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International Agreement Report

TRAC-BF1 to TRACE Model Semi-Automatic Conversion. PBTT Example

Prepared by:
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ABSTRACT

This publication intends to summarize a larger work and aims to establish a semi-automatic procedure to translate input decks from TRAC-BF1 to TRACE code. This work was developed at Universitat Politècnica de València (UPV). The main reason for this work is the importance to keep the models updated and adapted to be used on new codes. As a result, it is possible to take advantage of these codes, which are more powerful because of the new techniques used in their development and the increase of computer resources. As a working example, the Peach Bottom II (PB) model is presented. This model was chosen because it is one of the most used plant models to validate new codes or calculation models. Moreover, data is easily available due to the NEA/OECD BWR Peach Bottom Turbine Trip (PBTT) benchmark. This methodology presented hereafter, could be used to translate other TRAC-BF1 models to keep them updated and therefore useful for other applications.

FOREWORD

This report represents one of the assessment or application calculations submitted to fulfill the bilateral agreement for cooperation in thermal-hydraulic activities between the Consejo de Seguridad Nuclear (CSN) and the U.S. Nuclear Regulatory Commission (NRC) in the form of a Spanish contribution to the NRC's Code Assessment and Management Program (CAMP), the main purpose of which is to validate the TRAC/RELAP Advanced Computational Engine (TRACE) code.

CSN and the Asociación Española de la Industria Eléctrica (UNESA, Electric Industry Association of Spain), together with some relevant universities, have established a coordinated framework (CAMP-Spain) with two main objectives: to fulfill the formal CAMP requirements and to improve the quality of the technical support groups that provide services to the Spanish utilities, CSN, research centers, and engineering companies.

The AP-28 Project Coordination Committee has reviewed this report: the contribution of a Spanish University to the above-mentioned CAMP-Spain program, for submission to CSN.

ISIRYM - UPV

June 2015

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EXECUTIVE SUMMARY

In order to keep old models updated, a methodology to translate models from TRAC-BF1 to TRACE is developed at Universitat Politècnica de València. An additional advantage for this translation is that current and future TRACE features can be applied to the translated model. The methodology makes use of the TRACE executable and its feature to read TRAC-BF1 input decks and create the appropriate restart. Then, the restart file can be imported to SNAP tool and later exported as ASCII file. However, the methodology is said to be semi-automatic because some errors are done in the process. These errors must be corrected by hand as explained in this document.

As an example of the semi-automatic methodology, the Peach Bottom (PB) model in TRAC-BF1 is translated to TRACE. Nonetheless, the methodology is not exclusive for Peach Bottom. Rather, this study is presented to help any other TRAC-BF1 to TRACE translation, regardless of the plant model.

Two different cases are presented in this document, both modeling PB. First, the translated model is code-to-code compared in steady state. Moreover, to test the transient model, the second case is a modification of the translated original model to simulate the Peach Bottom Turbine Trip (PBTT). This case is compared with the Benchmark participant results. In general good agreements are obtained for both cases. However, thermal-hydraulic adjustments must be made prior to the comparisons. A schematic framework for these modifications is presented.

ABBREVIATIONS

BPV	Bypass Valve
BWR	Boiling Water Reactor
NRC	Nuclear Regulatory Commission
PBTT	Peach Bottom Turbine Trip
PWR	Pressurized Water Reactor
SNAP	Symbolic Nuclear Analysis Package
TSV	Turbine Stop Valve

1. INTRODUCTION

Nuclear codes are being developed and improved permanently. Examples include new physic models, updating old codes or parallelization of algorithms. In this work, mainly two thermal-hydraulic codes are used: TRAC-BF1 [1] and TRACE V5.0P3 [2]. PARCS v2.7 [3] is used as a coupled neutronic code for TRAC-BF1 and PARCS v3.0 [4] is used for TRACE. TRAC-BF1 is a code developed in the Idaho National Engineering Laboratory (USA) for boiling water reactors (BWR) simulation purpose. TRACE code is an updated version that could be used for both types of reactors: BWR and PWR simulations. Besides, PARCS is a 3D diffusion neutronic code, widely used, and developed at Purdue University (USA).

A Peach Bottom (PB) input deck for TRAC-BF1 is used to run plant transient simulations. It models not only the vessel and reactor core, but also other components, such as the jet pump, recirculation pump, separator and the steam line. However, to keep the PB model updated, a semi-automatic translation from TRAC-BF1 to TRACE is carried out with a methodology developed at Universitat Politècnica de València (UPV). This methodology makes use of the TRACE executable and SNAP tool [5].

Peach Bottom model is chosen for the translation purpose because a lot of data is available in the framework of the Peach Bottom Turbine Trip NEA Benchmark [6] and [6]. In this study, the methodology to translate the model from TRAC-BF1 to TRACE is presented. The main advantages of this translation process are explained next:

- Peach Bottom input deck model updated to new TRACE code, thus easier to maintain and improve.
- Get advantage of new models and features in TRACE, the ones that already are implemented, and the ones that will have TRACE in future versions.
- Nuclear Regulatory Commission (NRC) intends to license TRACE code in a middle-term future. Therefore, anticipation is made in this work in order to clear the path for new TRACE input decks.

It is worth to mention that this methodology is not specific to the Peach Bottom case. It is meant that the methodology, hereafter presented, could aid the translation for other TRAC-BF1 models.

Two cases are presented here, both modelling the Peach Bottom reactor. The first case is the direct translation of the TRAC-BF1 model in steady state, and thus, the TRAC-BF1 results are used for code-to-code comparison. The second case is the first model with modifications to simulate the Peach Bottom Turbine Trip NEA Benchmark, thus the benchmark results are used to validate the model.

The translation is done semi-automatically using a TRACE executable and the SNAP tool. TRACE executable has the capability to read input files from TRAC-BF1, but it does not execute the simulation. However, it could generate the restart file in TRACE format. Afterwards, SNAP tool could be used to read this restart file and then export the model in TRACE ASCII format. The methodology is said to be semi-automatic because the translation done by TRACE executable is not error-free. Thus, the mistakes, for now, must be corrected by hand.

The error correction could be a long task. Nevertheless, this publication is intended to make this task easier and less painful. The publication is divided in six sections. First, in section 2, the PB model, both thermal-hydraulic and neutronic parts are explained. In section 3 the translation methodology is explained and also the mistakes found in the PB translation are presented with a possible solution. In order to validate this work, section 4 shows the results for steady and transient state. Some concluding remarks and conclusions are drawn in section 5. Finally, in section 6, the references are presented.

2. PEACH BOTTOM MODEL

2.1 Thermal-Hydraulic Model

Peach Bottom reactor is composed of 764 fuel assemblies, in this model fuel assemblies are collapsed to 33 channel (CHAN) components [6], as shown in Figure 1.

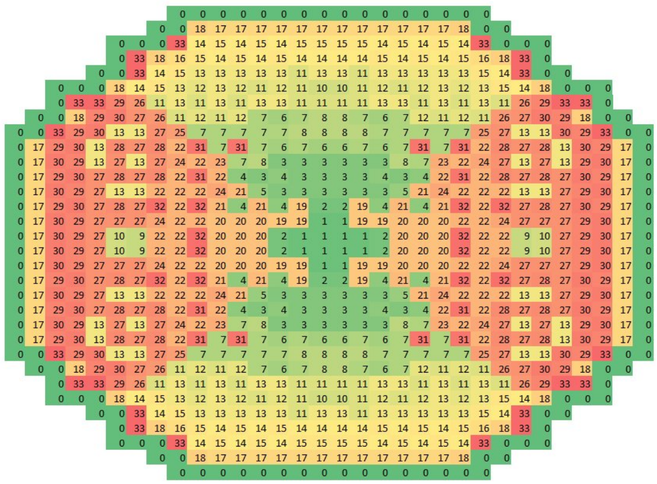

Figure 1 Thermal-Hydraulic Channels

The channels are inside the vessel, together with the jet pump and the separator. The vessel has 9 axial nodes and 2 radial nodes, the outer of which conforms the downcomer. The channels are between axial levels 4 and 5, in the inner radial node. The fill feeds water directly to the downcomer in the 7th axial node. The steam line starts in the 8th axial node, see Figure 2. The steam line contains several relief valves and breaks, the main ones are the bypass valve (id 77) and turbine stop valve (id 76), see Figure 3.

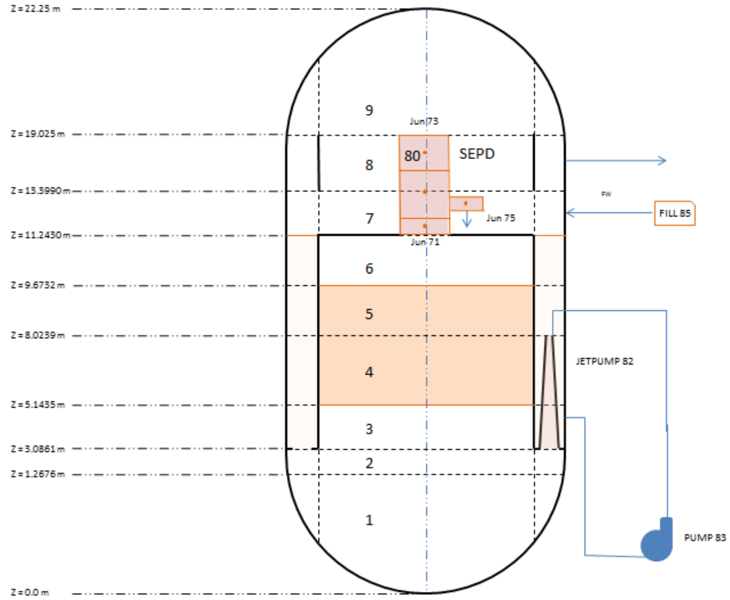

Figure 2 Vessel Nodalization and Main Containment Building Components

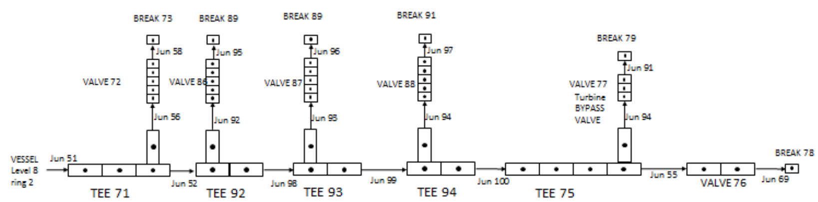

Figure 3 Steam Line Scheme

The boundary conditions for the main model components can be seen in Table 1.

Power (W)	$2.03 \cdot 10^9$
Fill Flow (kg/s) Velocity (m/s) Temperature (K)	 680.26 11.80 442.31
Break pressure Before turbine (Pa) Before condenser (Pa)	 $6.65 \cdot 10^6$ $1.25 \cdot 10^5$
Reactor Pressure drop (Pa) Bypass flow (kg/s) Core flow (kg/s) Total core flow (kg/s)	 $1.14 \cdot 10^6$ 841.38 9603.62 10445.00

Table 1 Main Boundary Conditions

2.2 Transient Model: PBTT Benchmark

In order to validate the full methodology, both steady state and transient state are modelled. For the transient simulation, a turbine trip accident is chosen to compare both models. The model corresponds to the NEA Peach Bottom Turbine Trip PB2 Benchmark (Exercise 3, Extreme Scenario 2: turbine trip without reactor SCRAM), the reader is referred to [6] for more information. In this scenario, the turbine trip signal is send and the turbine stop valve (TSV) is closed. After 0.06s, the bypass valve (BPV) starts to open. Moreover, regarding the transition simulation, a null transient simulation is set for 50 seconds prior to the real transient. This is convenient to check the steady state convergence before the simulation of any kind of perturbation. The main events and the occurrence time in this scenario are presented in Table 2.

TSV begins to close	0.000
BPV begins to open	0.060
TSV closed	0.096
BPV fully open	0.846
Turbine pressure initial response Steam line A Steam line D	 0.102 0.126
Steam line pressure initial response Steam line A Steam line D	 0.348 0.378
Vessel pressure initial response	0.432
Core exit pressure initial response	0.486

Table 2 Time for Main Events in Peach Bottom Turbine Trip Accident (s)

In Figure 4 the area fraction for both valves (TSV and BPV) as a function of time is shown. Even though there is a null transient of 50 s, the transient time beginning resets to 0 s in all figures. It can be seen that the TSV is closed in less than a tenth of a second, besides the BPV is opened in almost one second.

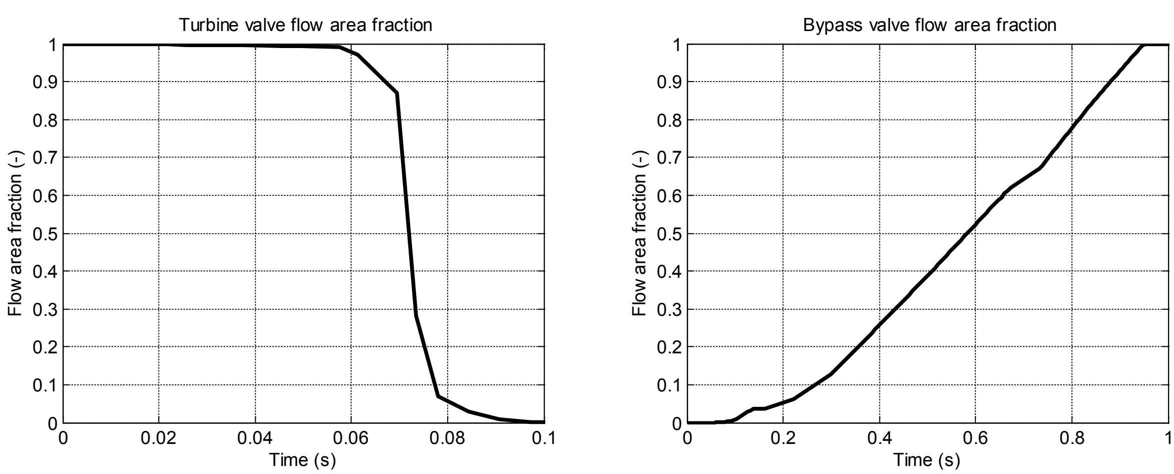

Figure 4 Turbine Stop Valve (Left) and Bypass Valve (Right) Area Fraction as Function of Time

The relative total reactor power for all the Benchmark participants is depicted in Figure 5. It can be seen that the power peak for all participants is produced almost one second from the turbine trip signal. Afterwards, the power oscillates and the second peak is produced between 2 and 3 seconds after the turbine trip signal. Finally, the power reaches a steady state after 10 seconds. In Figure 5, the power evolution is shown only from 0 to 5 seconds to be able to see the differences in the first power peak.

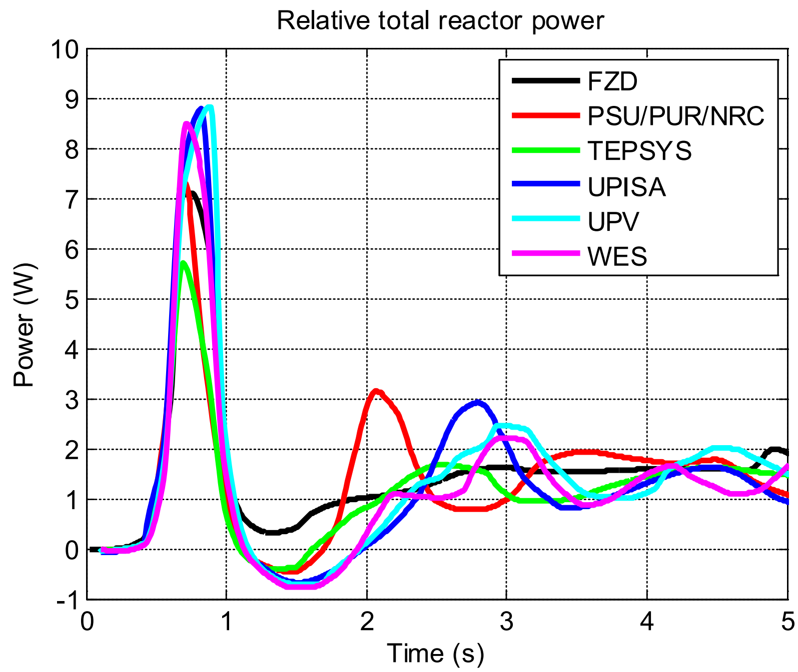

Figure 5 Relative Total Reactor Power for all Benchmark Participants

2.3 Neutronic Model

The 3D neutronic model is simulated using PARCS v2.7. The core is discretized in 26 levels and each of them has 888 cells, of which 124 represents the reflector, (total cells are 23088). All cells have the same dimensions 15.24 cm x 15.24 cm x 15.24 cm, see Figure 6 (left). The total simulated neutronic compositions are 1203, three of them used for reflectors. Besides, there are eight different control rod banks, their distribution and initial position for the transient simulation is given in Figure 6 (right). Position 48 means control rod bank totally withdrawn (*out*) and 0 means bank totally inserted (*in*).

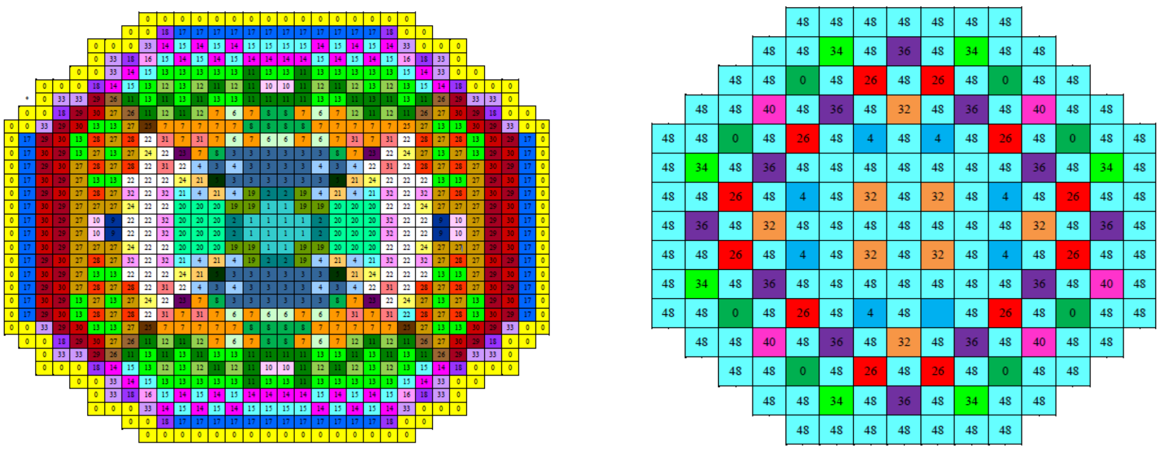

Figure 6 Fuel Radial Map (Left) and Initial Control-Rod Banks Position (Right)

3. METHODOLOGY

3.1 Translation Process

First, it is important to know that TRAC-BF1 allows some freedom degree regarding the physical model conditions. However, TRACE is restrictive dealing with parameters between different components, i.e. flow area, height, angle, friction factors, etc.

To start the methodology some adjustments need to be done to the TRAC-BF1 input file; these adjustments are explained hereafter.

- The input deck must be in lower case. This could be changed with any text editor with automatic features.

- Even though water rods should not be represented as the first rod group, TRAC-BF1 allows it for CHAN component [8]. Nonetheless, TRACE does not allow it. Thus, in case the first rod group is composed by water rods in TRAC-BF1, some changes are needed in order to proceed with the translation. This change involve changing some variables, i.e. *CPOWR* parameter (power distribution within the fuel bundle), *RDPWR* (radial rod power distribution), *RDX* (number of actual rods in each group), *MATRD* (rod group material), among other variables. The values corresponding to the water rod (first group) should be moved. For example in case the water rod group is moved to the end, these values should be moved as well to the end of the value list. In case of Peach Bottom model, there are not water rods, thus no worry about this issue is needed.

- TRACE does not allow the clad to be composed of only one node, whereas TRAC-BF1 does. This restriction is set to get a better radiation model results. If this parameter is changed, then the vector *TW* (initial wall temperature) must be resized. This is not the case for Peach Bottom model.

- Comment the first TRAC-BF1 line (=*3D*). This line appears when TRAC-BF1 is coupled with a neutronic code. Comments in TRAC-BF1 are done with the asterisk sign. This is the title line and it is not interesting in order to get the TRACE input file (steady state).

- When TRAC-BF1 is coupled with a neutronic code, the kinetics options should be 1D. Therefore, in this case, the parameter *IRPOP* (kinetic model option) must be changed from 8 (1D) to 1 (constant power). For this kinetic model option, *NDG* (delayed neutron groups) parameter must be 0. Both parameters are found in *POWER0001X* card.

- All cards related to the 1D kinetics model are deleted. With the exceptions of *POWER0001X* card (already modified in previous step) and *POWER00ZPOWRX* card (axial power distribution). Cards to delete are: *POWDECAY, POWER00020, POWER00030, POWONKIN*.

- For fill components, if *IFTY* parameter is equal to 4 (constant velocity until trip is on, then table), then the control block associated (card *cntrl20268*) must have *ncbout* (control block output identifier) equal to 0. Otherwise, the following error is thrown:

```
*WireCBOut*

CB output not compatible with input     IFTY

   Fill Component=       85
 Control Block ID=      268
 icbout=                -42

          *****************
          ** fatal error **
          *****************

*ConBlkDataF* call WireCbOut
```

- For pump components, if *IPMPTY* parameter is equal to 1 (constant speed until trip is on, then table), then the control block associated (card *cntrl20104*) is not compatible. The *IPMPTY* must be changed to 3 (pump motor torque controlled by control system). Otherwise, the following error is thrown:

```
*WireCBOut*

CB output not compatible with input   IPMPTY

   Pump Component= 83
 Control Block ID=      104
 icbout=                 -1


          *****************
          ** fatal error **
          *****************

 *ConBlkDataF* call WireCbOut
```

Afterwards, the modified input is run with a TRACE executable. Even though the simulation is stopped with a warning output, some output files are created. Specifically it is of interest the restart file (.*tpr*). This file can be imported as a TRACE file by SNAP tool (using *tpr* option), and therefore, after successfully reading the *tpr* file, a TRACE input deck file can be exported as an ASCII file. In Figure 7, the main model components (from *tpr* file) are shown as seen in SNAP tool.

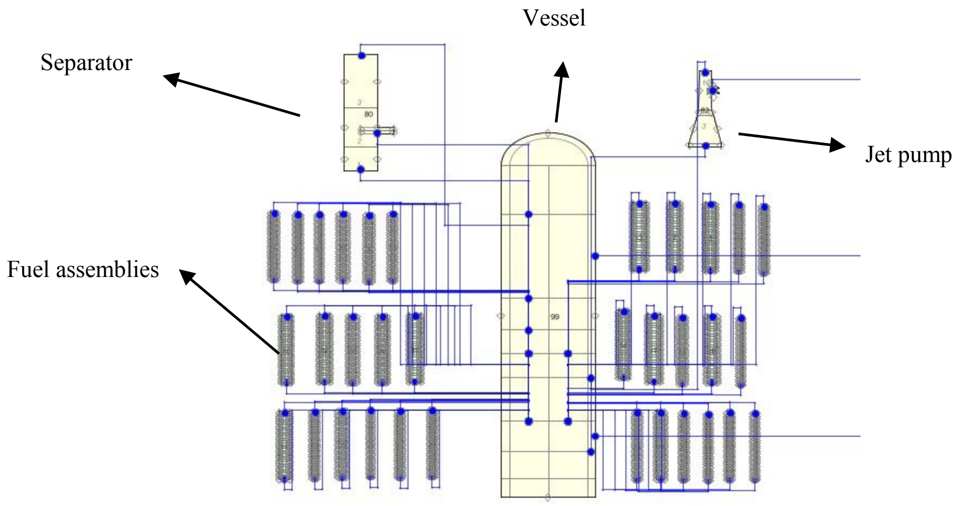

Figure 7 Reactor Area Components in SNAP Tool

3.2 Error Correction

From now on, next modifications could be made either on SNAP or in the ASCII TRACE input file. The main mistakes done by TRACE/SNAP translation are explained next, they must be corrected by hand. This section is exclusively for Peach Bottom Turbine Trip model case. However, it is expected that this section helps in order to achieve a good translation in other inputs.

- In trip section, since a null transient is desired for an appropriate steady state convergence, the set point for trip with ID 10 is set to 50 seconds.

- In control system blocks, parameter *cbcon2* (control constant 2) has bad values for most of the controls. Table 3 shows the control block IDs for which *cbcon2* value is mistranslated, the correct *cbcon2* value, and other mistranslated variables if any.

CB ID	cbcon2	Other variables
2	9.834	
54	0.672	
50	0.208	
52	-0.381	
54	0.208	
58	0.88	icbn=3
100		cbgain=cbxmin=cbmax =cbcon1=cbcon2= 9603.32
101, 102, 103	0.0	
105 to 137		icbn=59 cbcon1=cbon2=1.0
138	7.4884E6	
139	7.5553E6	
140	7.6222E6	
141	8.3245E6	
206	0.0	
208, 210, 214, 220, 222	0.9568	
224	0.0	
228	1.0	
230	0.0	
234, 236	62.37	
238	26.90	
240		cbcon1=1.17647
248, 250, 252, 256, 262	64.3	
254	1.0	
264	1.036	
266	1046.0	
267	1.3	
268	0.0	
512	0.226	
516	0.0	

Table 3 Variables to Correct in Control Blocks

- In channel components, in order to facilitate the coupling with a neutronic code, *ncrz* (number of heated nodes) is reduced to 24, and *icrnk* (number of CHAN cells below the powered region) and *icrlh* (number of CHAN cells below the lower tie plate) are set to 1. Because of these changes, some vector variables for channels components must be resized. These vector variables are summarized in Table 4.

Variable	Comp. location	Meaning
nfax	Channel	Number of fine-mesh cells added in each coarse mesh cell
rftn	Channel	Rod element temperatures, initial distribution
radpw	Channel	Core wide radial chan-to-chan power peaking factor
burn	Channel	Fuel burnup, initial condition
zpwtb1	Power	Axial power-shape, initial condition

Table 4 Variables to Resize when *ncrz* is Changed

- Some channel variables in TRACE are not defined in TRAC-BF1. However, TRACE assigns some default values to them, see Table 5. Other channel variables change their definition between codes or need some comments, see Table 6.

Variable	Default value	Meaning
iaxcnd	0	Specification of axial conduction (0 means off)
liqlev	0	Liquid-level tracking (currently not used).
reflood	0	Reflood flag, redundant parameter (use *fmon*)
nff	1	Friction-factor correlation option
ilev	-1	Level tracking (-1 means off)

Table 5 TRACE Variables in a CHAN Component not Defined in TRAC-BF1

TRAC-BF1		TRACE	
Variable	Comment	Variable	Comment
hgapo	Fuel rod gap conductance coefficient Value in card 30 is not used. Instead, variable HGAP vector is used. It specifies a value for each cell in CHAN component.	*hgapo*	Rod gas gap HTC. Constant for each CHAN component.
nrod	Number of fuel rods in a single bundle row.	*nrow*	Number of rods in a row. Same definition, the name is changed.
bundw	Inside channel width.	*width*	Inside perimeter of the canister wall.
epsc	Fuel rod surface emissivity. Constant.	*emcof*	Rod Surface, second order polynomial.
epsr	Channel wall inside emissivity. Constant.	*emcif*	Canister Wall, second order polynomial.
irad	Radiation heat transfer option. IRAD = 0 includes steam and droplets in radiation heat transfer calculation. IRAD = 1 does not include steam and droplets in radiation heat transfer calculation.	*norad*	Radiation heat transfer option. *norad* = 0, radiation heat transfer model is turned on. *norad* = 1, radiation heat transfer model is turned off.
iani	Anisotropic radiation reflection flag. *iani* = 0, No anisotropic correction. *iani* = 1, Correct view factors for anisotropic reflection.	*noani*	Anisotropic option. *noani* = 0, anisotropic view factor corrections are applied to the view factor calculation. *noani* = 1, anisotropic view factor corrections are not applied.
epsd	Ratio, surface roughness/hydraulic diameter. It specifies a value for each cell in CHAN component.	*epsw*	Wall surface roughness. Constant for each CHAN component.
ihts	Indicator for heat transfer to the fluid of this component from the outer wall of one or more other components.	*nhcom*	Component number receiving outside wall energy.
ichoke	Choking calculation flag. *ichoke* = 0, no choking. *ichoke* = 1, choking calculation.	*icflg*	Cell edge choked flow model option. *icflg* = 0, no choked flow model calculation. *icflg* = 1, choked flow model using default multipliers. *icflg* = 2 to 5, using NAMELIST variable defined multipliers.
iccfl	Countercurrent Flow (CCFL) control flag. *iccfl* = 0, Turn off CCFL model. *iccfl* = 1, CCFL upper tie plate constants. *iccfl* = 2, CCFL side entry orifice constants.	*lccfl*	Countercurrent flow limitation option. *lccfl* = 0, no countercurrent flow limitation calculation. *lccfl* = N, the countercurrent flow limitation parameter set number used to evaluate countercurrent flow limitation.
rdx	Number of rods in each rod group.	*rdx*	Number of actual rods in each rod group. Water rods must not be the first group.
ichf	Choke Flow calculation flag. Negative value means that CHF model is off.	*ichf*	Choke Flow calculation flag. Negative value not permitted.
alptst	Threshold void fraction for radiation calculation.	-	Do not exist in TRACE.
nrad	Number of time steps between radiation calculations.	-	Do not exist in TRACE.

Table 6 TRACE Variables in a CHAN Component that Change Definition in TRAC-BF1

- Parameter *nff* (friction factor option), present in most of the thermal-hydraulic components in TRACE is not defined in TRAC-BF1. It is chosen to have value 0 (constant friction factor) for all components since it reduces the oscillations in the solution.

- Vessel nodal height is recalculated in order to fit node faces height with components length, see Table 7. Some vessel friction factors and hydraulic diameters need to be cheeked since some of them are not the same as in TRAC-BF1, see Table 8 and Table 9. In these tables, values shown are the correct TRAC-B values, cells in blank correspond to correct translated values

<table>
<tr><th colspan="4">Vessel Component, ID = 99</th></tr>
<tr><th rowspan="2">Level</th><th rowspan="2">Upper height (m)</th><th colspan="2">Adjoin component</th></tr>
<tr><th>R=1 inner radial cell</th><th>R=2 outer radial cell</th></tr>
<tr><td>9</td><td>22.250</td><td></td><td></td></tr>
<tr><td>8</td><td>19.9585</td><td rowspan="2">SEPARATOR
Δz = 7.78256 m</td><td></td></tr>
<tr><td>7</td><td>13.9990</td><td></td></tr>
<tr><td>6</td><td>12.17594</td><td></td><td></td></tr>
<tr><td>5</td><td>9.67320</td><td rowspan="2">CHANNELS
Δz = 3.9624 m</td><td></td></tr>
<tr><td>4</td><td>9.09682</td><td rowspan="2">JET PUMP
Δz = 5.01072 m</td></tr>
<tr><td>3</td><td>5.71080</td><td></td></tr>
<tr><td>2</td><td>4.08610</td><td></td><td></td></tr>
<tr><td>1</td><td>1.26760</td><td></td><td></td></tr>
</table>

Table 7 Vessel Nodalization to Adjust Adjoin Components

level	cfzlz	cfzlxr	cfzvz	cfzvxr	cfrlz	cfrlxr	cfrvz	cfrvxr
4		0.5 0.5		0.5 0.5		1.5 0.5		1.5 0.5
5		1.5 0.5		1.5 0.5		1.5 0.5		1.5 0.5
6					5.0 5.0		5.0 5.0	
8		1.0 0.0		1.0 0.0				
9	5.0 5.0		5.0 5.0					

Table 8 Incorrect Friction Factor Translation in Vessel Component as Function of Nodal Level

level	hdz		hdxr	
1	4.079495	1.0	2.8776495	0.0
2	4.0795116	1.0	5.7633977	0.0
3			0.0	0.0
4				
5			0.0	0.0
6	1.0	1.2577906	0.0	0.0
7			5.7409076	0.0
8			0.0	0.0
9	1.0	1.0	10.175143	0.0

Table 9 Incorrect Hydraulic Diameter Translation in Vessel Component as Function of Nodal Level

- Changes in other components are detailed in Table 10 to Table 16.

Variable	Correct Value	Comment
ibeam	0	View factors not translated.
noani	1	The anisotropic view factor corrections are not applied to the view factor calculation.
dznht, dznhtw *dtxht1, dtxht2*	0	TRAC-BF1 value.
toutl, toutv	559.71	TRAC-BF1 value.
nzmax, nzmaxw	27	TRAC-BF1 value.
hgapo	4542.56	TRAC-BF1: an array, TRACE: constant value, see Table 6.
epsw	See comment	Depending on the fuel type. 1.467E-4 in CHANS with 49 rods. 1.314E-4 in CHANS with 64 rods. Different definition, see Table 6. TRAC-BF1: an array, TRACE: constant value.
rdx	64	For TRAC-BF1 CHANS with *rdx*=63 (water rod not included), corresponding TRACE CHANS must have *rdx*=64 (8*8). See Table 6.
cpowr	See comment	Depending on the fuel type. 2.04081633E-02 in CHANS with 49 rods. 1.58730159E-02 in CHANS with 64 rods.
radpw	See comment	Depending on the fuel type. 8.67373056E+03 in CHANS with 49 rods. 1.13962021E+04 in CHANS with 64 rods.
ncrz	24	For couple easiness.
icrnk, icrlh	1	For couple easiness.
nfax, rftn *rdpwr, burn*	See comment	Reshape arrays to *ncrz.*

Table 10 Chan Component (ID 1 to 33) Variables to Change

Variable	Correct Value	Comment
ichf	0	Negative values not allowed. See Table 6.

Table 11 Tee Component (ID 71, 75, 92, 93 and 94) Variables to Change

Variable	Correct Value	Comment
radin	0.0011	Only valves with ID 72, 86, 87 and 88.
th	0.0011	
hd(2)	1E-5	Only valves with ID 72, 77, 86, 87 and 88.
vl(2)	1E-10	
vv(2)	1E-10	
ichf	0	Only valves with ID 76 and 77.
kfac(1)	325.0	Only valve with ID 77.
kfacr(1)	325.0	
grav(1)	1.0	
ivsv	36	Only valve with ID 72.
ivsv	37	Only valve with ID 86.
ivsv	38	Only valve with ID 87.
ivsv	39	Only valve with ID 88.

Table 12   Valve Component (ID 72, 76, 77, 86, 87 and 88) Variables to Change

Variable	Correct Value	Comment
ichf	0	Negative values not allowed. See Table 6.
toutl, toutv	561.4	TRAC-BF1 value
toutl2, toutv2	561.4	

Table 13   Separator Component (ID 80) Variables to Change

Variable	Correct Value	Comment
toutl, toutv	549.3	TRAC-BF1 value
kfac1, kfacr1	0.02	
kfac2, kfacr2	0.03	

Table 14   Jet Pump Component (ID 82) Variables to Change

Variable	Correct Value	Comment
ichf	2	TRAC-BF1 value
kfacr(10)	0.024	TRAC-BF1 value

Table 15   Pump Component (ID 83) Variables to Change

Variable	Correct Value	Comment
tvin	442.31	TRAC-BF1 value

Table 16   Fill Component (ID 85) Variables to Change

Finally, some adjustments are needed to supress some TRACE warnings, alerts, and errors, see Table 17.

Warning/Note	Comment
Warning: Model Options. The water packing model is currently disabled	Model Flag *ipak* = 1.
Break 73 (relief valve break) Alert: The maximum rate of change of the break pressure is set to 0.0	For all breaks, *rbmx* variable is set to 1E+20.
Warning: Hydraulic [22] from Pump 83 to Vessel 99 Inconsistent connection from Pump 83 (intact loop recirc pump) to 3D Cell (2, 1, 3) of Vessel 99 (bwr-4 254 inch ID vessel). 1D Connections to a radial face of a 3D Cell must have a GRAV term of 0.0. (-0.57 != 0.0)	For pump, *grav* array variable, first element is set to 0.0.
Error: Valve 77 (bypass valve): Inconsistent GRAV terms on junction 59 from Tee 75 edge 7 (-0.074) to Valve 77 edge 1 (1.0). Tee 75 will be used.	For valve with ID 77, *grav* array variable, first element is set to -0.074.
Separator 80 (separator/dryer (simple) 226) [2] Errors Error: Wall Power Table The independent variable signal has not been set. Error: Wall Power Table The independent variable signal has not been set.	For separator, variable *iqsv* is set to 59.
JetPump 82 (intact loop jetpump) [2] Errors Error: Wall Power Table The independent variable signal has not been set. Error: Wall Power Table The independent variable signal has not been set.	For jet pump, variable *iqsv* is set to 59.
namelist option useSJC must be 2 when jun1=0 ***************** ** warning ** ***************** *rfill* disconnected fill input error	Namelist variable *usesjc* is set to 2.
***************** ** warning ** ***************** *chbd* Junction boundary error detected Comp= valve ;num= 77; junction= 59; variable= rev. friction factor Junction left side= 3.568685E+00; right side= 1.976502E-02	For tee with ID 75, *kfacr2* array variable, second element is set to 163.4 For valve with ID 77, *kfacr* array variable, first element is set to 163.4
***************** ** warning ** ***************** *chbd* Junction boundary error detected Comp= valve ;num= 77; junction= 59; variable= friction factor Junction left side= 3.568685E+00; right side= 1.976502E-02	For tee with ID 75, *kfac2* array variable, second element is set to 163.4 For valve with ID 77, *kfac* array variable, first element is set to 163.4

Table 17 Actions to Supress TRACE Warnings, Alerts and Errors

3.3 Thermal-Hydraulic Adjustment for Steady State Simulation

This case (steady state simulation) begins with the input deck obtained directly following all steps in section 3.1 and 3.2. When all model translation is properly checked, the input deck is further modified. To this end, some flow adjustments must be made. The code-to-code comparison for this model is done using the TRAC-BF1 steady state results. To get a good agreement in flow distribution some friction factors are changed. See Table 18 for detailed information.

Component		Variable	Element	Original value	Changed value
Channels with ID: 2, 4,6, 10, 12, 15, 26, 28, 30, 31, 32		*kfac*	1	31.2	34.0
Channels with ID: 17, 18, 33		*kfac*	1	191.07	113.07
All Channels		*kfac*	15, 18, 21, 24 and 27	1.08497 1.2141 1.2341	0.0
Jet Pump 82		*fa1*	1	2.5084E-2	3.6484E-2
			2	2.9358E-2	4.8358E-2
		fa2	1	4.2740E-3	3.9050E-3
			2	3.0434E-2	1.5434E-2
Pump 83		*ipmpty* *ipmptr* *npmpmt* *pmpmt*	-	3 0 2 -	1 1 delete variable delete table
Vessel 99	level 4	*cfzlz* *cfzvz*	1 1	9.0 9.0	6.0 6.0
	level5	*cfzlz* *cfzvz*	1 1	30.0 30.0	18.5 18.5

Table 18 Changes Made to Adjust the Thermal-Hydraulic Steady State Model

As seen in Table 18, for all channel components, the last five friction factors, representing last grids, were removed. The reason for this change was that otherwise some oscillations were observed in the axial void fraction distribution, obviously unreal in a BWR.

In consideration of the effort done to adjust the model, and for sake of simplicity, hereafter an algorithm for automatic model adjustment is proposed for future works, see Figure 8. Please, note that $\propto$ is used to indicate that two values are proportional.

1. The pump flow is adjusted changing the side tube flow area in the jet pump (first node only).

2. The main tube flow area in the jet pump (first and second nodes only) is modified to achieve the total core flow rated value.

3. The bypass flow is adjusted by means of the friction factor in vessel levels 4 and 5. Steps 1 to 3 are repeated iteratively until TRAC-BF1 values were obtained.

4. The flow in each channel is modified using the friction factor in first level, until a good flow distribution through the whole core is obtained.

5. To get the desired vapor mass flow in the dome, the reverse friction factor for vapor in levels 7 and 8 are changed. The whole process (steps 1 to 5) is repeated iteratively until proper convergence is achieved.

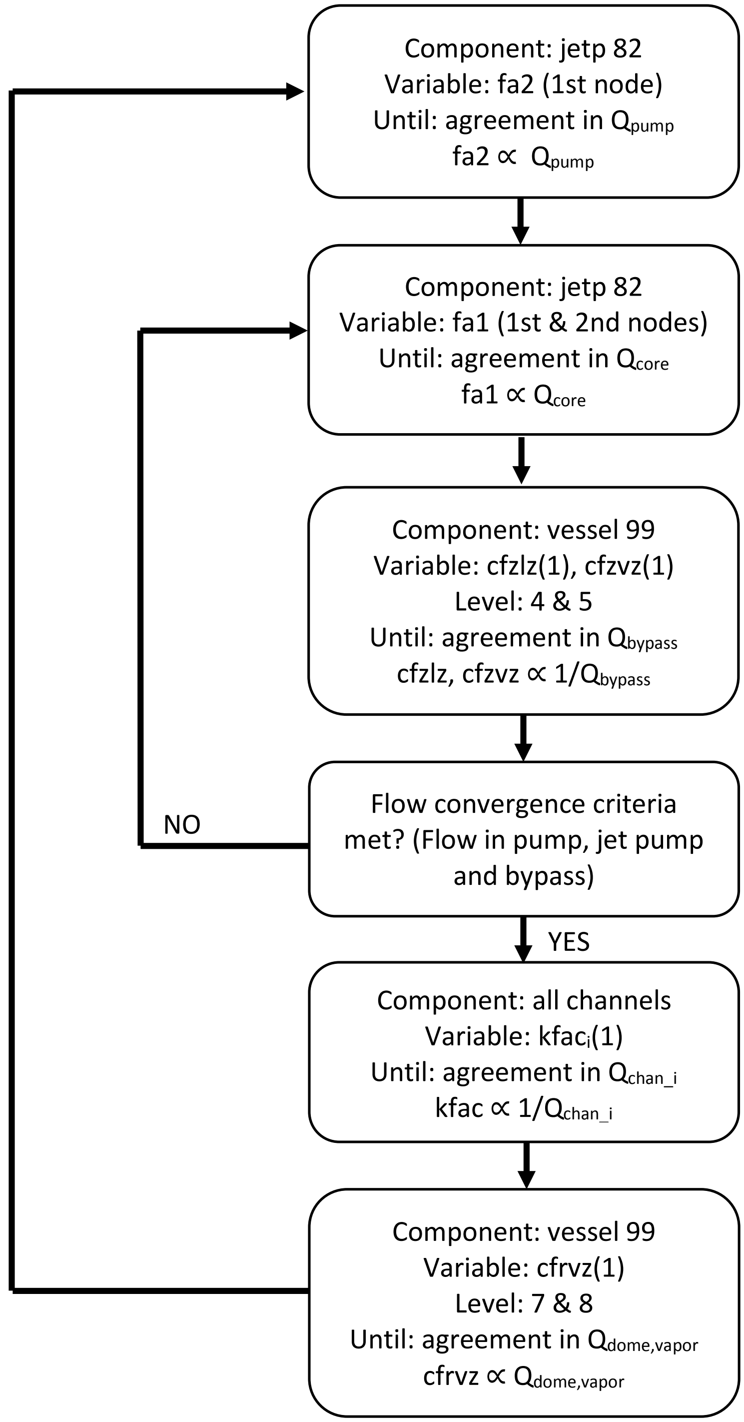

Figure 8 Proposed Algorithm for Automatic Thermal-Hydraulic Adjustment in PBTT Model

3.4 Thermal-Hydraulic Adjustment for Transient State Simulation

For the second case (transient state simulation), as in the first case, the input deck obtained following steps in section 3.1 and 3.2 is used. The modifications in the thermal-hydraulic model to simulate the Peach Bottom Turbine Trip NEA Benchmark are presented in this section, see Table 19. Therefore, the second case is validated using the Benchmark results. In order to obtain a good steady state convergence, a null transient spanning 50 seconds is simulated prior to the turbine trip accident. Thus, all times in TRACE model are shifted 50 seconds.

Component		Variable	Element	Original value	Changed value
All Channels		*kfac*	15, 18, 21, 24 and 27	1.08497 1.2141 1.2341	0.0
Jet Pump 82		*fa1*	1 2	2.5084E-2 2.9358E-2	3.5794E-2 3.7258E-2
		fa2	1 2	4.2740E-3 3.0434E-2	3.9540E-3 3.0434E-2
Pump 83		*ipmpty* *ipmptr* *ipmpsv* *npmptb* *pmptb* *npmpmt* *pmpmt*	-	3 0 1 0 - 2 -	1 1 45 14 see Figure 9 delete variable delete table
Vessel 99	level 7	*cfrlz* *cfrvz*	1 1	5.0 5.0	0.0 1E4
	level8	*cfrvz*	1	5.0	1E4

Table 19 Changes Made to Adjust the Thermal-Hydraulic Transient State Model

Due to the fact that there are no information about rotational pump speed in Benchmark specifications, the rotational pump velocity in TRACE table (second case) is obtained from TRAC-BF1 transient simulation results (first case), see Figure 9. Thus, in order to simulate a real transient state in the recirculation pump with ID 83, according to Table 19, *ipmpty* variable was changed from 3 (pump controlled by control block, TRAC-B value) to 1 (pump speed obtained from table). Then, a table containing pump-impeller rotational speed vs time is set in TRACE input deck. This table makes use of *npmptb* and *pmptb* variables, number of data pairs and its time vs. velocity points respectively.

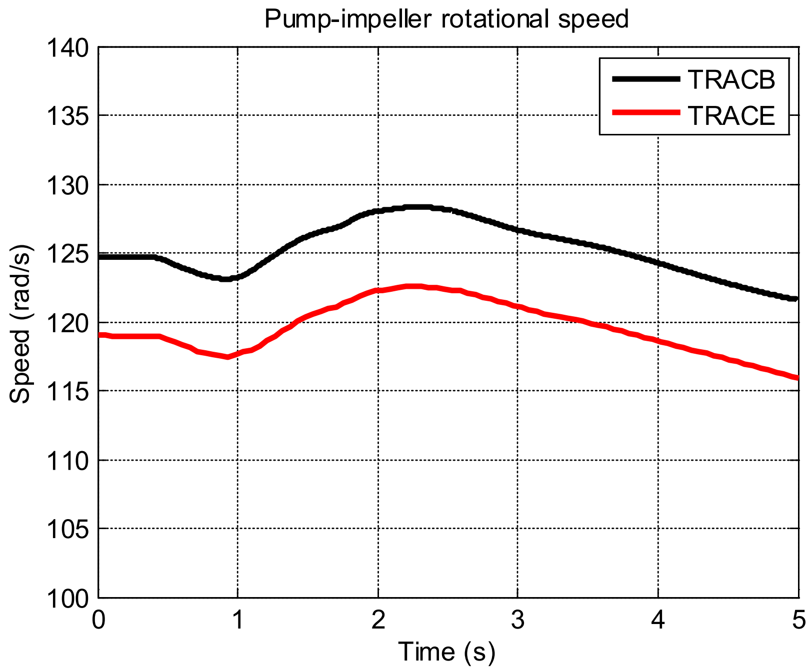

Figure 9 Pump-Impeller Rotational Speed, TRACE and TRAC-BF1 Comparison

4. RESULTS

4.1 Steady State

In this section, the results for the first case (steady state) are code-to-code compared against TRAC-BF1. In Table 20, the mass flow through the main system points are compared.

Location		TRACE (kg/s)	TRAC-BF1 (kg/s)	Abs Difference (kg/s)
Fill		982	982	0
Downcomer		9895	9845	50
Jet Pump inlet		7075	7038	37
Pump		2820	2820	0
Bypass		597	606	9
Core		9297	9245	52
Separator	Inlet (vap.)	991	759	232
	Inlet (liq.)	8903	9076	173
	Main Outlet (vap.)	960	979	19
	Main Outlet (liq.)	0	95	95
	Lateral Outlet (vap.)	27	34	7
	Lateral Outlet (liq.)	8908	8713	195
Steam line		986	979	7

Table 20 Main Components Flow for TRACE and TRAC-BF1 Comparison

Once the total flow inside vessel agrees in both models, the flow inside each channel is compared. As explained in Figure 8, to modify the flow through one channel, the first friction factor is modified according to the desired change. Figure 10 shows the core flow distribution in TRACE model and its absolute difference compared with TRAC-BF1.

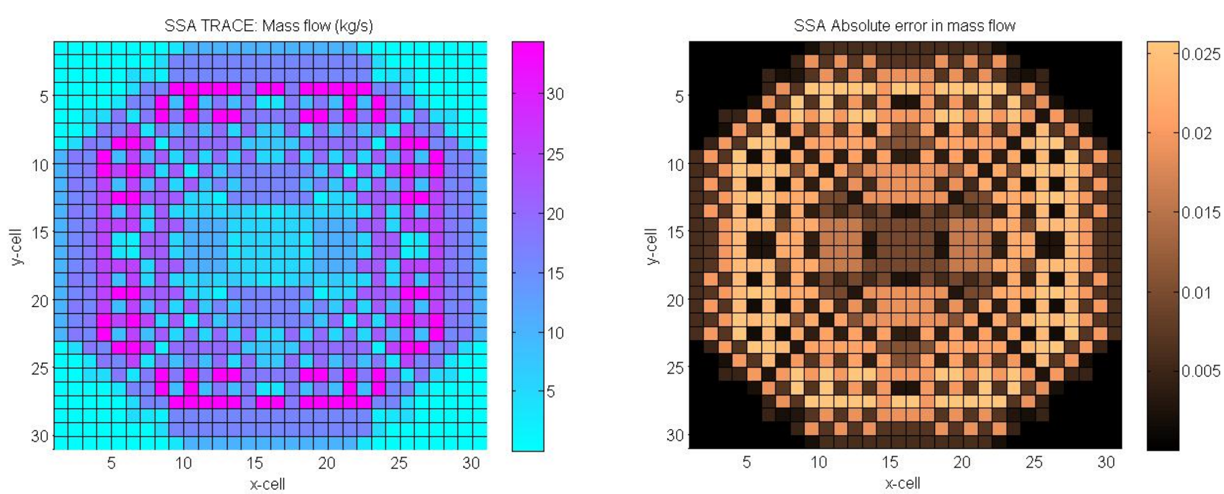

Figure 10 Core Flow Distribution in TRACE Model (Left) and Absolute Difference Between TRACE and TRAC-BF1 (Right)

Other variables, such as the liquid temperature or the void fraction could be compared. The latter is important for BWR because it has a strong effect on the separator and the neutronic calculations. It is also important to consider the axial distribution, because it is the dimension where the gradients are bigger. Figure 11 shows the mean core liquid temperature (left) and mean void distribution (right), both inside the core. Both charts compare TRAC-BF1 and TRACE codes.

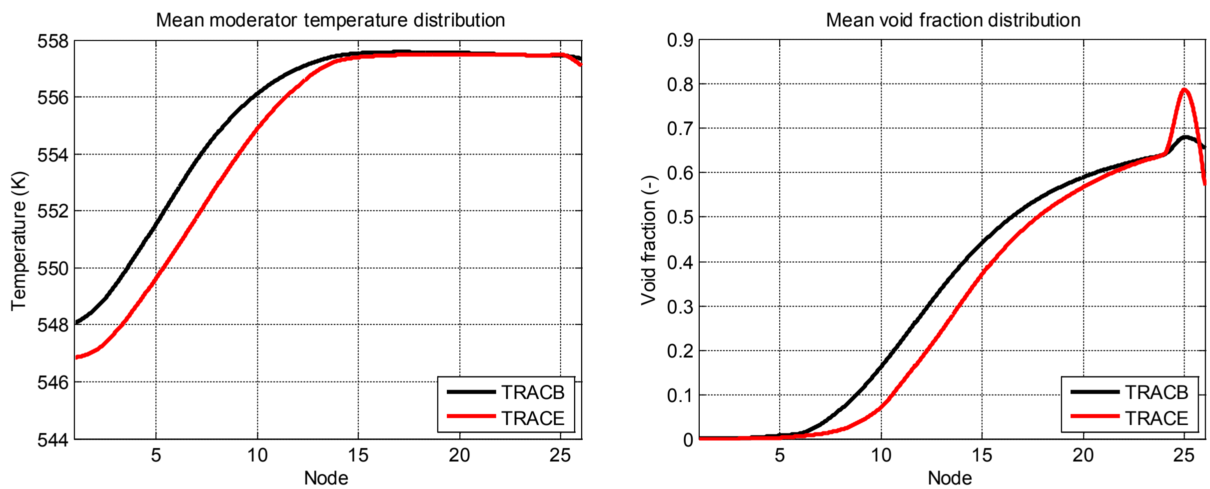

Figure 11 Mean Axial Moderator Temperature (Left) and Void Fraction (Right) Distribution

4.2 Transient State (Turbine Trip)

In Figure 12, the axial power profile for the core average before the accident is depicted in the left side. It corresponds to the initial transient simulation time. Results are shown for TRACE/PARCS coupled codes and reference (plant) code. On the right side, the total reactor power (relative to initial power) for the whole transient simulation. A 50-seconds null transient is simulated. However, the accident is shown at time 0 s in subsequent figures. Results are shown for TRACE/PARCS and Benchmark data.

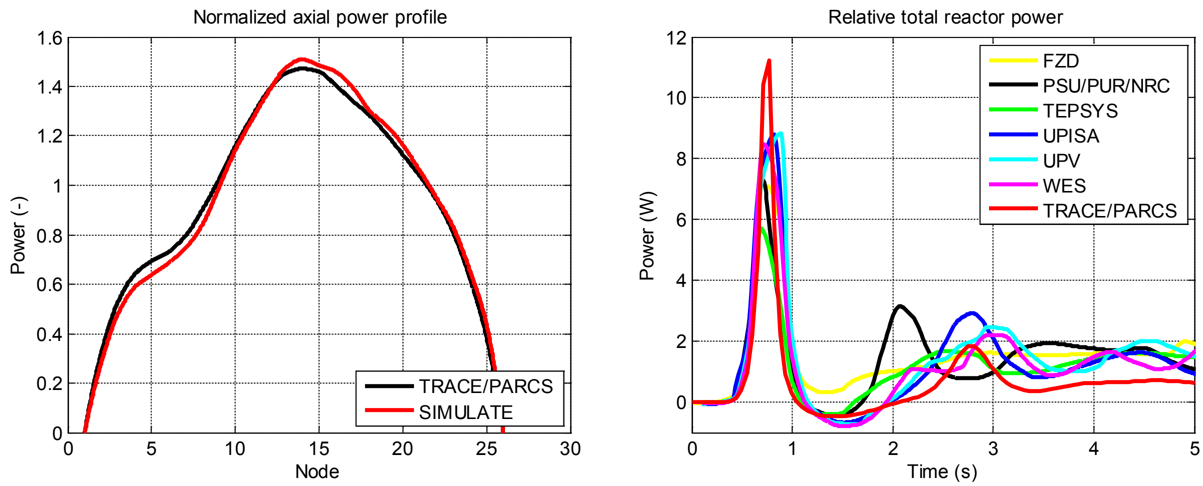

Figure 12 Core Average Axial Power Profile TRACE/Plant Data (Left) and Relative Total Reactor Power (Right) TRACE/Benchmark Data

Moreover, Figure 13 shows the pressure at dome (upper vessel cell) and core exit (vessel cell just after the channels). TRACE/PARCS and Benchmark results are shown. Besides, Doppler reactivity, moderator reactivity and total reactivity are shown in Figure 14 and Figure 15.

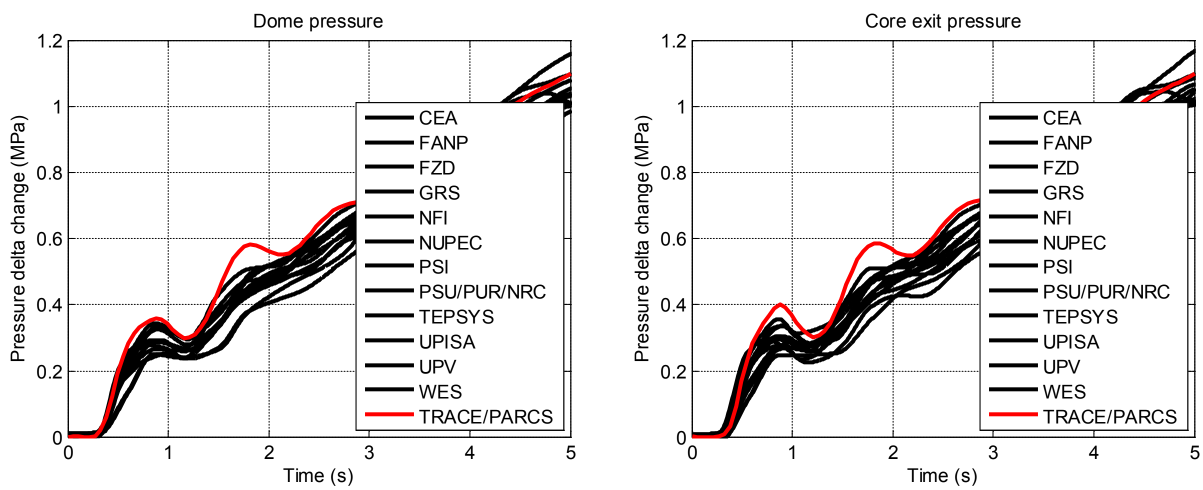

Figure 13 Dome (Left) and Core Exit (Right) Pressure, TRACE/Benchmark Data

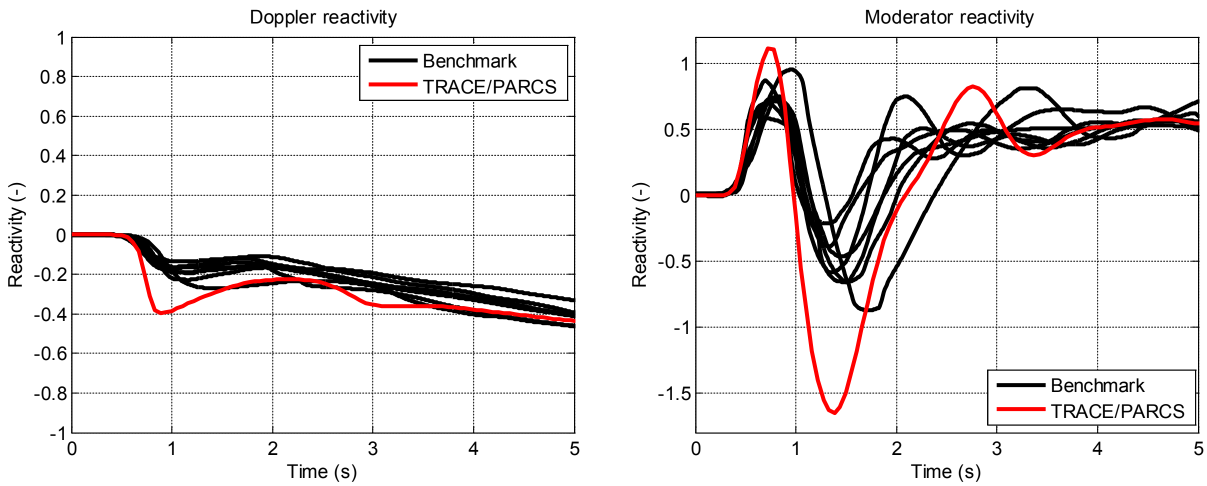

Figure 14 Doppler (Left) and Moderator (Right) Reactivity, TRACE/Benchmark Data

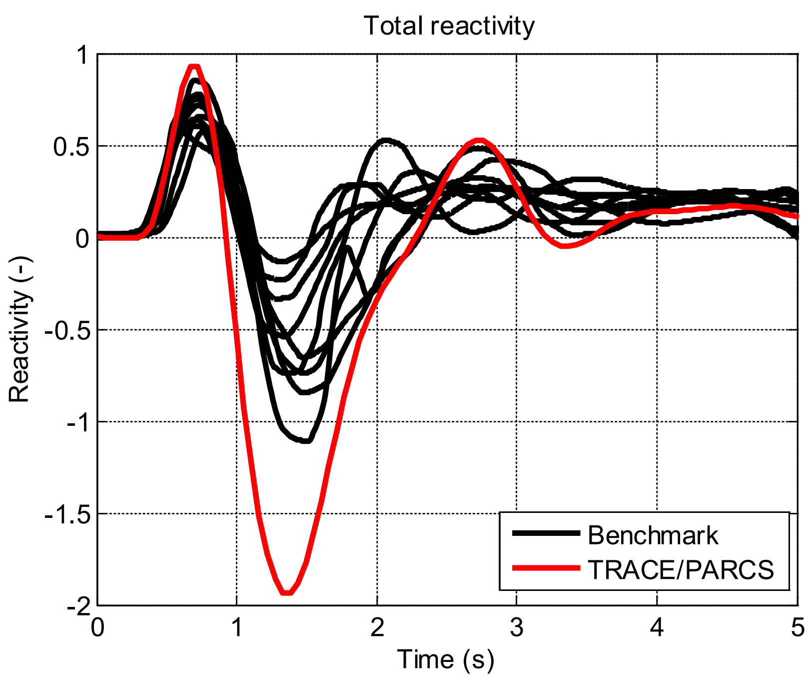

Figure 15 Total Reactivity, TRACE and Benchmark Results

5. CONCLUSIONS

A new semi-automatic translation procedure for translating models from TRAC-BF1 to TRACE is presented in this publication. It is explained how TRACE executable and SNAP tool could be used in order to achieve this translation. However, these tools are not completely error-free and afterwards several handmade corrections need to be made. The main corrections are also explained in this study. Finally, two different cases are simulated to withdraw some conclusions: a steady state case (TRACE and TRAC-BF1 comparison) and a transient state case (TRACE and Benchmark comparison).

As explained in this publication, after the conversion, some adjustments need to be made to the TRACE input deck in order to achieve a good thermal-hydraulic agreement between codes, see Table 7 to Table 17. Nevertheless, a huge amount of time is saved in comparison to begin a complete handmade translation from scratch. In addition, an algorithm for an automatic thermal-hydraulic adjustment is proposed, see Figure 8.

According to the data shown in Table 20, the flow through the main components is in agreement between codes. Due to the fact that the separator component has a strong effect on the thermal-hydraulic calculations, some discrepancies could be found on Table 20 regarding this component. The algorithm depicted in Figure 8 was followed to reach flow concordance. Thus, a good agreement can be seen in the core flow distribution (Figure 10), mean axial moderator temperature distribution and mean axial void fraction distribution (Figure 11). Special attention must be paid on the void fraction distribution since this variable determines the separator behavior after the core outlet. Moreover, in case of neutronic coupling, it can have a strong effect on the neutronic calculations. It is important the fact that the last five friction factors in channel components were suppressed, see Table 18, otherwise, some oscillations were observed in the axial void fraction distribution, obviously unreal in a BWR.

Regarding the transient simulation, a turbine trip accident is simulated successfully. Power profiles (1D and 0D) are presented in Figure 12. According to these figure, TRACE/PARCS result has a good agreement with the reference code (plant code). However, the total reactor power, shown reveals that the first power peak is slightly over predicted with respect to Benchmark participants. Besides, the dome pressure, exit core pressure and different reactivity components are in line with Benchmark participants (Figure 13 to Figure 15).

In general, the obtained results are in agreement with TRAC-BF1 for the steady state case, and Benchmark results for the transient state case.

Finally, just to mention that this work tried to present a fast general procedure for the conversion of legacy TRAC-BF1 input decks to TRACE, and in any case represents a new contribution to the results of the NEA Boiling Water Reactor Turbine Trip (TT) Benchmark. This Benchmark was selected for this work because availability of the data for both steady state and transient scenarios.

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10. SUPPLEMENTARY NOTES

K.Tien, NRC Project Manager

11. ABSTRACT (200 words or less)

In order to keep old models updated, a methodology to translate models from TRAC-BF1 to TRACE is developed at Universitat Politècnica de València. An additional advantage for this translation is that current and future TRACE features can be applied to the translated model. The methodology makes use of the TRACE executable and its feature to read TRAC-BF1 input decks and create the appropriate restart. Then, the restart file can be imported to SNAP tool and later exported as ASCII file. However, the methodology is said to be semi-automatic because some errors are done in the process. These errors must be corrected by hand as explained in this document. As an example of the semi-automatic methodology, the Peach Bottom (PB) model in TRAC-BF1 is translated to TRACE. Nonetheless, the methodology is not exclusive for Peach Bottom. Rather, this study is presented to help any other TRAC-BF1 to TRACE translation, regardless of the plant model. Two different cases are presented in this document, both modeling PB. First, the translated model is code-to-code compared in steady state. Moreover, to test the transient model, the second case is a modification of the translated original model to simulate the Peach Bottom Turbine Trip (PBTT). This case is compared with the Benchmark participant results. In general good agreements are obtained for both cases. However, thermal-hydraulic adjustments must be made prior to the comparisons. A schematic framework for these modifications is presented.

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