

# On the Experience of the Start-up Measurements at the Temelín, Unit 1, with TVSA-T Fresh Fuel Loading

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- Experimental equipment
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# Introduction

After 4 years of extensive development program, licensing and plant documentation modification effort we finally got the opportunity to start the plant with Temelín Unit 1 - first time with TVSA-T.

- October 8, 2010 – first criticality, HZP
- **October 8-11, 2010 – Low power start-up tests**
- October 17, 2010 – 100% power

Some new (modified) tests; unusual experimental techniques; first-of-a-kind combination of calculation and experimental methods;  
Expert support team

# Purpose of start-up tests, criteria

Demonstrate compliance with core design parameters and safety analyses

Assess the measured results against criteria

**Safety criteria** – compare the real value with the limiting values used in safety analysis

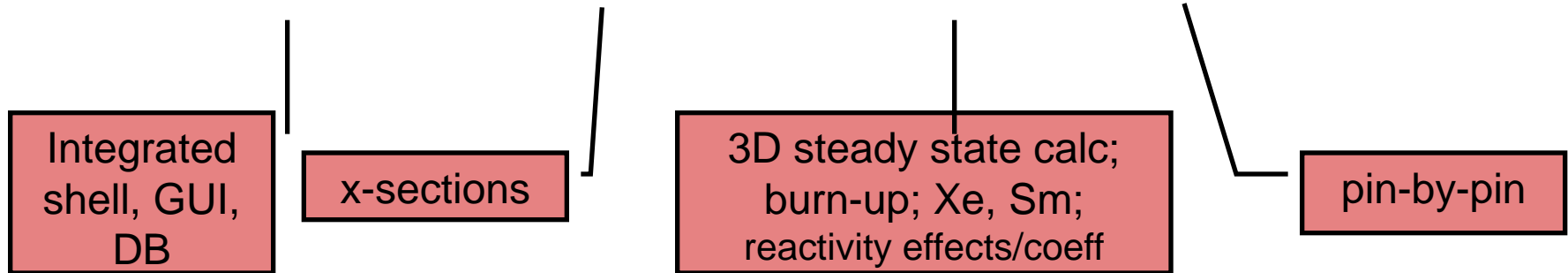
**Design criteria** – compare the real values with the predicted ones

**Realization criteria** – confirm the test realization based on (approved) procedure and acquisition of data necessary for its evaluation

# Preparation to the tests: calculations

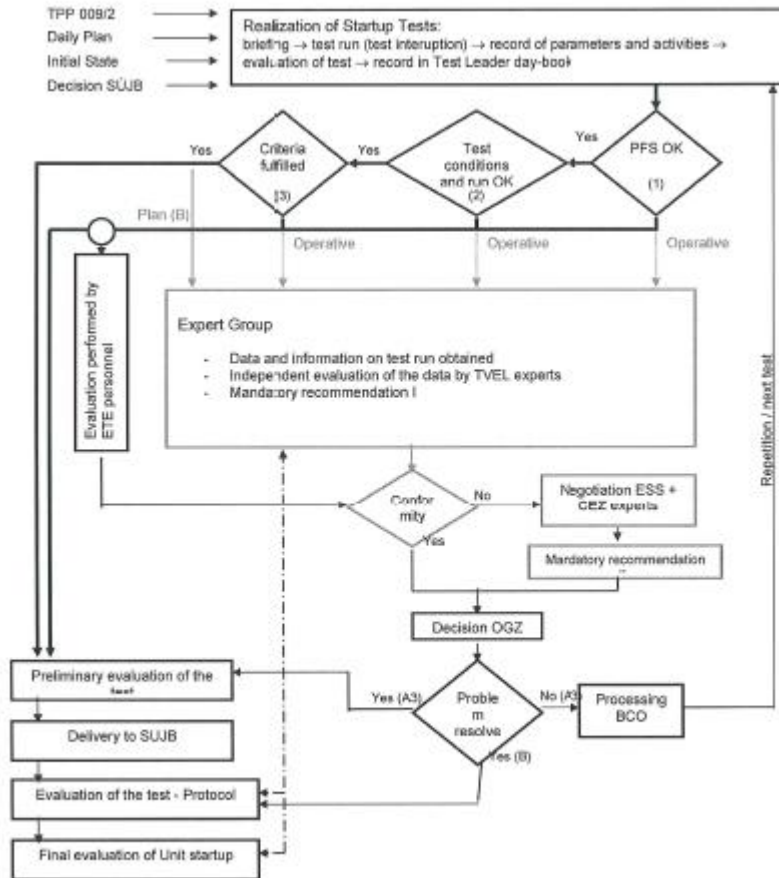
Calculation results – by KASKAD complex

KASKAD=TVS-M+BIPR-7A+PERMAK-A+...



Design calculations & parameters for experimental data treatment

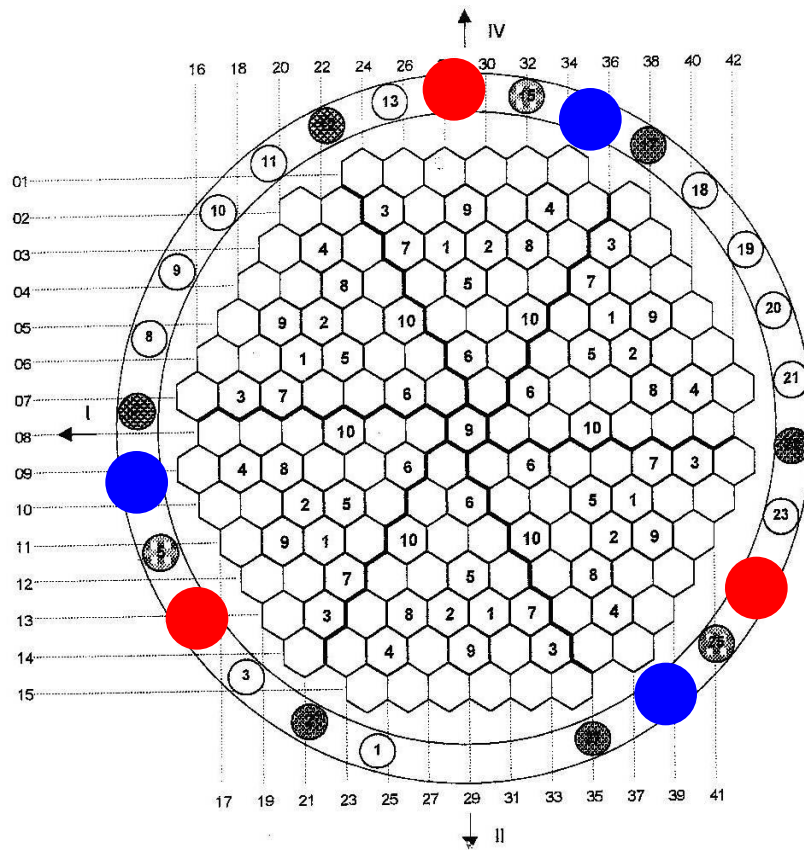
# Preparation to the tests: expert support team



Support and independent supervision of the start-up

- ČEZ, a.s.
- UJV, a.s.
- VUJE, a.s.
- “TVEL”, JSC
- RRC “Kurchatov Institute” (KI)
- “OKBM”, JSC

# Experimental Equipment



## Physics Startup Control Board

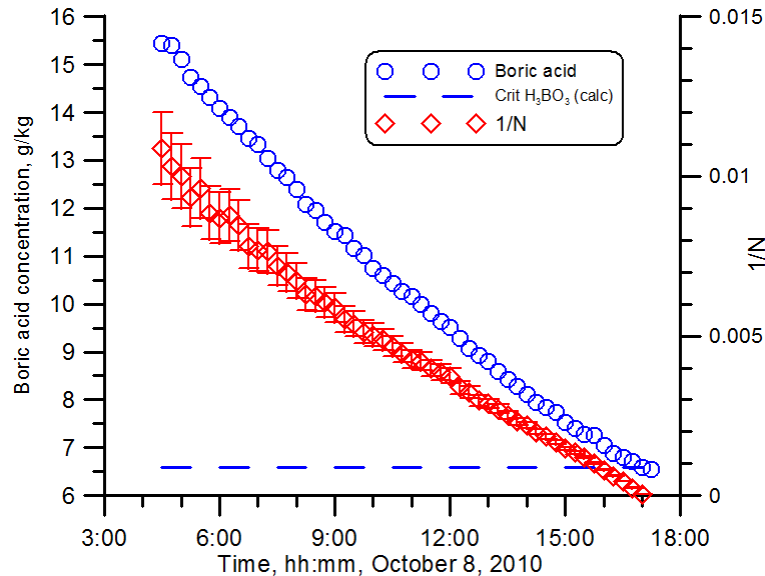
(VUJE a.s.) - independent complex system for Physics Startup tests control and evaluation.

Consist of measuring, data processing and evaluating parts

III → Inputs:

- 3 gamma-compensated ion chambers in 120 symmetrical pos. **No. 4,14, 24**
- 3 wide range fission chambers in 120 symmetrical pos. **No. 6,16,26** (backup signals for reactivity)
- selected data from technology

# Exp result: First criticality



predicted ( $\pm 0,10$ )

$C(\text{H}_3\text{BO}_3) = 6,58 \text{ g/kg}$

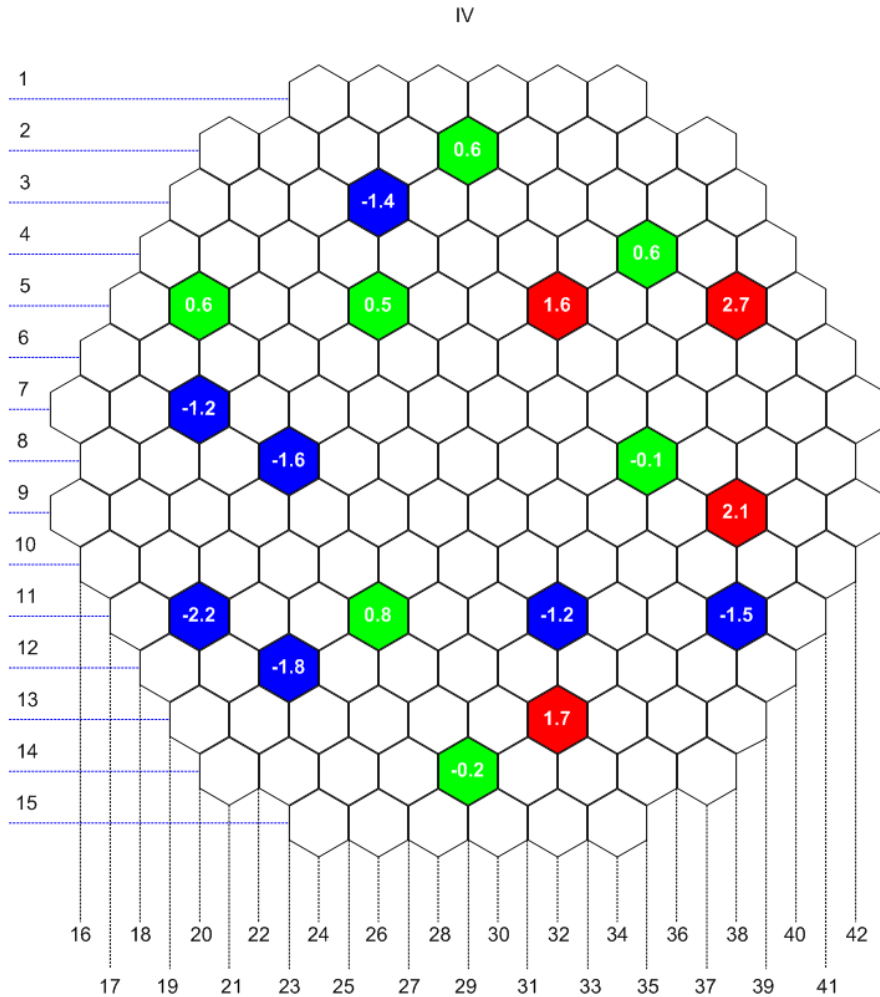
- HZP
- H10=140 steps
- $T_{\text{inlet}} = 280,0 \text{ }^\circ\text{C}$
- $P = 15,6 \text{ MPa}$

measured ( $\pm 0,05$ )

$C(\text{H}_3\text{BO}_3) = 6,58 \text{ g/kg}$



# Exp result: symmetry assessment



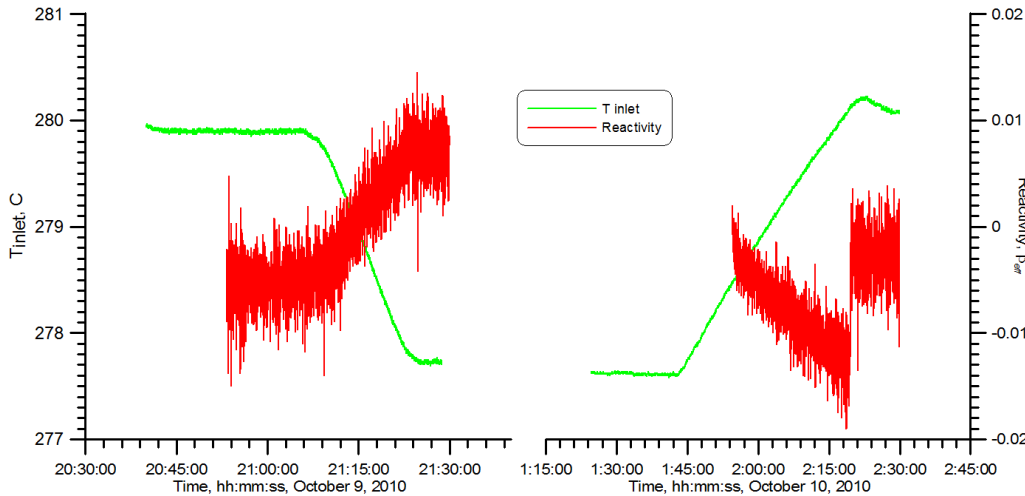
$$\varepsilon_{ik} = \left| \sqrt{\rho_{ik} / \bar{\rho}_k} - 1 \right|$$

Design criterion:

$$\varepsilon_{ik} \leq 0,11(11\%)$$

Result by ČEZ-ETE  $\approx$   
Result by RRC KI

# Exp result: ITC, MTC



Safety criterion:  
MTC less than 0

Design criterion:  
 $\Delta ITC \leq 3,5 \text{ pcm}/^\circ\text{C}$

Realization criterion  
 $\Delta \uparrow \downarrow ITC \leq 3 \text{ pcm}/^\circ\text{C}$

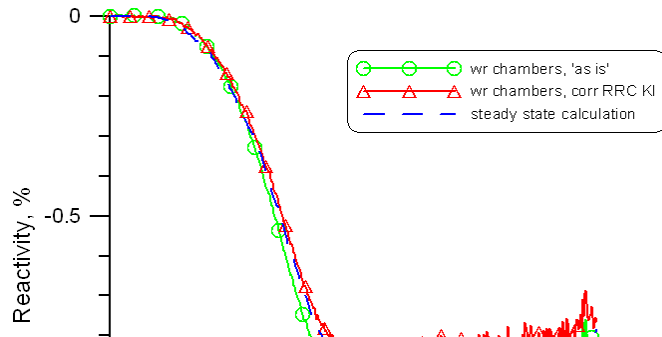
RRC KI assessment of ITC, %/°C	ČEZ-ETE assessment of ITC, %/°C	RRC KI assessment of MTC, %/°C	ČEZ-ETE assessment of MTC, %/°C
↓T $-(4,3 \pm 0,4) \times 10^{-3}$	↓T $-(4,3 \pm 0,2) \times 10^{-3}$	↓T $-(1,7 \pm 0,4) \times 10^{-3}$	↓T $-(1,7 \pm 0,2) \times 10^{-3}$
↑T $-(4,5 \pm 0,5) \times 10^{-3}$	↑T $-(3,5 \pm 0,2) \times 10^{-3}$	↑T $-(1,9 \pm 0,5) \times 10^{-3}$	↑T $-(0,9 \pm 0,2) \times 10^{-3}$

Predicted:

$$ITC = -6,7 \times 10^{-3}$$

$$MTC = -4,1 \times 10^{-3}$$

# Exp result: single bank worth



RCCA Bank	Worth, measured by ČEZ-ETE, [pcm]	Worth, measured by RRC KI, [pcm]	Calc worth [pcm]
1. bank	531	556	607
2. bank	522	537	607
3. bank	787	835	858
4. bank	774	850	858
5. bank	463	475	471
6. bank	245	259	233
7. bank	565	578	646
8. bank	561	567	646
9. bank	883	935	949
10. bank	425	435	416
Sum of Banks	5762	6027	6291

Test by DRWM method used for PWR plants, modified by VUJE for Temelin (used from 2005)

Unusual for VVER practice

Two independent method of data processing [spatial correction]

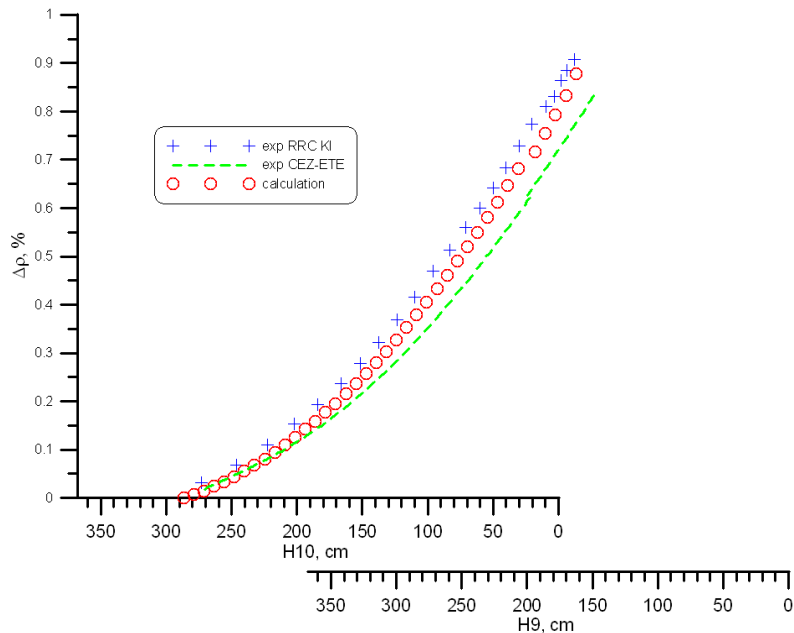
VUJE method:

- static correction ← BIPR-7A
- dynamic correction ← DYN3D

RRC KI method:

dynamic correction ← NOSTRA

# Exp result: diff and integral worth boron reactivity coefficient



Design criterion:  
measured to predicted integral  
worth deviation is  $\leq \pm 15\%$

Safety criterion:  
Boron acid reactivity coefficient  
(- 970 to - 2400) pcm/(g/kg)

Design criterion:  
measured to predicted deviation  
of boron acid reactivity coefficient  
is  $\leq \pm 15\%$

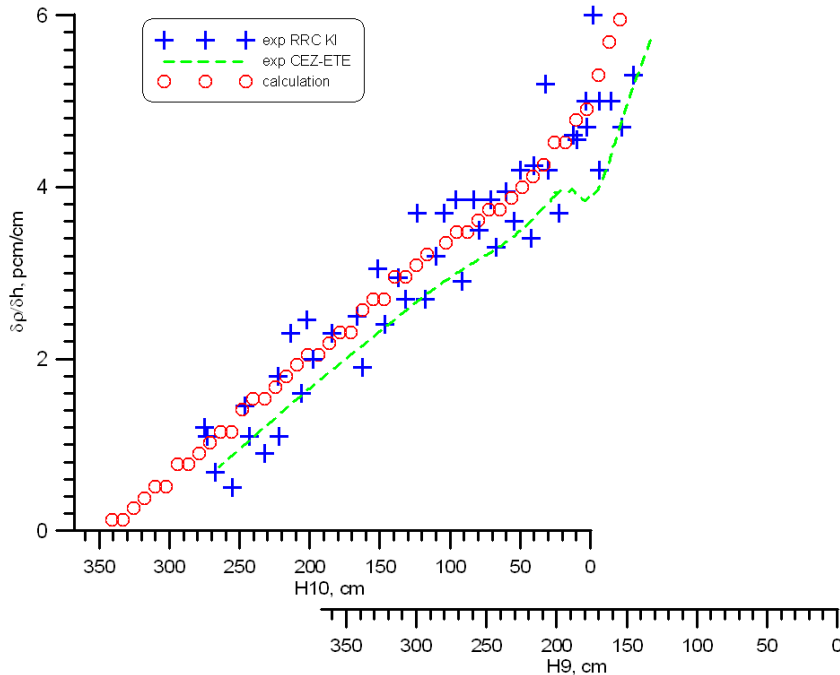
Boron acid reactivity coefficient

ČEZ-ETE - 1,99 %/(g/kg)

RRC KI - 2,02 %/(g/kg)

predicted - 2,11 %/(g/kg)

# Exp result: diff and integral worth



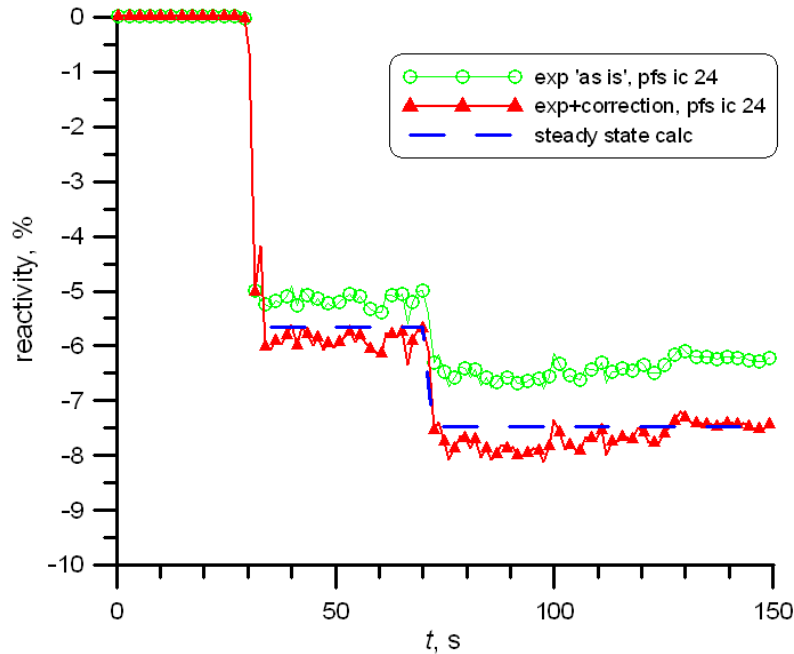
Safety criterion:  
measured differential worth  
is  $< 0,07 \beta_{ef}/\text{step}$

Design criterion:  
measured to predicted differential  
worth deviation in the measured  
interval is  $\leq \pm 20 \%$ ;

Measured data from wide range fission chambers signals

Noise  $\rightarrow$  excessive uncertainties

# Exp result: Emergency Shutdown Efficiency



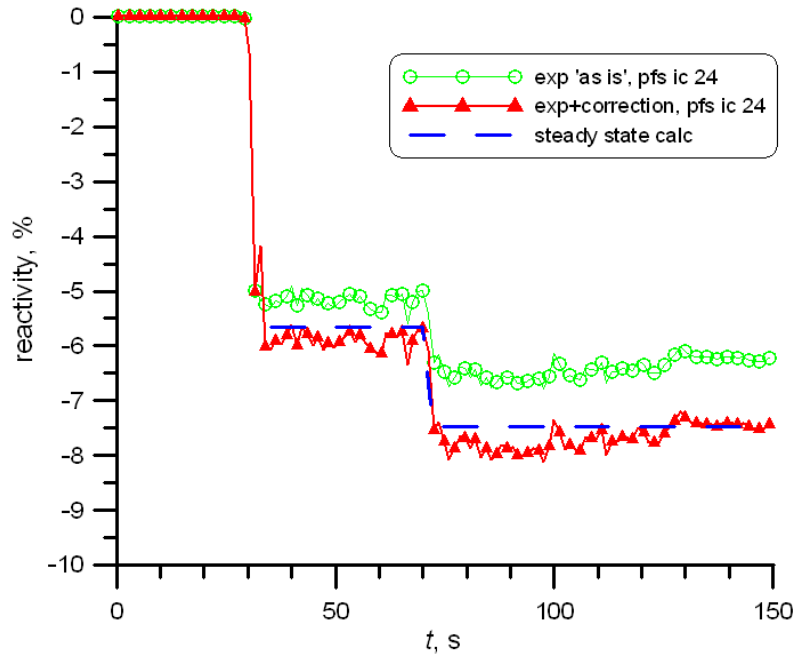
Measured with PFS ic24 signal

## Safety criterion:

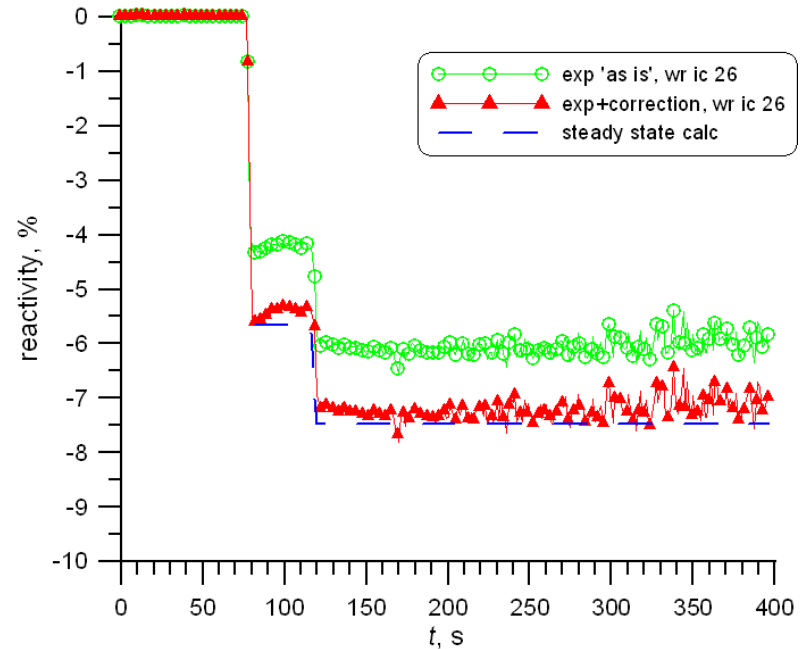
integral rod worth of  
emergency trip system  
with one worst stuck rod  
fully withdrawn is  
> 3300 pcm

No any spatial  
corrections assumed

# Exp result: Emergency Shutdown Efficiency



Measured with PFS ic24 signal



Measured with wide range chamber 26 signal

# Conclusions

- Start-up tests at Unit 1, Temelín NPP fuel loading with fresh TVSA-T have confirmed its characteristics
- New experience with Czech-Russian cooperation for start-up test was positive
- Expert team has developed some recommendations for further Temelín tests

*“Despite problems occurred and assessed during start-up, the test results demonstrate acceptability of further operation ... It is concluded, that the start-up test results demonstrated compliance with core design parameters and safety analyses, [...] and therefore the operation is safe”*



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