Safety Reevaluation of Indonesian MTR-Type Research Reactor

by:

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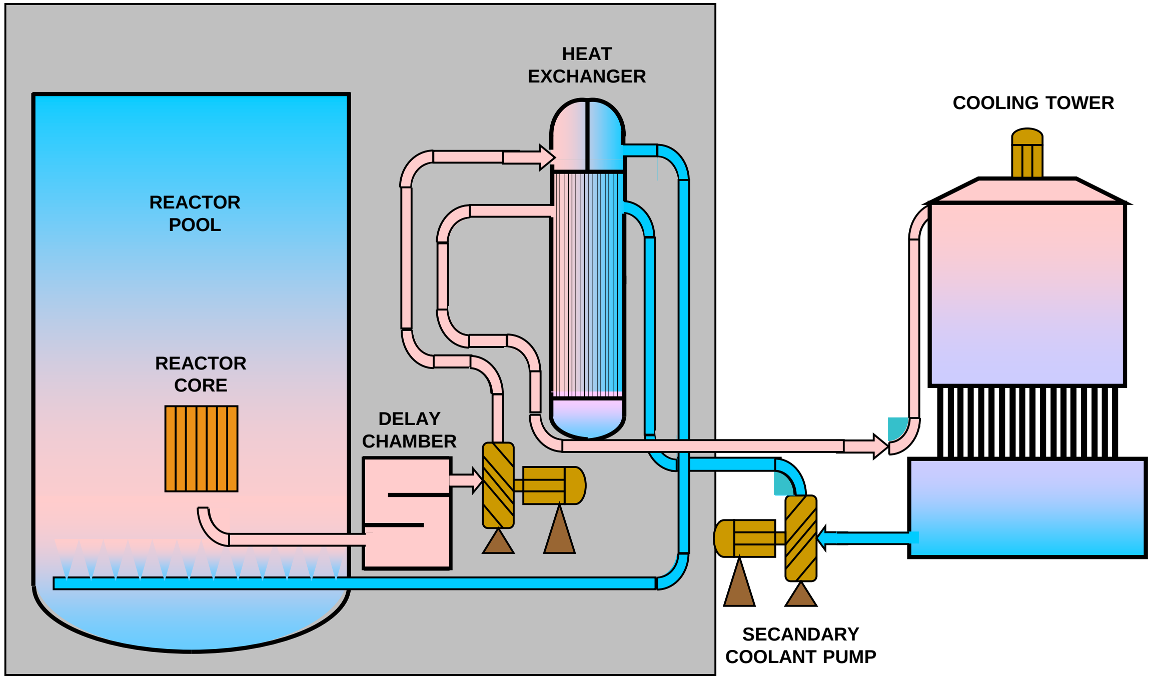
DESCRIPTION OF RSG GAS

- MTR Pool type Research Reactor
- Nominal power: 30 MW
- Cooling mode:
  - Downward forced convection for high power operation
  - Natural convection for low power
- Fuel material: U_3Si_2-Al
- 40 Fuel Elements
- 8 Control elements
- Reflector: Beryllium
- Moderator: H_2O
- Enrichment: 19.75%
- Cladding material: AlMg2
- Absorber: AgInCd

CONTENTS

- Loss Of Flow Accident (LOFA) of RSG GAS.
- Loss of offsite power of RSG GAS
- Inadvertent control rods withdrawal



SAFETY CRITERIA

- Maximum fuel design temp.: 200°C
- Maximum clad design temp.: 145°C
- Min. Safety Margin against Flow Instability (S) for anticipated transient: 1.48

$$S = \frac{\eta_C}{\eta_E}$$

$$\eta(z) = \frac{[T_s(z) - T_c(z)]V(z)}{q''(z)}$$

where:

η_E: experimental Bubble Detachment Parameter of 22.1 cm^3K/Ws

q'': Heat flux, w/cm^2

V : Coolant velocity, cm/s

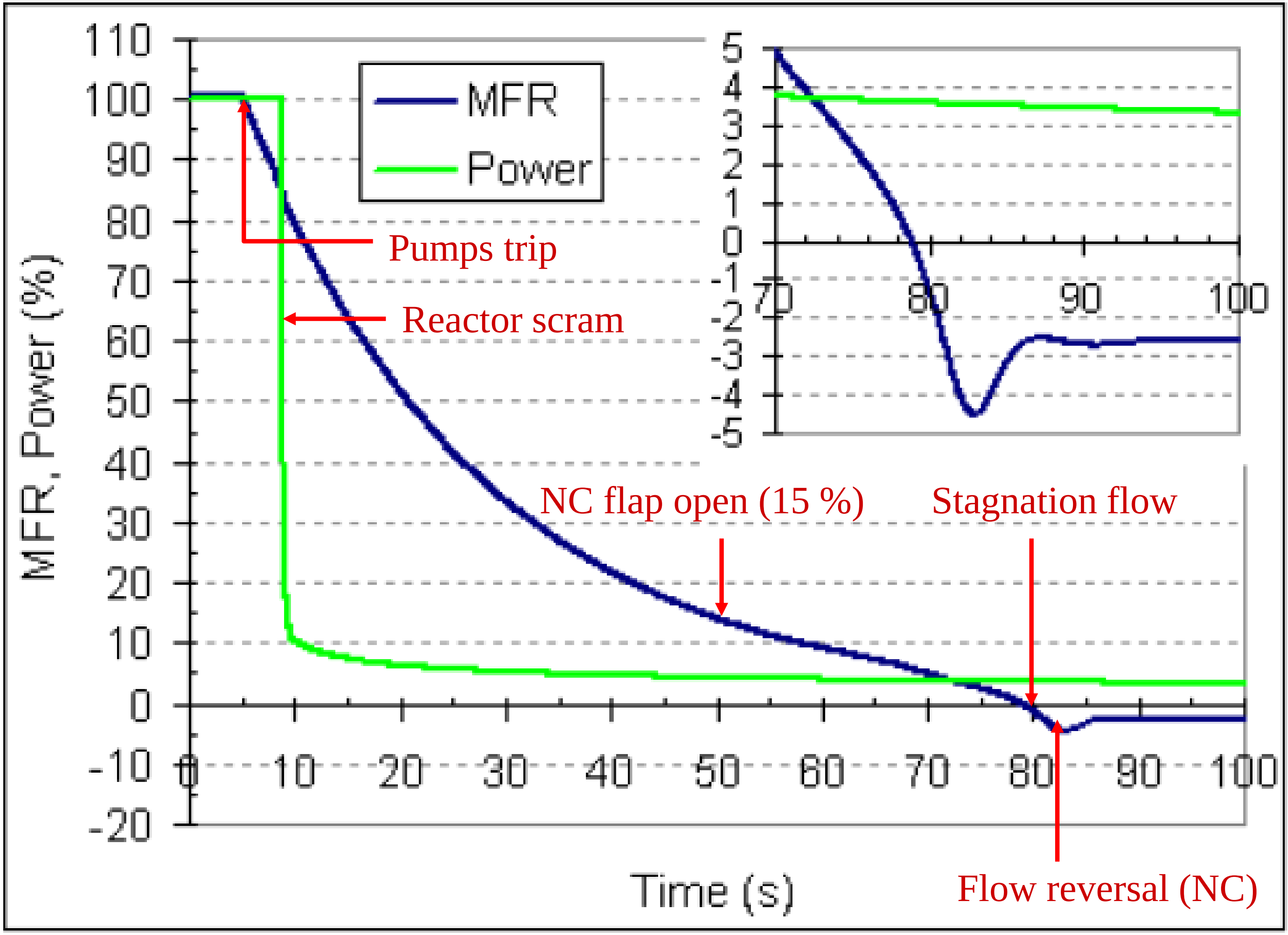
z : distance from coolant inlet channel, cm

T_s, T_c: Saturated temp. and coolant bulk temp., K

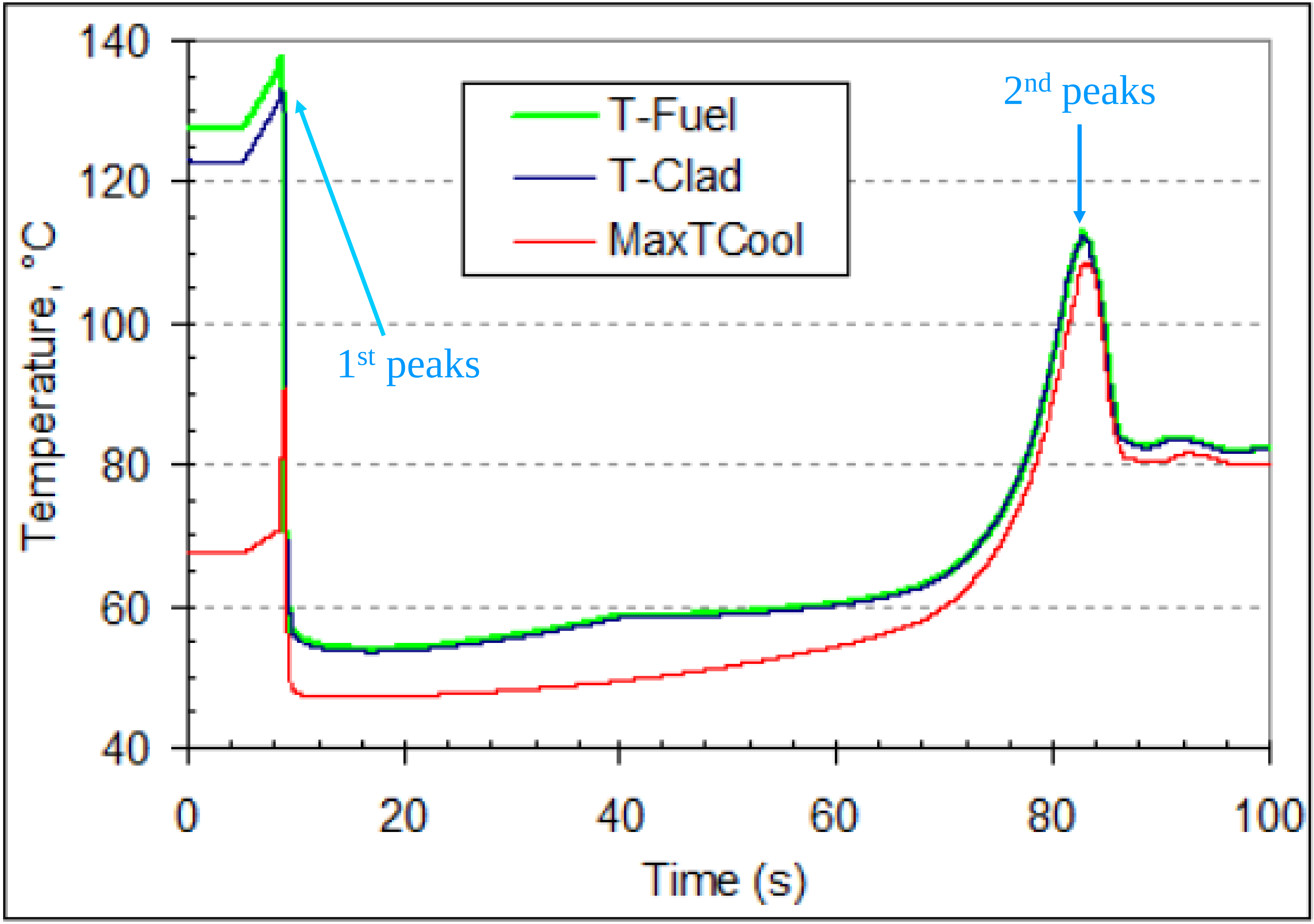
LOSS OF FLOW ACCIDENT (LOFA)

- Initial power: nominal 30 MW
- Cooling mode: downward forced flow
- Initiation: all primary pumps simultaneously off
- Trip signal: low flow trip signal (80% of nominal flow)
- Transient starts at t=5 s
- Computer code: PARET/ANL

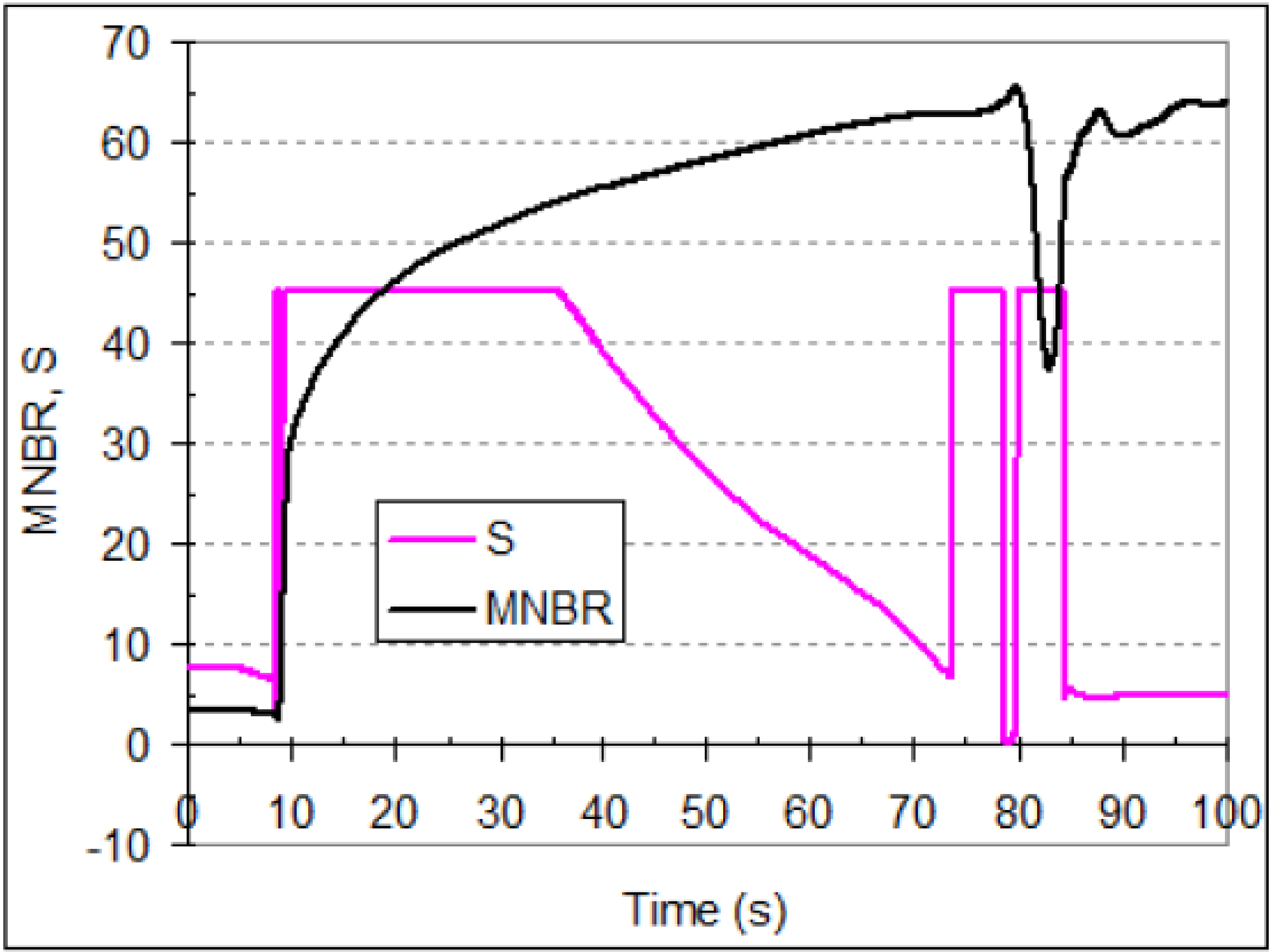
RESULTS: LOFA



RESULTS: LOFA



RESULTS: LOFA



SUMMARY: LOFA

Time (s)	Parameter / phenomenon	value
Steady state		
0 – 5.0	Max . Fuel temp., °C	127.41
	Max . Coolant temp. At hot channel, °C	67.56
	Min. Flow stability parameter (S)	7.46
Transient conditions (first peak)		
8.45	Max. Fuel temp., °C	137.38
8.82	Min. Flow stability parameter (S)	2.64
8.85	Reactor scram	
8.89	Max . Coolant temp. At hot channel, °C	90.66
Second peak		
78.86	Stagnant flow	0.0
82.76	Max. Fuel temp., °C	112.69
83.26	Max . Coolant temp. At hot channel, °C	108.64
Stable condition with natural convection		
86.00	Core power, MW	1.04
	Max . Fuel temp., °C	84.26
	Max . Coolant temp. At hot channel, °C	82.92
	Mass flow rate of natural circulation, % of nominal MFR	2.66

CONCLUSIONS: LOFA

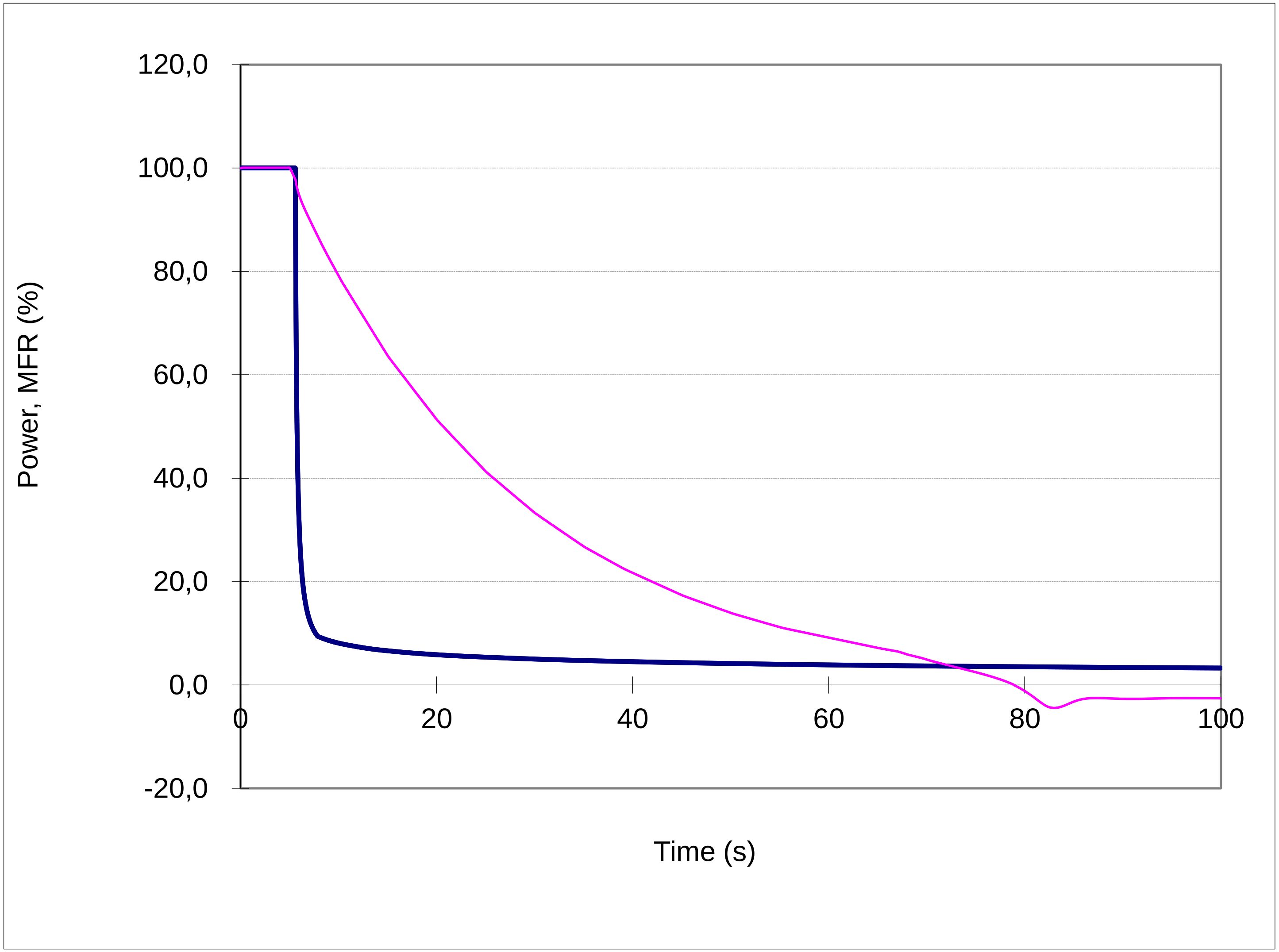
- Reactor can be maintained secured during loss of flow accident. No safety parameter exceeds the design limits. Both fuel and clad temperature can be maintained below their design limits of 200 °C and 145 °C, respectively. As for flow stability parameter, the S value is kept above 1.48 suggesting that the condition leading to flow instability is unseen.

LOSS OF OFFSITE POWER (LOOP)

LOSS OF OFFSITE POWER (LOOP)

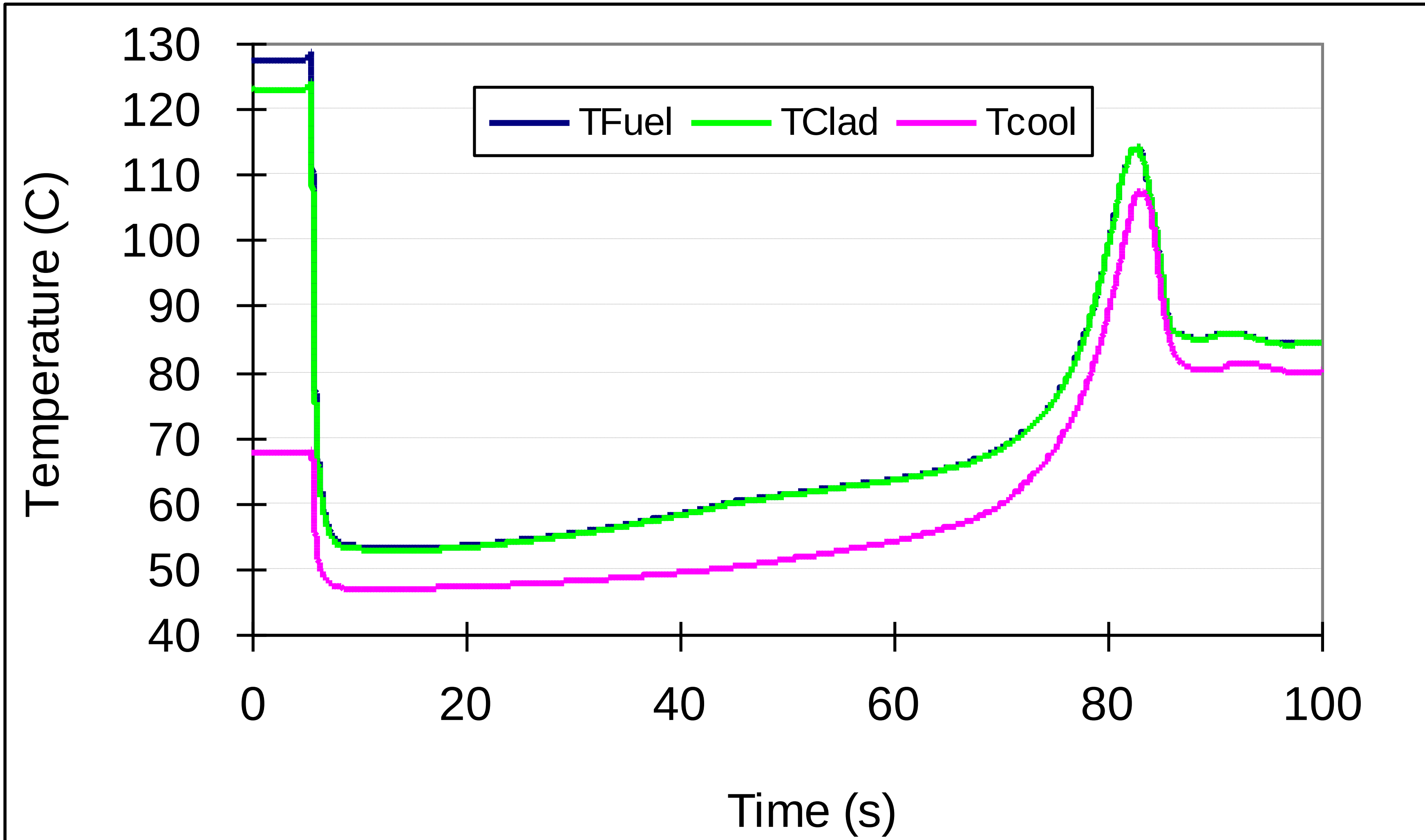
- Initial power: nominal 30 MW
- Cooling mode: downward forced flow
- Initiation: all primary pumps and reactor trip at the same time due to loss of power
- Pump coast down flow and natural circulation cool down the remining decay heat.
- Transient starts at t=5 s
- Computer code: PARET/ANL

LOSS OF OFFSITE POWER (LOOP)



Time history of power and mass flow rate (MFR)

LOSS OF OFFSITE POWER (LOOP)



Time history of fuel, clad and coolant temperatures

SUMMARY: Loss of off-site power

Time (s)	Parameter / phenomenon	value
Steady state		
0 – 5.0	Max . Fuel temp., °C	127.41
	Max . Coolant temp. At hot channel, °C	67.56
	Min. Flow stability parameter (S)	7.46
Transient conditions (first peak)		
5.59	Max. Fuel temp., °C	128.62
5.59	Min. Flow stability parameter (S)	7.27
5.50	Reactor scram	
5.61	Max . Coolant temp. At hot channel, °C	68.0
Second peak		
78.91	Stagnant flow	0.0
82.86	Max. Fuel temp., °C	112.08
83.01	Max . Coolant temp. At hot channel, °C	108.08
Stable condition with natural convection		
86.00	Core power, MW	0.98
	Max . Fuel temp., °C	82.10
	Max . Coolant temp. At hot channel, °C	80.07
	Mass flow rate of natural circulation, % of nominal MFR	3.28

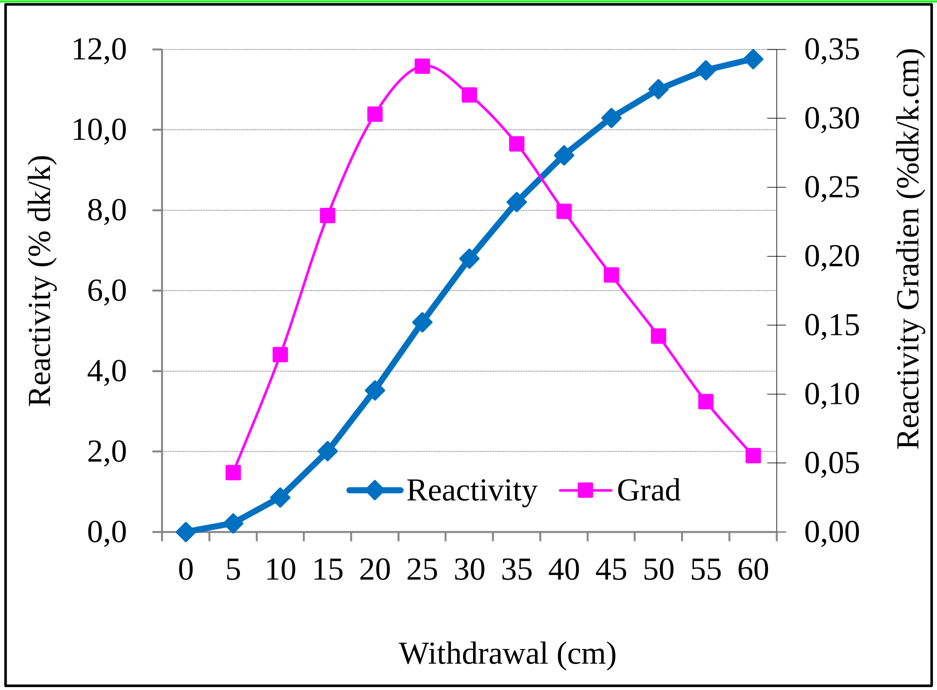
RIA: INADVERTENT CONTROL ROD WITHDRAWAL

INADVERTENT CONTROL ROD WITHDRAWAL (RIA)

- Initial power: 1 MW
- Initiation: inadvertent CRs withdrawal → fast (+) reactivity into the core
- Single failure → 1st trip signal (Floating Limit Value) fails to scram
- 2nd trip signal (Over Power=34.2 MW) eventually scrams the Rx.
- Delay time from trip signal to CR Drop: 0.5 s.
- Downward forced normal cooling
- Reactivity insertion rate: 2.2×10^{-4} /s (calculated with MCNP5)
- Transient starts at t=5 s

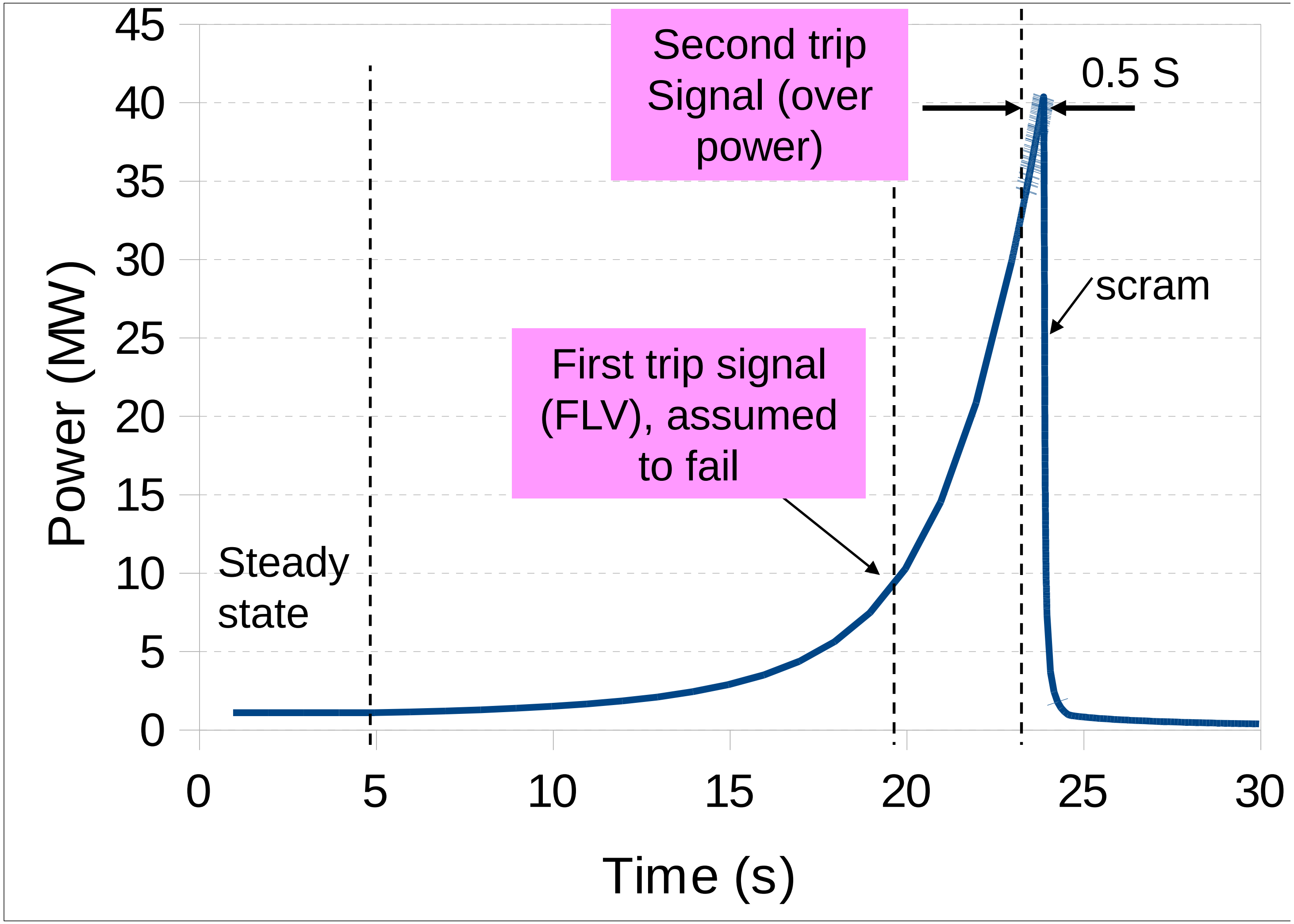
REACTIVITY INSERTION RATE OF 8 CONTROL ELEMENTS

- Calculated with MCNP5 code
- The reactivity profile of CEs forms an ***S*** curve, with maximum gradient is located in the midplane, where neutron flux is maximum.



- Maximum reactivity gradient = *0.338 %dk/k.cm*.
- With the average CEs movement speed of *0.0564 cm/s*, the maximum reactivity insertion rate of 8 CEs is $1.91x10^{-4}$ *dk/k.s*.
- For safety analysis, safety factor of *15%* is added, therefore maximum reactivity insertion rate of 8 CEs is $2.19x10^{-4}$ */s*. (Note: $2.2x10^{-4}$ */s* in SAR CHAP. V)

EVENT SEQUENCE



Results: Effect of Delay Time

Delay time (s)	Max. Power (MW)	Max. Fuel Temp (C)	Max. Clad Temp (C)	Max. Cool Temp (C)	S
0.5	40.265	185.32	138.04	98.95	2.249

•all safety parameters (*T fuel*, *T clad* & *S*) meet the design criteria.

Future analyses: BDBA

- Anticipated Transient Without Scram (ATWS)
  - ULOF: Unprotected Loss of Flow (RELAP5 code)
  - UTOP: Unprotected Transient Over Power (RELAP5 code)
- Loss of Coolant Accident (LOCA) → RELAP5/SCDAPSIM
- Blockage Cooling Channel → CFD code (Fluent, Saturne)

Conclusions

All three simulated accidents have confirmed that all safety parameters can be maintained secured. The fuel and clad temperatures can be maintained well below safety criteria of 200° C and 145 ° C, respectively. In addition, the safety margin against flow instability (S) is kept well above the criterion of 1.48.

Thank You
Terima kasih