NURESAFE WP1.3
BWR ATWS WITH UNCERTAINTY QUANTIFICATION

Status of CTF input deck

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Outline

- **Remarks about NURESAFE CTF version**
- **D13.22 submitted:** ***Description of the CTF input deck for BWR ATWS analysis***

  (KIT & GRS)
- **Conclusion & Outlook**

EUROPEAN COMMISSION

Community Research

EURATOM

NURESAFE

NUclear REactor SAFEty Simulation Platform

Collaborative Project (Large – scale Integrating Project)

Seventh Framework Programme EURATOM

Contract Number: 323263

Start date: 01/01/2013 Duration: 36 Months

D13.22 – Description of the CTF input for BWR ATWS analysis

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NURESAFE – D13.22 – version 0 – Issued on 17/12/2013

NURESAFE CTF version

- **Updated PSU Version of CTF received from GRS (20.11.2013)**
- **Non-regresion tests cases run and 8 out of 193 failed.**

```
96% tests passed, 8 tests failed out of 193

Label Time Summary:
COBRA_TF    = 3456.22 sec

Total Test time (real) = 3456.30 sec

The following tests FAILED:
         34 - COBRA_TF_run_par_quarter_cross_nopetsc (Failed)
         35 - COBRA_TF_run_par_quarter_cross_petsc (Failed)
         65 - COBRA_TF_run_bfbt_70027 (Failed)
         66 - COBRA_TF_run_bfbt_70032 (Failed)
         67 - COBRA_TF_run_bfbt_70036 (Failed)
         81 - COBRA_TF_preproc_1x1_assembly (Failed)
         82 - COBRA_TF_preproc_2x2_assembly (Failed)
        124 - COBRA_TF_preproc_even_bundle_cross (Failed)
Errors while running CTest
```

- **CTF version assessment at KIT resulted in a small report documenting some errors and other issues (21.11.2013):**
  - EMAIL exchange (PSU, ORNL, GRS and KIT) on the following days up to 26.11.2013
  - Up-to-day, there has been no more email/information exchange.

O2 Core modeling with CTF

- **444 channels: Every channel represents a FA**
- **There are 4 types of different fuel assemblies**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1																								
2						1	1	1	1	1	1	1	1	1	1	1	1	1	1					
3					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
4				1	1	1	3	1	2	2	1	2	2	2	2	2	1	2	1	1	1			
5			1	1	2	2	1	3	4	1	3	1	4	3	1	4	1	1	2	2	1	1		
6		1	1	2	2	1	4	2	1	3	2	3	1	1	3	1	3	4	1	2	2	1	1	
7		1	1	2	1	4	3	1	1	2	3	1	3	3	1	2	1	3	4	1	3	1	1	
8		1	1	1	2	3	1	4	2	2	2	2	2	2	1	1	3	1	2	3	2	1	1	
9		1	1	4	4	1	3	1	3	2	2	2	3	3	1	3	1	3	1	4	2	1	1	
10		1	1	4	1	3	2	3	1	1	1	3	2	2	2	2	2	2	2	1	2	1	1	
11		1	1	1	2	1	3	1	3	2	3	2	2	3	3	2	2	3	1	3	2	1	1	
12		1	1	1	4	1	3	1	3	3	2	2	2	2	2	1	1	1	3	1	2	1	1	
13		1	1	2	1	3	1	1	1	2	2	2	2	2	3	3	1	3	1	4	1	1	1	
14		1	1	2	3	1	3	2	2	3	3	2	2	3	2	3	1	3	1	2	1	1	1	
15		1	1	2	1	2	2	2	2	2	2	2	3	1	1	1	3	2	3	1	4	1	1	
16		1	1	2	4	1	3	1	3	1	3	3	2	2	2	3	1	3	1	4	4	1	1	
17		1	1	2	3	2	1	3	1	1	2	2	2	2	2	2	4	1	3	2	1	1	1	
18		1	1	3	1	4	3	1	2	1	3	3	1	3	2	1	1	3	4	1	2	1	1	
19		1	1	2	2	1	4	3	1	3	1	1	3	2	3	1	2	4	1	2	2	1	1	
20			1	1	2	2	1	1	4	1	3	4	1	3	1	4	3	1	2	2	1	1		
21				1	1	1	2	1	2	2	2	2	2	1	2	2	1	3	1	1	1			
22					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
23						1	1	1	1	1	1	1	1	1	1	1	1	1	1					
24																								

Current model limitations

- **The current model has the following limitations:**
  - The bypass channel and the internal bundle water channel are not explicitly modelled.
  - Only the active part of the core is modelled. For the coupling with a neutronic core model, a bottom and top reflector part will be needed.
  - The axial power distribution is the same in all assemblies.
  - The 444 fuel assemblies are modelled in parallel (no flow between channels).
  - The flow area, wetted perimeter and pressure loss coefficients are taken from the specifications.
- **The input deck has around 3900 lines**

CTF INPUT DECK STRUCTURE

- **MAIN PROBLEM CONTROL DATA**
  - CARD GROUP 1: Selection of the Physical Models, Global Boundary Conditions, and Initial Conditions
  - CARD GROUP 2: Channel Description
  - CARD GROUP 3: Transverse Channel Connection Data (Gap definition)
  - CARD GROUP 4: Vertical Channel Connection Data
  - CARD GROUP 7: Local Pressure Loss Coefficient and Grid Spacer Data
  - CARD GROUP 8: Rod and Unheated Conductor Data

CTF INPUT DECK STRUCTURE

- **MAIN PROBLEM CONTROL DATA**
  - CARD GROUP 9: Conductor Geometry Description
  - CARD GROUP 10: Material Properties Tables
  - CARD GROUP 11: Axial Power Distribution Tables, Radial Power Distribution, and Transient Forcing Functions
  - CARD GROUP 12: Turbulent Mixing and Void Drift Data
  - CARD GROUP 13: Boundary Condition Data
  - CARD GROUP 14: Output Options
  - CARD GROUP 15: Time Domain Data

CARD GROUP 1, 2 and 3

- **The input deck developed is in SI units**
- **The solver choice for the system pressure matrix is Bi-CGSTAB.**
- **Global boundary conditions taken from the specifications.**
- **Regarding the mixing:**
  - Single-phase mixing coefficient according to Rogers and Rosehart (1972)
  - Two-phase multiplier according to Beus (1970)
- **The flow area and wetted parameter for each channel are provided. The data are taken directly from the distributed data**
- **There is no CARD GROUP 3, BWR fuel bundles are wrapped**

CARD GROUP 4, 5 and 6

- Only one section was specified for the whole axial length of the active core (3.712 m).
- 50 equidistant axial nodes are used.
- Only the active part of the core is modelled.
- Fuel bundle type 4 contains partial fuel rods. Card group 5 and 6 allow for the modification of the flow area in selected channels (bundle type 4)

INPUT CARD GROUP 7, 8, 9 and 10

- **Local Pressure Loss Coefficient and Grid Spacer Data**
  - The data is taken directly from the distributed data
- **There are 444 nuclear fuel rods representing each FA (*nucl* component CARD 9)**
  - For the fuel rod modeling, a constant gap conductance of 9500 W/cm^2 is assumed
- **There are 444 unheated structures representing the canister walls (*wall* component CARD 9)**
- **In CARD 10, default material properties for UO2 fuel and Zircalloy are used**

CARD GROUP 11, 12 and 13

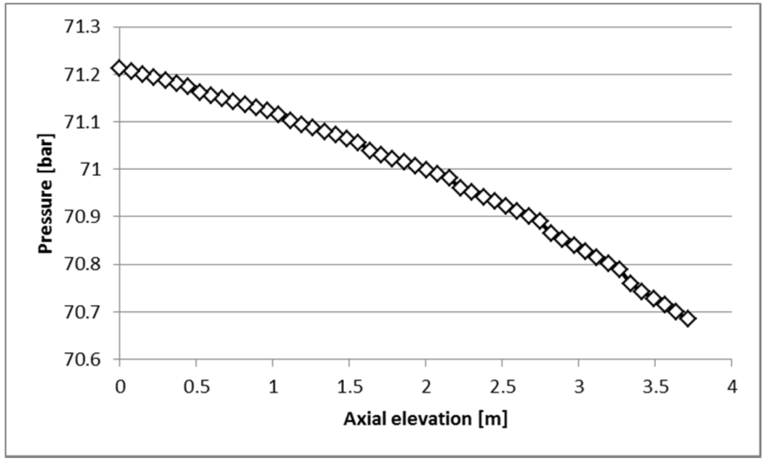
- **The radial power distribution is taken from a steady-state coupled calculation performed with ATHLET-PARCS.**
- **The axial power distribution is the core averaged axial power distribution extracted from the same coupled calculation and thus is the same in all assemblies**
- **Turbulent mixing and void drift data is specified in this input card.**
  - single-phase mixing coefficient is taken according to Rogers and Rosehart
  - two-phase multiplier is taken according to Beus
  - A value for THETM of 5.0 is suggested according to Sato (1992) for the ratio between maximum two-phase turbulent mixing coefficient (near the transition between slug and annular flow) and single-phase turbulent mixing coefficient (in single phase liquid)
- **In total there are 888 (444*2) boundary conditions specified**

General model assumptions

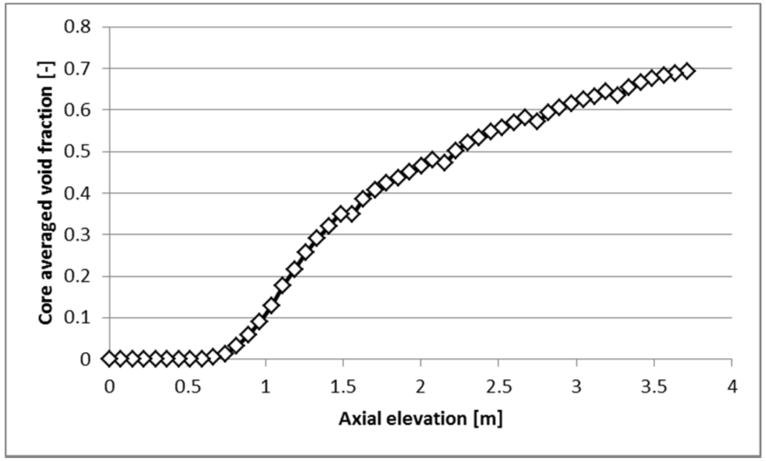
Model option	Where	Choice
Rod friction factor correlation (IRFC)	CARD GROUP 1	2 ($\lambda = 0.204\ Re^{-0.2}$)
Entrainment and deposition model (EDMOD)	CARD GROUP 1	0
Mixing and void drift model (IMIX)	CARD GROUP 1	2
Iterative Solver for pressure equation (ISOL)	CARD GROUP 1	3 (Bi-CGSTAB)
Number of simultaneous solution groups (NSIM)	CARD GROUP 4	1
Rebalancing option for iterative control (IREBAL)	CARD GROUP 4	0
Conduction in solid structures (NC)	CARD GROUP 8	1 (radial only)
Flag for steady state calculation of rod temp. (NSTATE)	CARD GROUP 8	2
Renoding flag for heat transfer solution for rod N (NRENODE)	CARD GROUP 8	0
Fuel relocation flag (IRELF)	CARD GROUP 9	0
Fuel degradation flag (ICONF)	CARD GROUP 9	0
Flag for metal-water reaction, ZrO_2 only (IMWR)	CARD GROUP 9	0

CTF Results at HFP

- **CTF converge to steady state without major problems in a 3 seconds void transient**



Core pressure versus height



Radial average void fraction versus height

- **Good agreement between O2 reference values and predictions although bypass flow is not modeled.**

O2 Modeling with subchannel codes

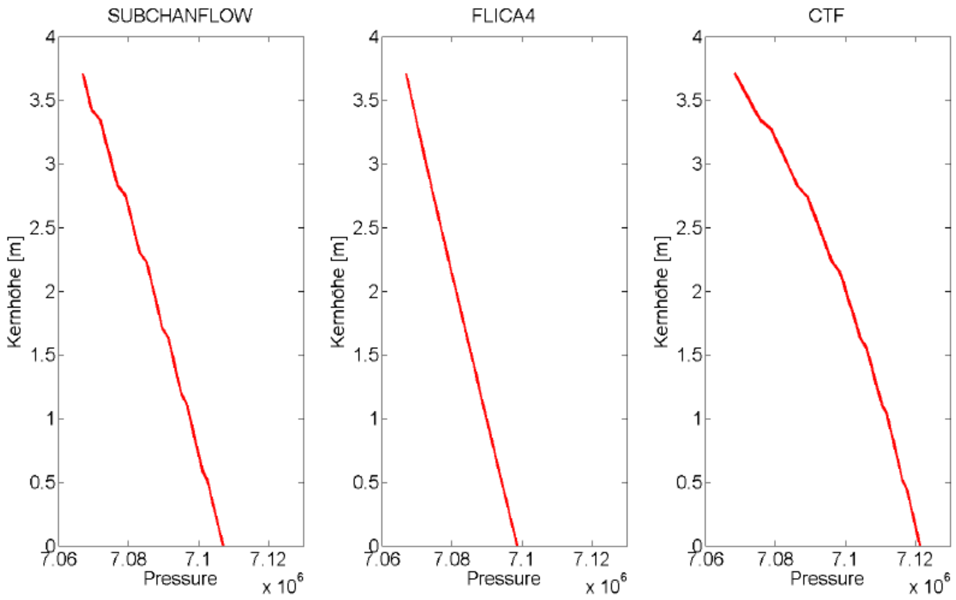
- **Oskarshamn-2 Core has being modeled with COBRA-TF, SUBCHANFLOW and FLICA4**
- **Code versus measured data comparison**

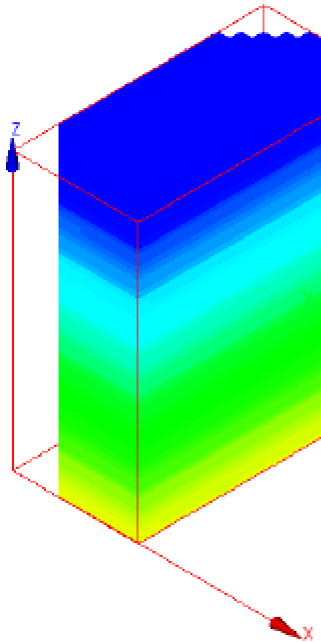
Parameter at HFP	Benchmark	SCF	FLICA4	CTF
Thermal Power (MW)				
Core inlet Temperature (K)				
Core Inlet Mass Flow (kg/s)				
Core outlet Temperature (K)				
Average void fraction (-)				
Void fraction at core outlet (-)				
Presure drop in the core (kPa)				
Average flow velocity in the core (m/s)				

NON-DISCLOSURE AGREEMENT

Results: Pressure drop

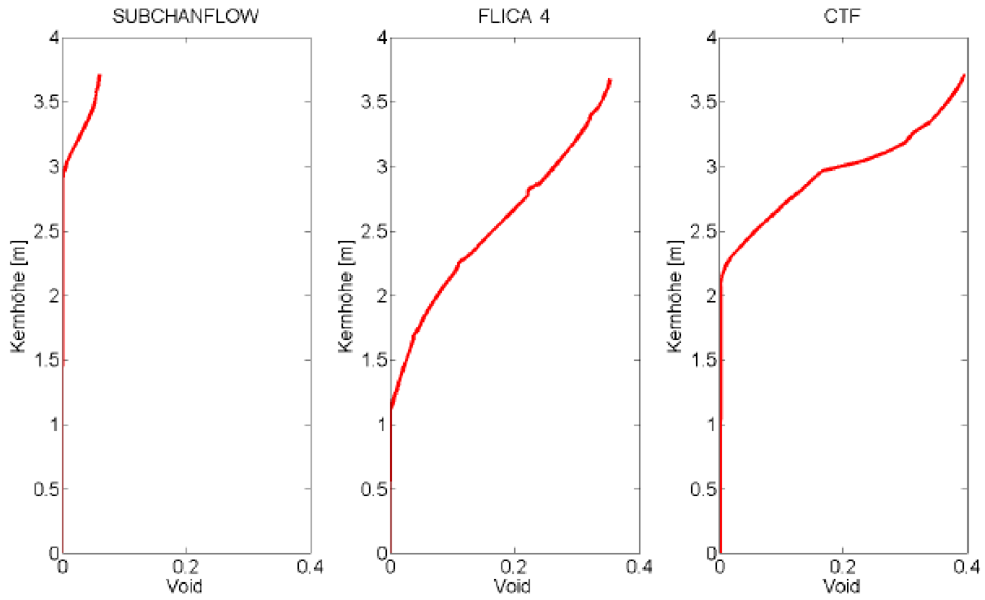
- **3D Power distribution take from converge steady state TRACE/PARCS**

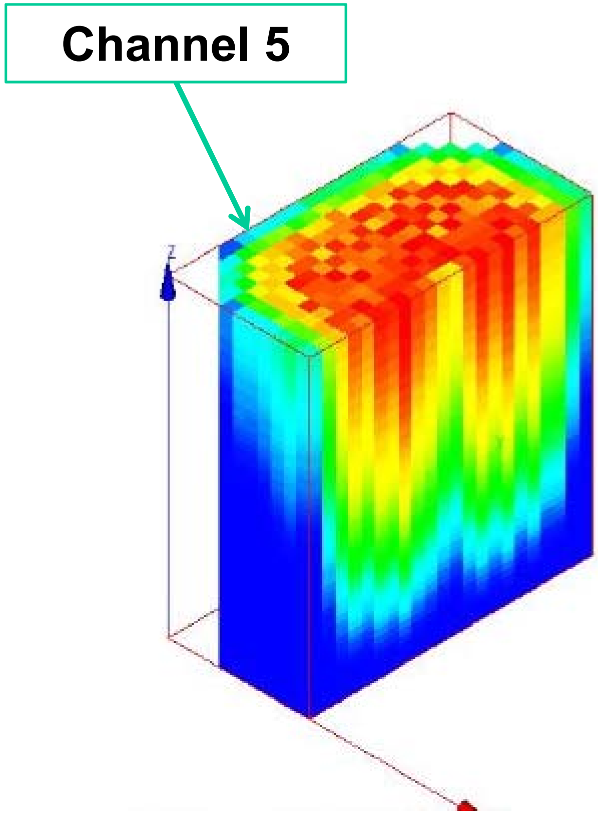




	Benchmark	SUBCHANFLOW	FLICA4	CTF
Average Pressure drop in the core (kPa)	Ref.	-1.9%	-12.8%	+16.3%

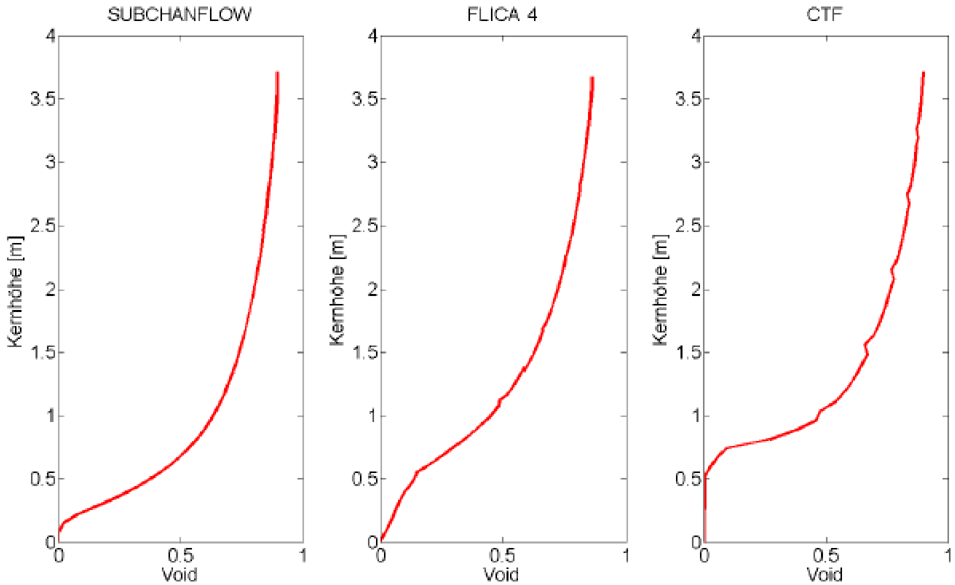
Results: Void fraction in channel 5

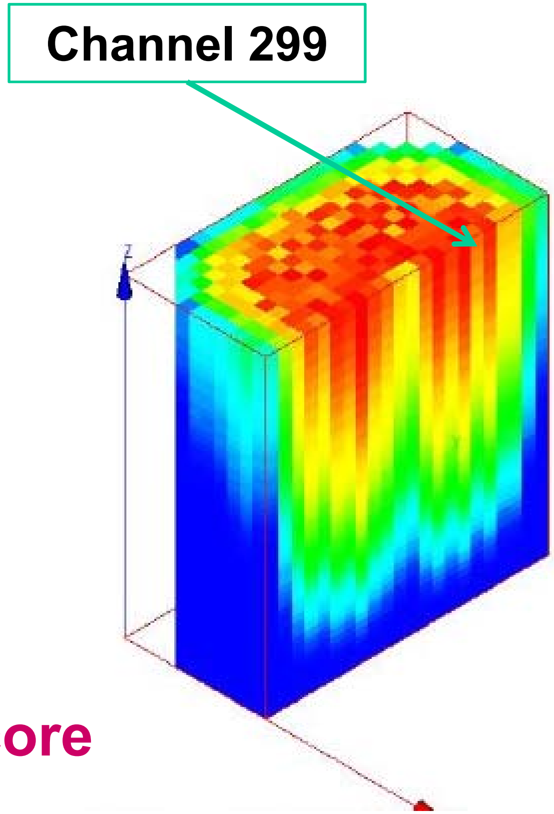




- **Very different onset of boiling**
- **Effects of subcooled boiling are modeled differently**

Results: Void fraction in channel 299





- **Similar vapor volume fraction at the core outlet**
- **The position of the spacers grids in FLICA and COBRA-TF can be seen clearly**

Conclusions and Outlook

- **COBRA-TF model for O2 core completed**
  - Good agreement between O2 reference values and predictions,
  - FLICA4 and SUBCHANFLOW models developed as a backup solution for O2
- **D13.22 Released on time (t0+12)**
- **Application to coupled simulations is foreseen in the next months.**

THANKS FOR YOUR ATTENTION