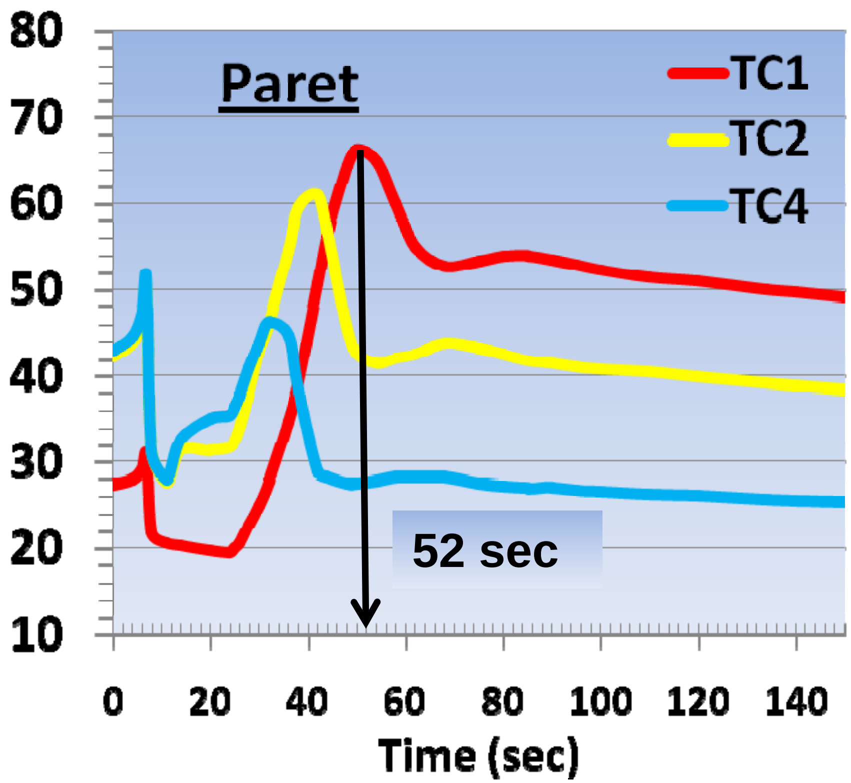
Initial Flow Rate: **750 m^3/h**

Pool Water Temperature: **17 ºC**

Decreased Decay Heat



5 Minute Power Operation at
1 MW and
5 MW before SCRAM



5 Minute Power Operation
at 5 MW
before SCRAM

Pool water temperature: 17ºC

Conclusions:

- **Residual decay heat calculation and the natural convection modeling for narrow rectangular channels of PARET code are not quite realistic.**

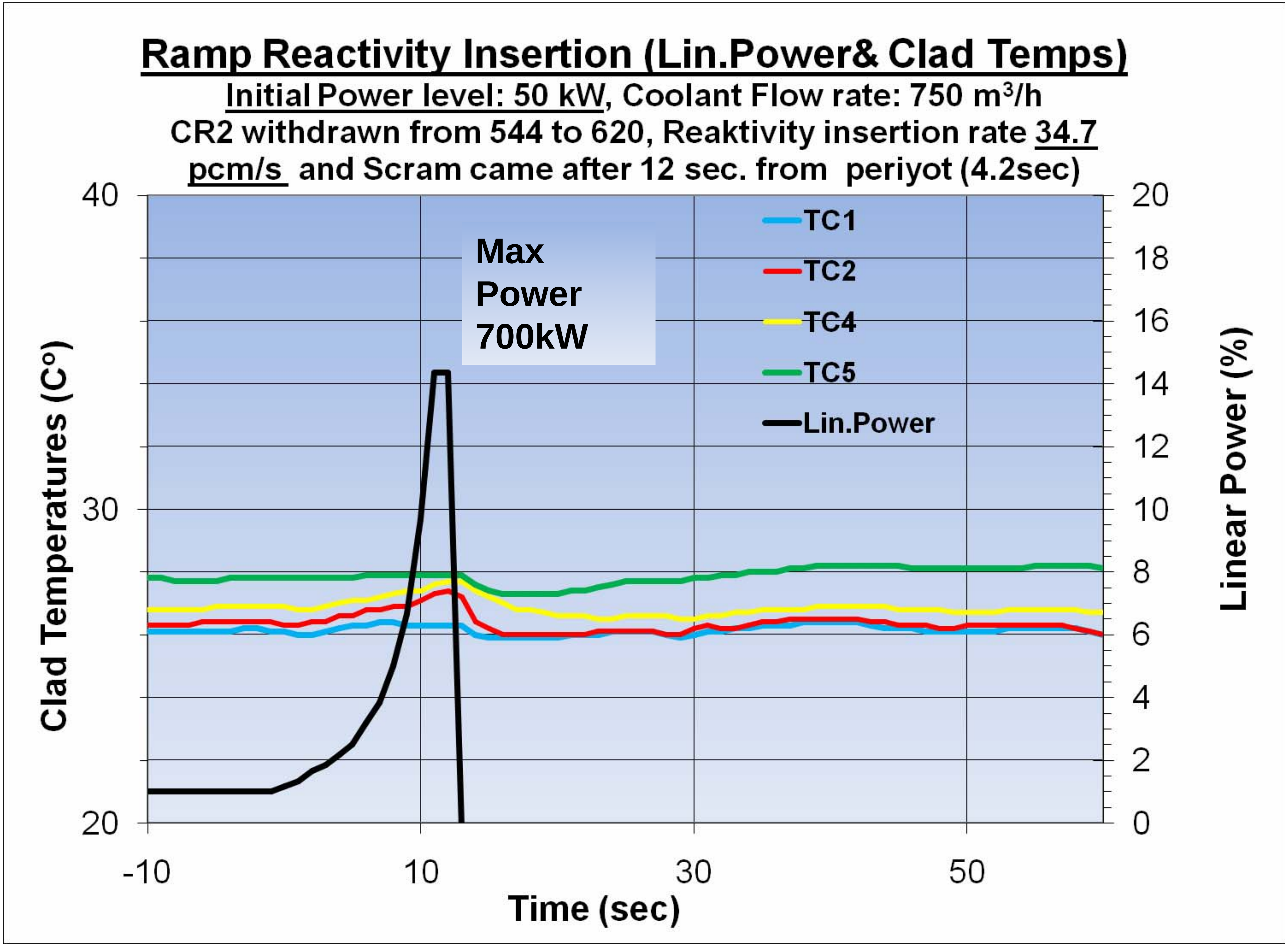
- **PARET uses the standard fission-product decay heat curve for uranium-fuelled thermal reactors published by the American Nuclear Society as a proposed standard (ANS-5.1/N18.6).**

- **For the calculation of the residual decay heat, special attention must be given to the fact that**
- *"Approximately one-half of the decay heat is due to gamma radiation with energies in the range of about 0.2-2.0 MeV.*
- *The e-folding length for 1 MeV gamma radiation in aluminum is 6 cm, i.e., the source gamma intensity is attenuated to 1/e of its original value after passing through 6 cm of aluminum.*

- *This corresponds to a penetration of 40-50 fuel plates and hence shows that a significant portion of a given level of fuel element decay heat will be deposited at the* ***outside of the fuel element".***

- **Realistic calculations can be done for LOFA and LOCA analysis by using the decreased (1/2) values of decay heat generation curve of ANS.**

Thank you very much

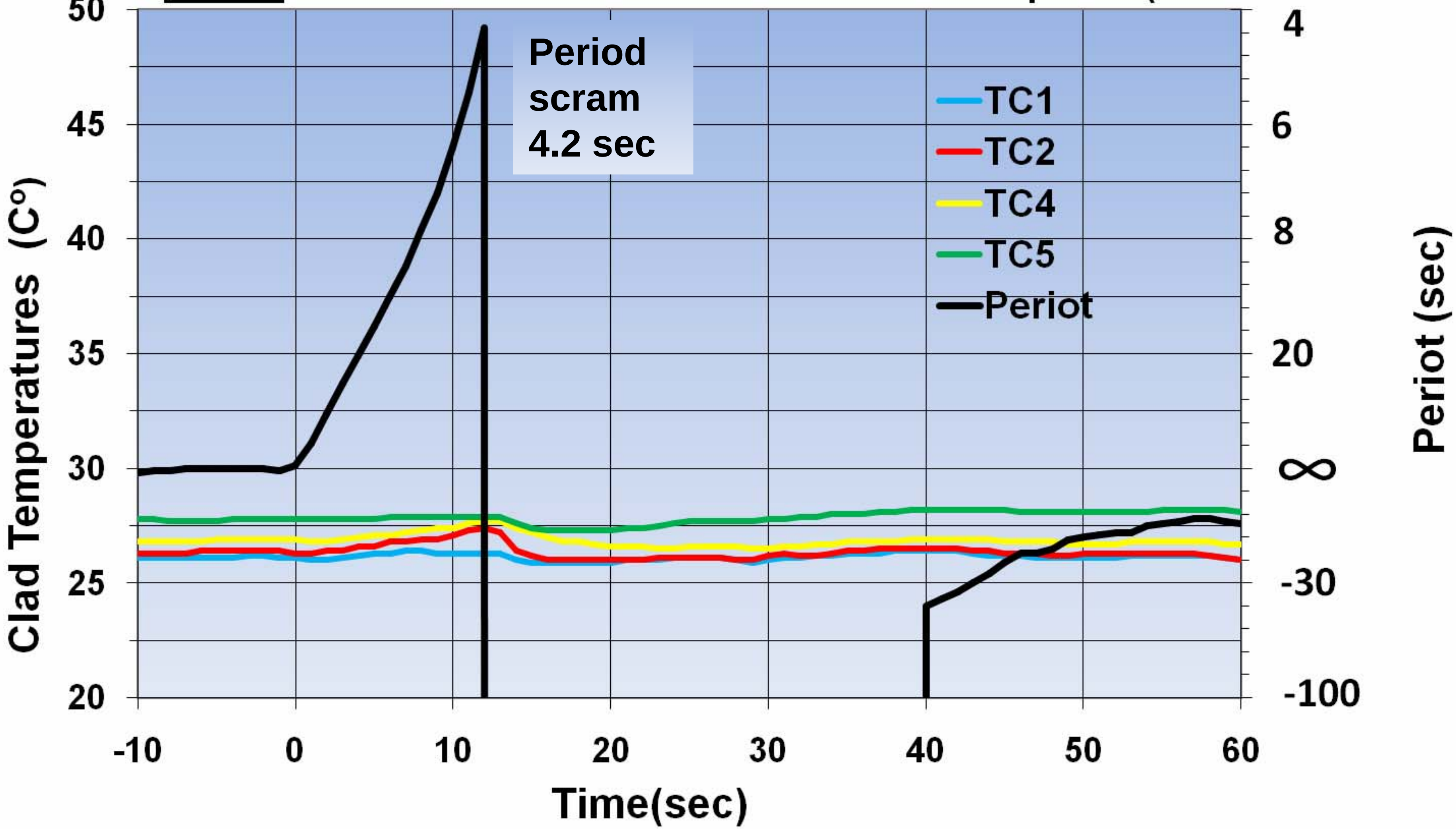


Ramp Reactivity Insertion (Lin.Power& Clad Temps)
Initial Power level: 50 kW, Coolant Flow rate: 750 m³/h
CR2 withdrawn from 544 to 620, Reaktivity insertion rate 34.7 pcm/s and Scram came after 12 sec. from periyot (4.2sec)
Max Power 700kW
TC1
TC2
TC4
TC5
Lin.Power
Clad Temperatures (C°)
Linear Power (%)
Time (sec)
40
30
20
20
18
16
14
12
10
8
6
4
2
0
-10
10
30
50

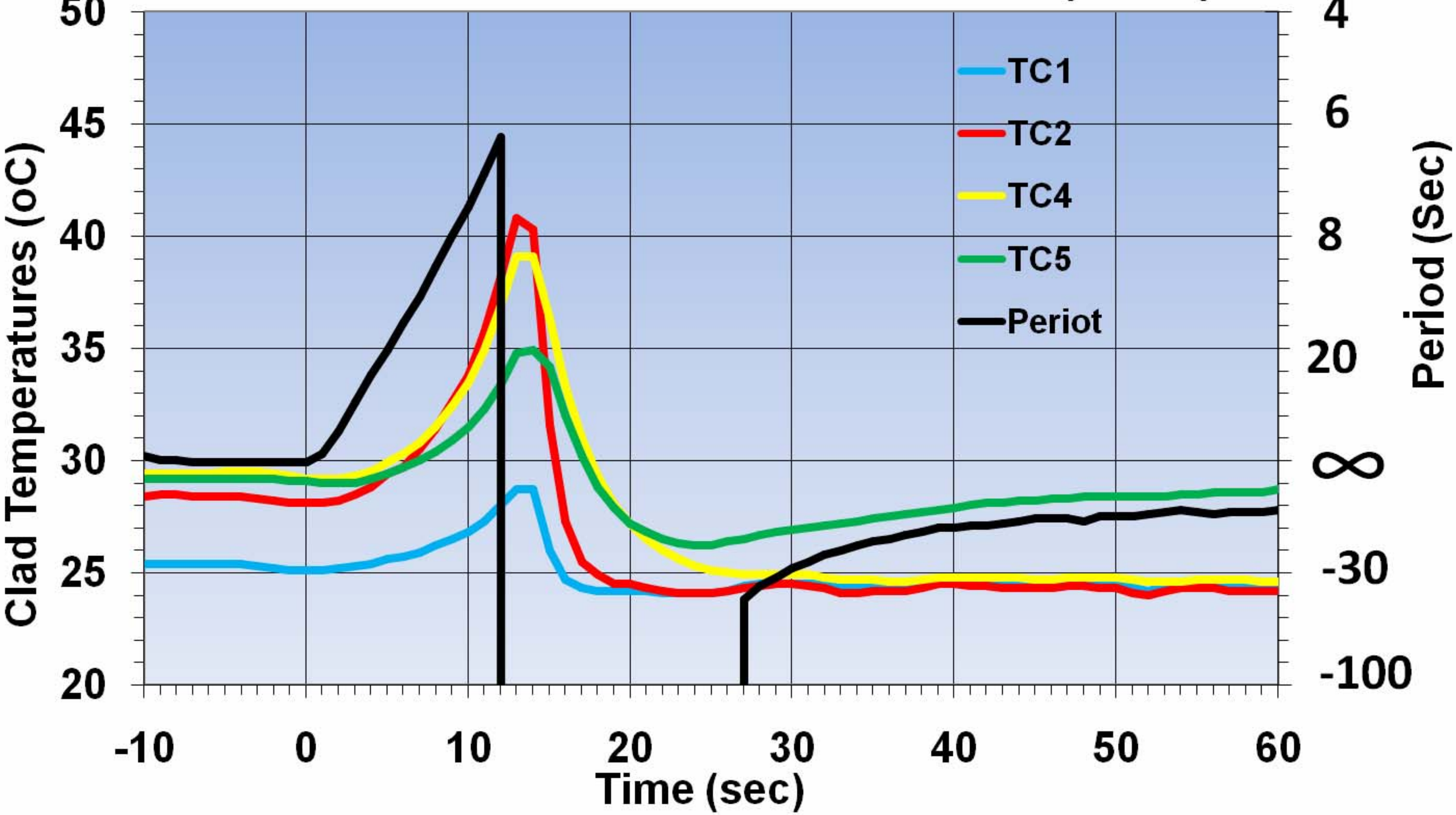
Ramp Reactivity Insertion(Periot&Clad Temps)

Initial Power level: 50 kW, Coolant Flow Rate: 750 m^3/h

CR2 withdrawn from 544 to 620, Reactivity insertion rate: 34.7 pcm/s and after 12 seconds Scram came from periot (4.2sec)



Ramp Reaktivity Insertion (Clad Temps& Periot)
Initial Power 1 MW, Flow rate: 730m3/h
Reactivity insertion rate 30 pcm/s and after 13 sec Scram came from Max.Power (5MW) .



Ramp Reaktivity Insertion (Lin.Power& Clad Temps)

Initial power level 1MW, Cooland Flow Rate: 730 m3/h

CR2 withdrawn from 478 to 550'ye çekildi. Reaktivityinsertion rate

30 pcm/s and after 13 sec SCRAM came from Max.Power (5 MW) .