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Evaluation of computer codes for nuclear safety analyses in the Czech Republic

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Outlook

- Introduction
- Computer Code Classification
- Comissions structures
- Software Evaluation
- SWAMUP-II ATHLET 3.1A Patch 1 for SCWL Applications
- HEFUS-3 TRACE 5 Patch 4 for Helium Technology Applications
- THAI and PHEBUS FPT3 MELCOR 2.1 v. 6342 for Severe Accident Applications
- Conclusion

Introduction of Qualification Procedure

The importance of software for nuclear safety is covered by the requirements of several decrees, which are (Act No. 263/2016 Coll).:

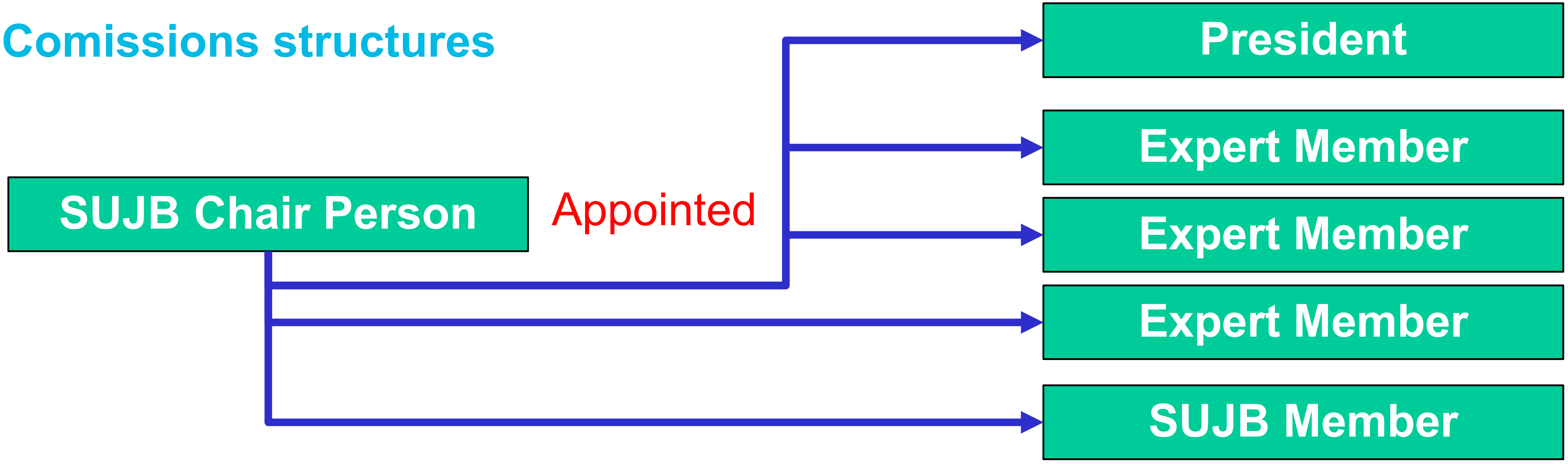
- SÚJB DECREE No. 329 of 26 September 2017 on Requirements for a Nuclear Installation Design, which in § 25 (2) explicitly requires that in the safety assessment verified methods corresponding to the currently achieved level of science and technology should be used
- SÚJB DECREE No. 162 of 25 May 2017 on Safety Assessment Requirements under the Atomic Act, which in § 3 "General Safety Assessment Requirements", para (1) also requires that safety assessment be performed according to current and practical application proven methodologies in line with current science and technology levels and good practice, and also
- SÚJB DECREE No. 408 of 6 December 2016 on Requirements for a Management System whose general objective is ensuring and improving the level of nuclear safety and radiation protection

Computer Code Classification

- Reactor physic calculations
- Thermohydraulic analyses
- Calculations of nuclear fuel behaviour
- Analysis of severe accidents
- Strength calculations of components and piping systems
- Calculations of radioactive products propagation
- Probabilistic safety and reliability analyses.

For each of these areas, an expert evaluation committee has been established

Comissions structures



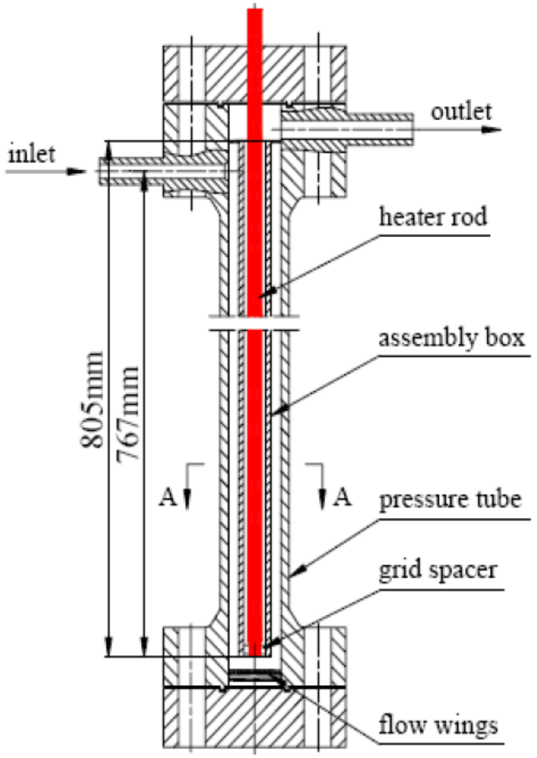
The comission should evaluate computer codes:

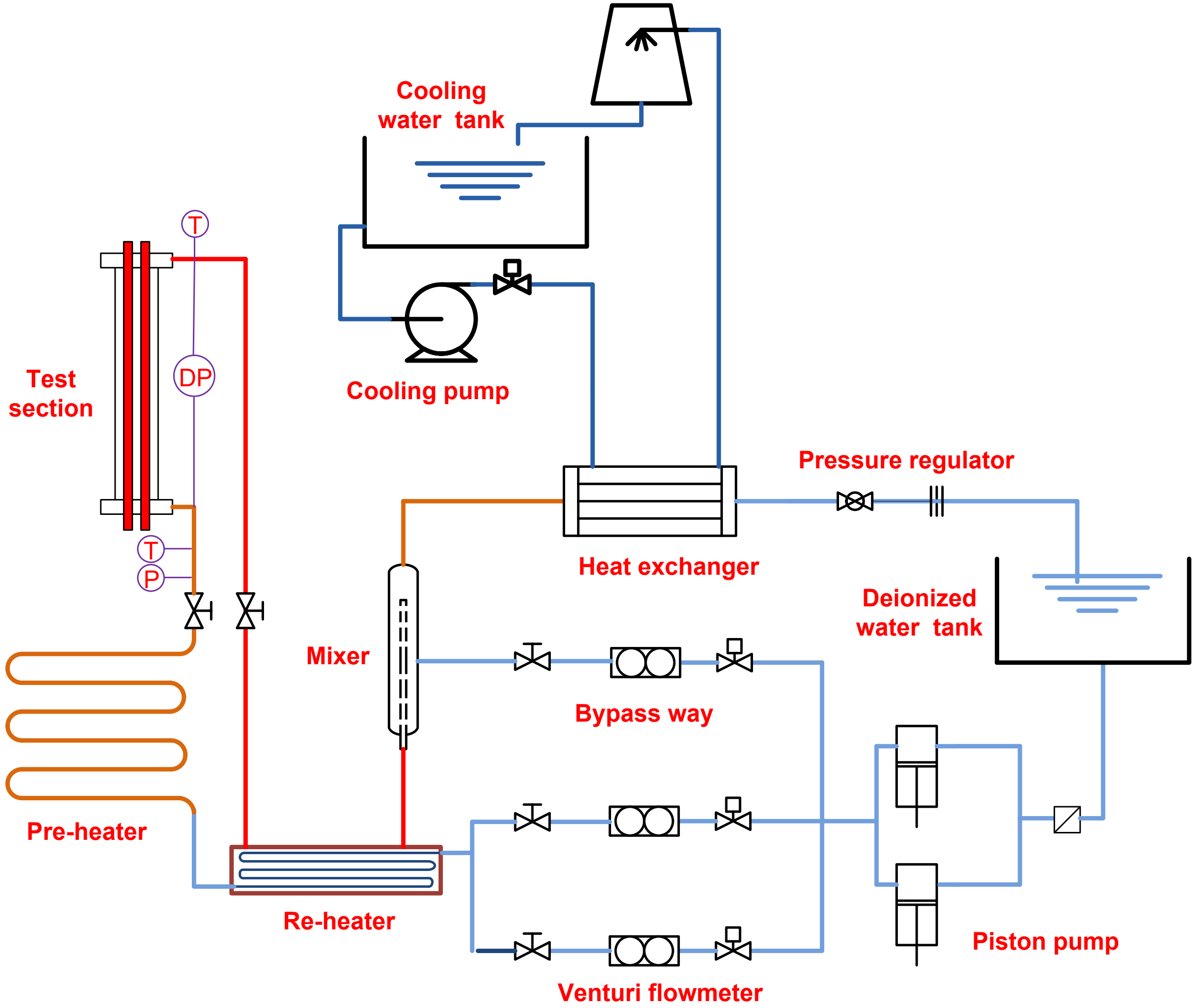
- quantitative results
- qualitative results
- indicating the quality of the software product a
- user's ability to use it in applications to Czech nuclear facilities.

Software Evaluation

1. The evaluation starts when an applicant for evaluation in a letter addressed to SÚJB
2. Request for the evaluation is forwarded to an appropriate Commission.
3. Codes can only be evaluated after providing the legal acquisition
4. The request at SÚJB is documented, inter alia by:
   - an evidence that the author's organization holds a quality assurance document
   - an evidence that the authors ' organization agrees to carry out the evaluation,
5. Other key documents for the evaluation of the code that the submitting organization must provide include:
   - Abstract of the code (Code Summary)
   - Technical report(s) on code testing
   - User Guide - manual instructions for using the program

SWAMUP-II Facility

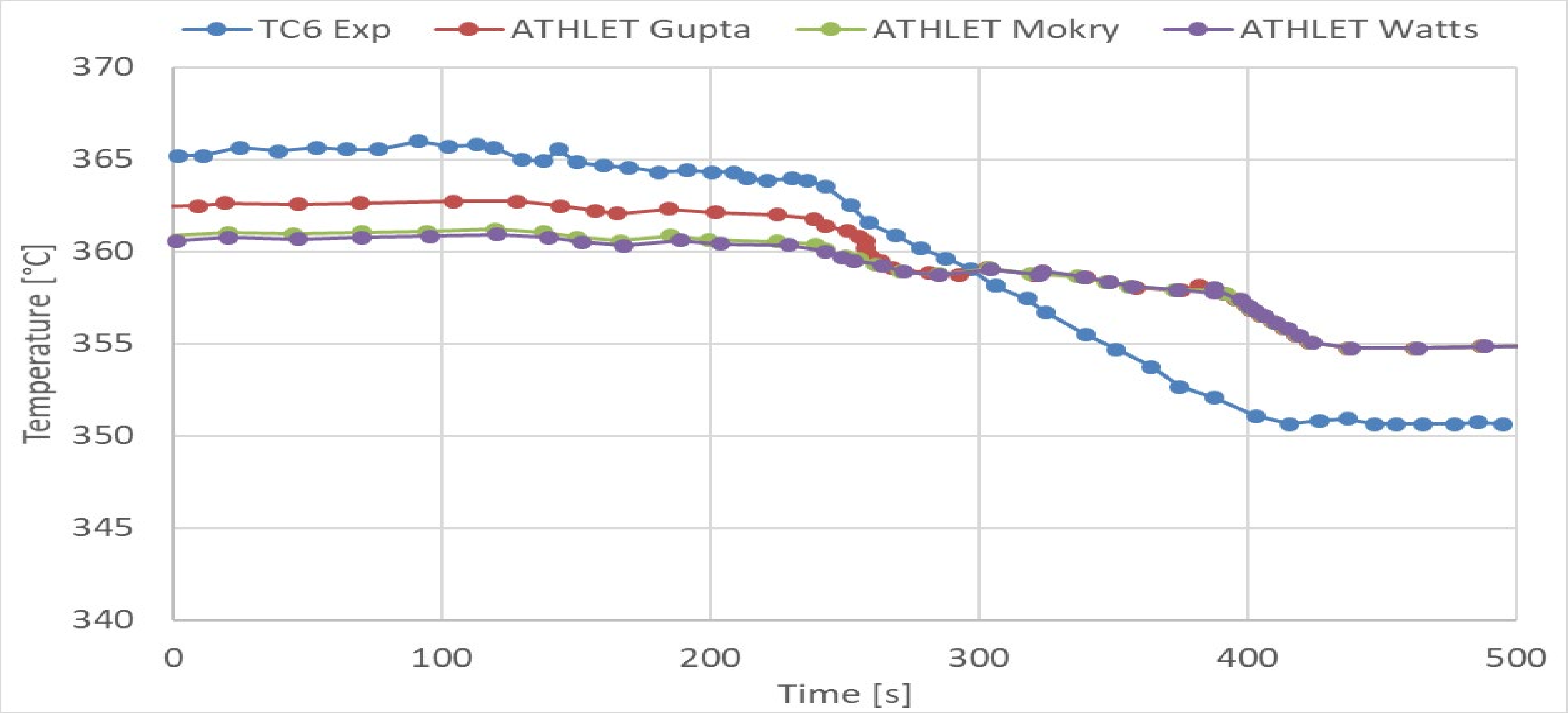




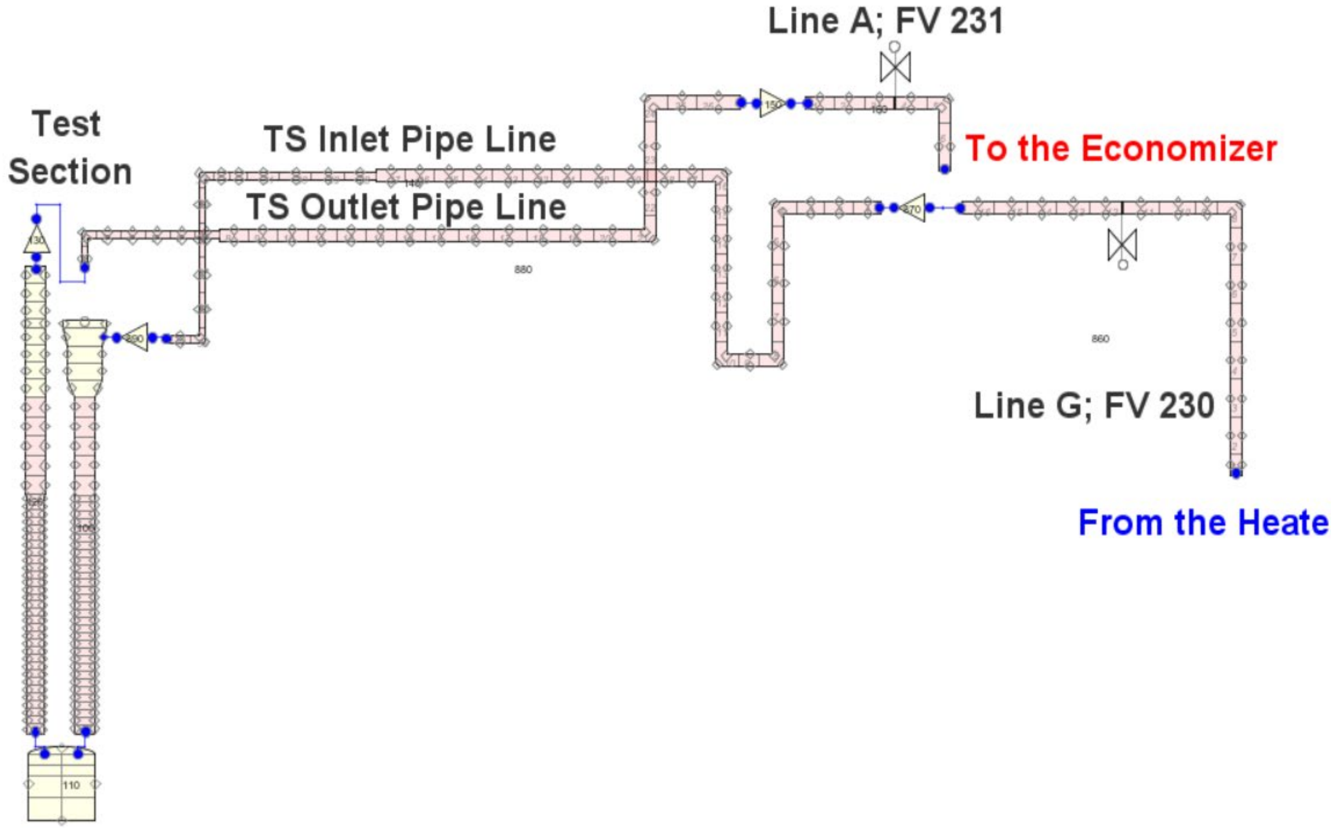
No.	Initial Pressure [MPa]	Final Pressure [MPa]	Maximal Δ Pressure [$MPa.min^{-1}$]	Mass flux [$kg.m^{-2}s^{-1}$]	Heat flux [$kW.m^{-2}$]	Inlet Temperature [°C]
Case 2-D	25	17	-2	1410	428.5	345

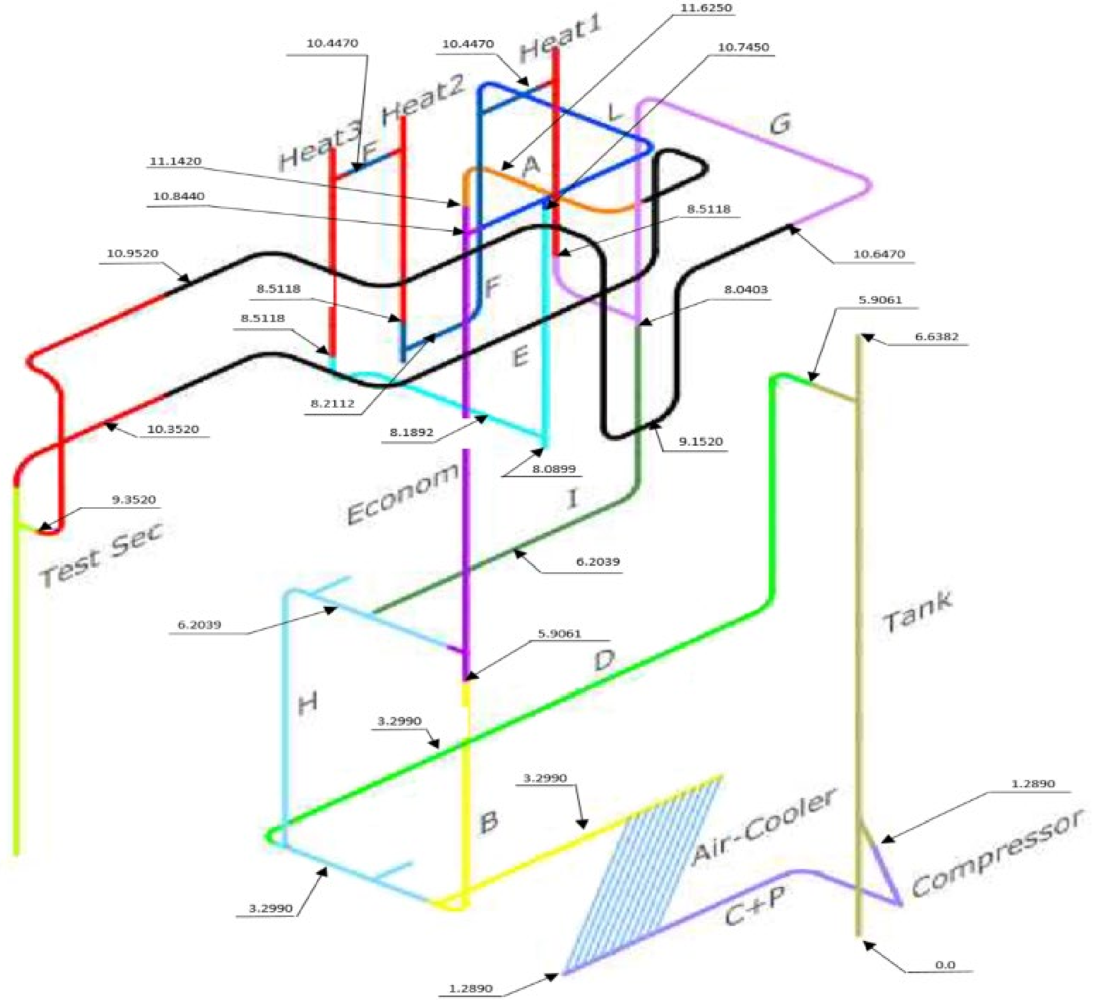
From SCRIPT Project

SWAMUP - TC6 Rod Temperature



HEFUS-3 Nodalization

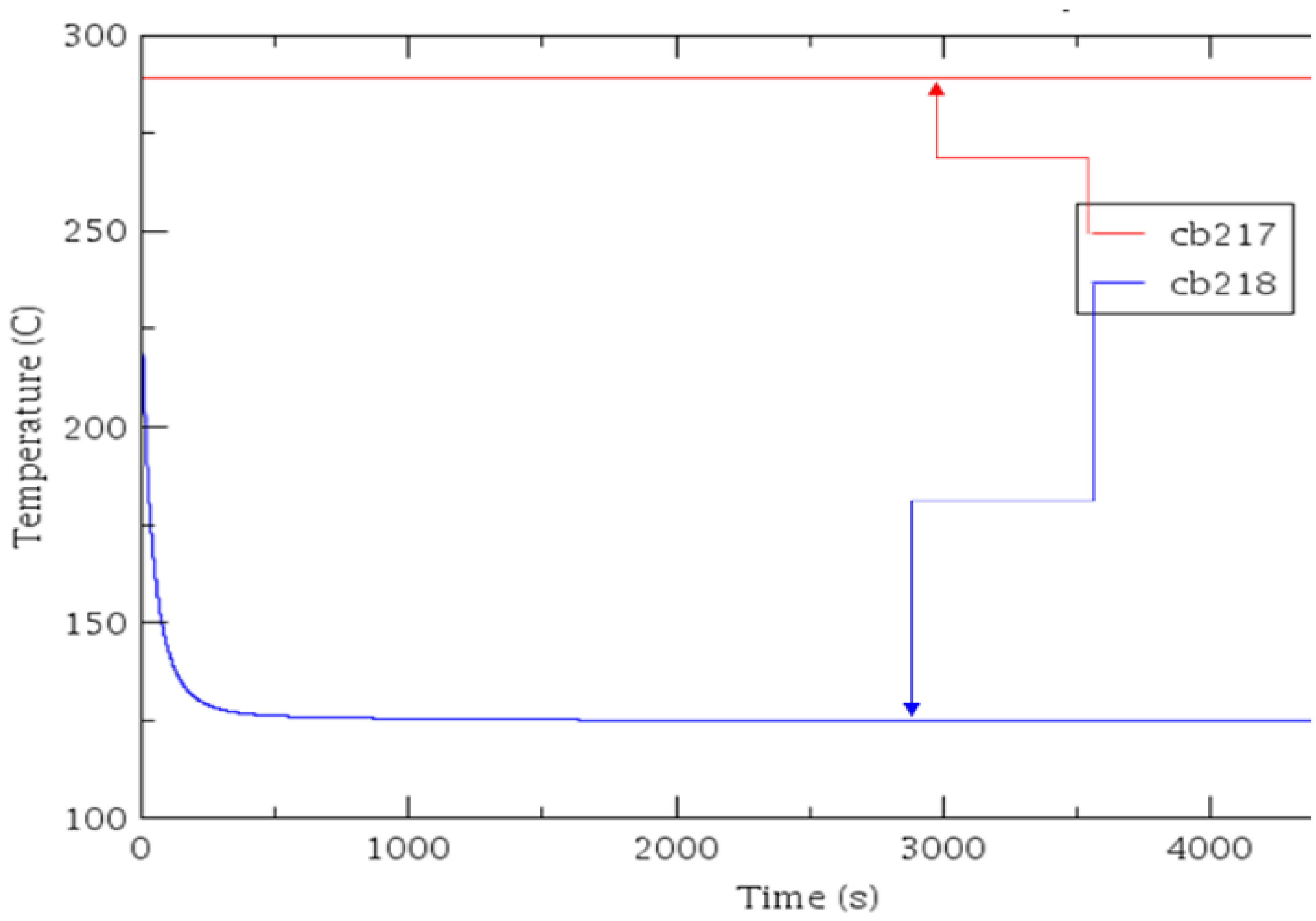




From GoFASTER Project

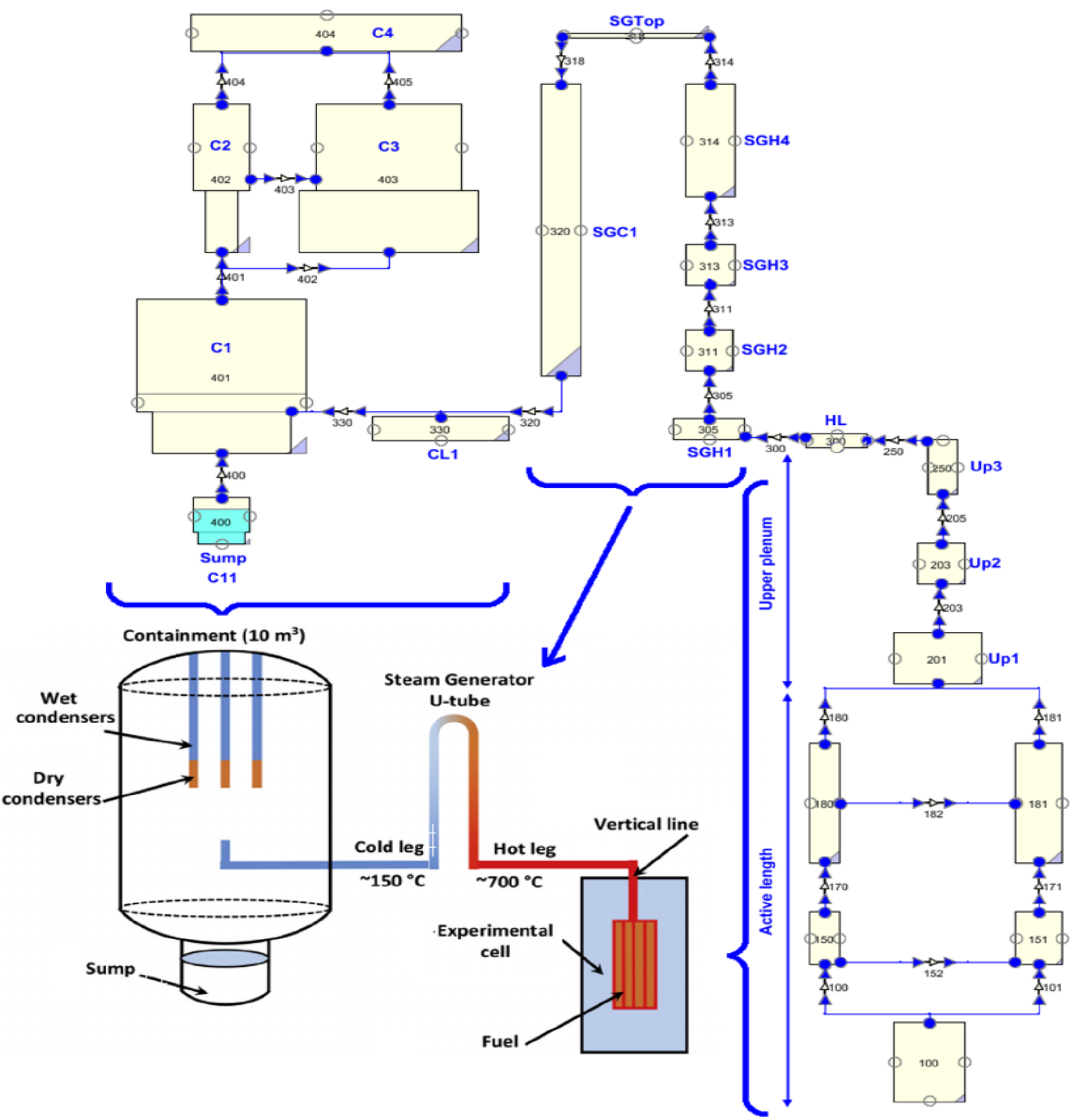
Fig. 6 - He-FUS3 piping layout 3D sketch [9] ID	Parameter	ID	Parameter
TR 218	Economizer Outlet Temperature (Hot Side) [°C]	TR 221	Heater E219/3 Outlet Temperature [°C]
TR 217	Economizer Inlet Temperature (Hot Side) [°C]	TIC 222X	Heater E219/2 Outlet Temperature for Power Regulation [°C]
TIC 223X	Heater E219/1 Outlet Temperature for Power Regulation [°C]	TIC 232X	Test Section Inlet Temperature for Regulation Valves V234/V213 [°C]
TE 101	Test Section Inlet Temperature [°C]	TE 102	Test Section Outlet Temperature [°C]

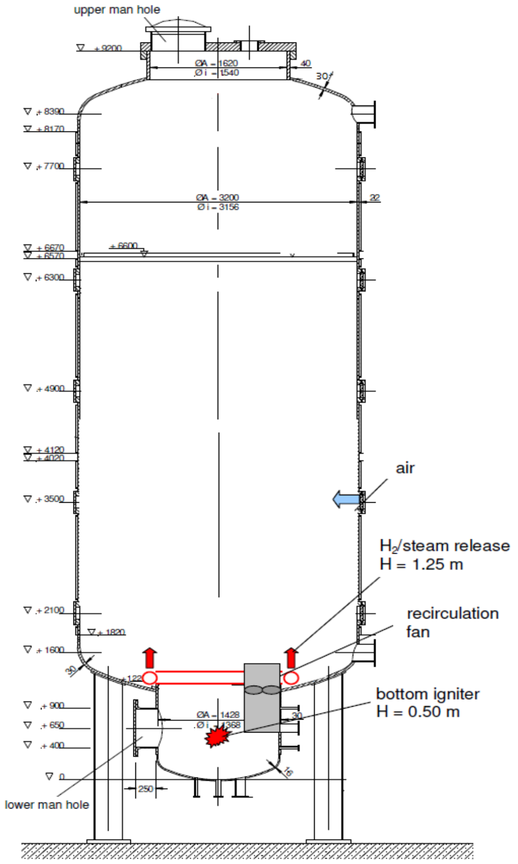
He-FUS3 Steady State #1 Selected Parameters					Difference	
Parameter	ID_{exp}	Value [°C]	ID_{cal}	Value [°C]	°C[(a)]	%[(b)]
TS Inlet Helium Temperature	TE 101	230	cb_101	234.1	4.1	1.78
TS Outlet Helium Temperature	TE 102	292	cb_102	294.0	2	0.68
Economizer Inlet Temperature (Hot Side)	TR 217	289	cb_217	291.3	2.3	0.80
Economizer Outlet Temperature (Hot Side)	TR 218	122	cb_218	123.1	1.1	0.90
Heater E219/3 Outlet Temperature	TR 221	237	cb_221	240.0	3	1.27
Heater E219/2 Outlet Temperature	TIC 222X	235	cb_222	239.1	4.1	1.74
Heater E219/1 Outlet Temperature	TIC 223X	235	cb_223	237.5	2.5	1.06
TS Inlet Temperature - Regulation	TIC 232X	233	cb_232	236.7	3.7	1.59

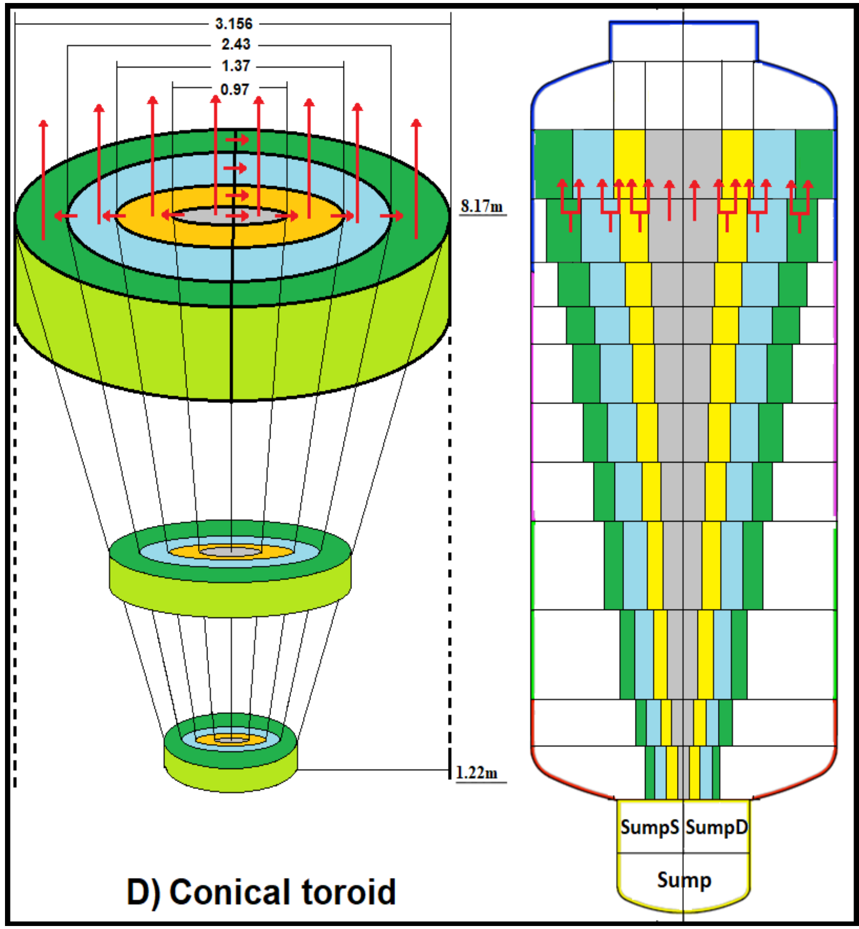


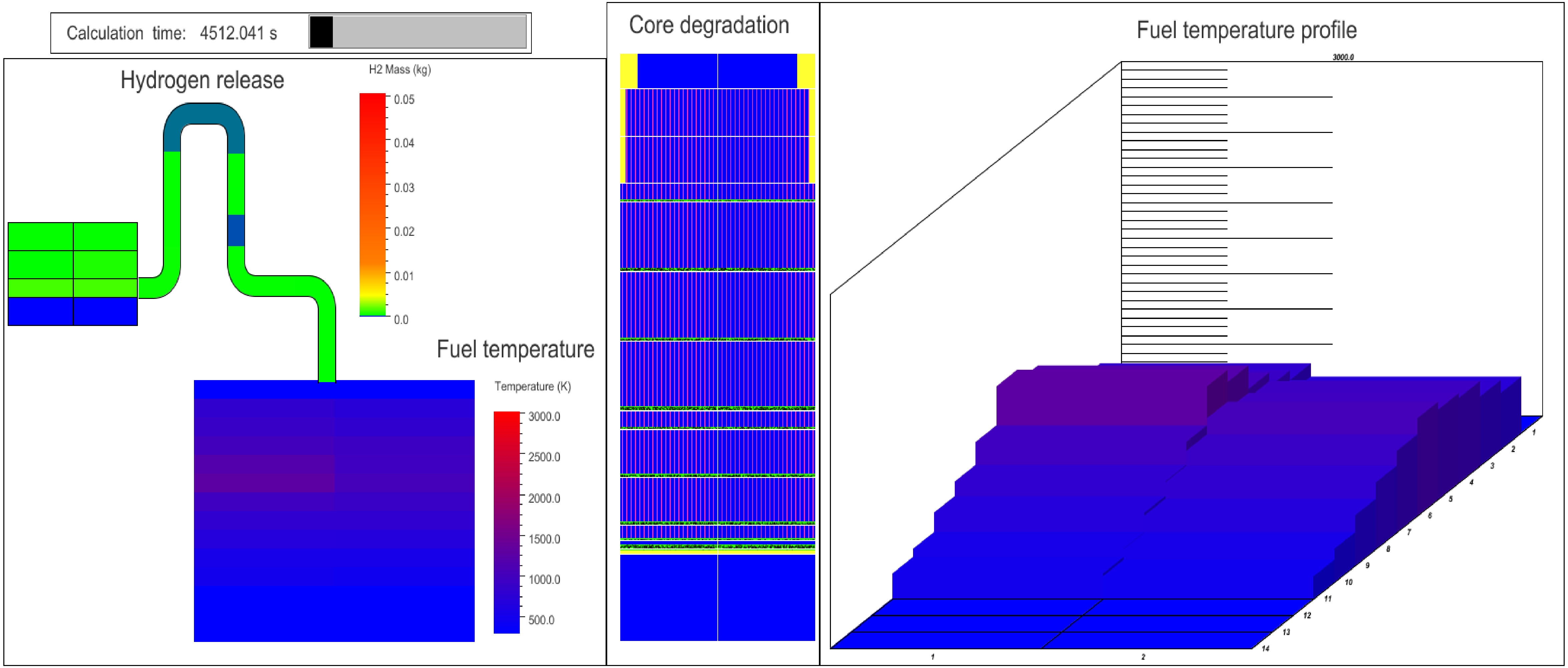
300
250
200
150
100
Temperature (C)
0
1000
2000
3000
4000
Time (s)
cb217
cb218

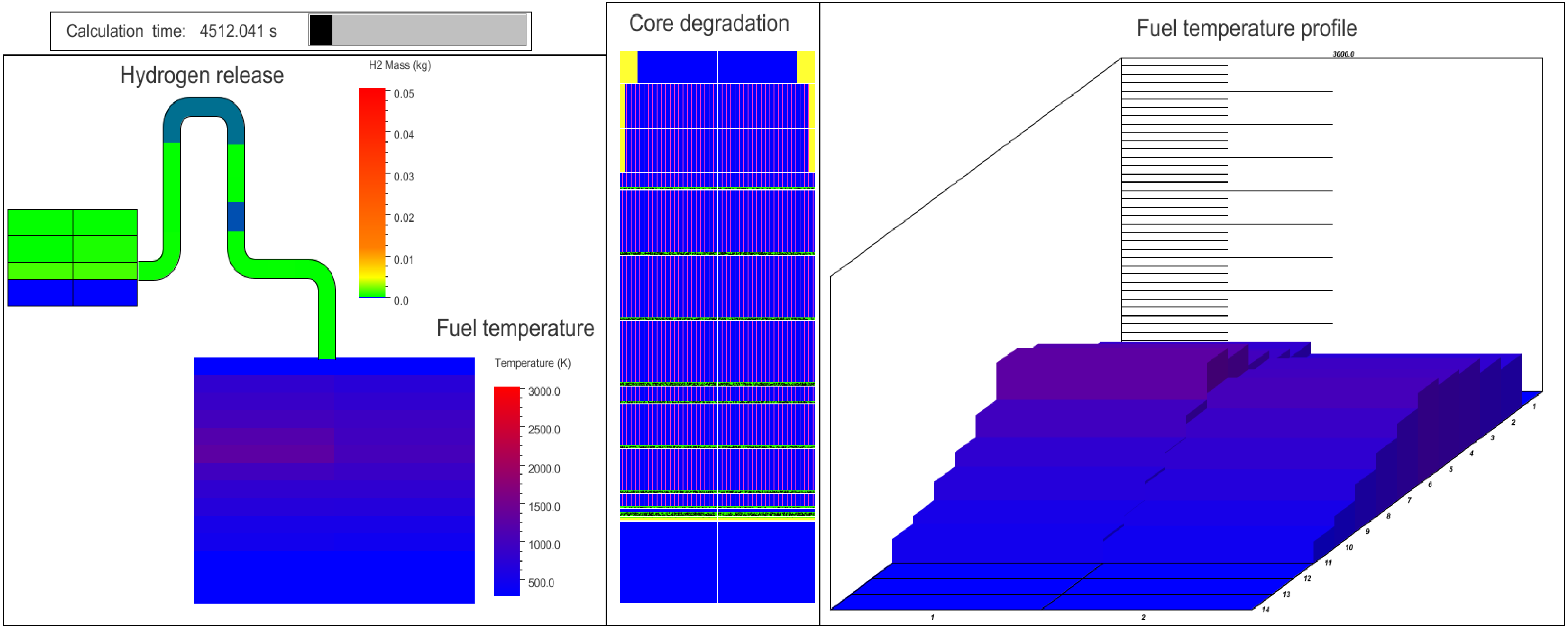
THAI and PHEBUS FPT3 Models



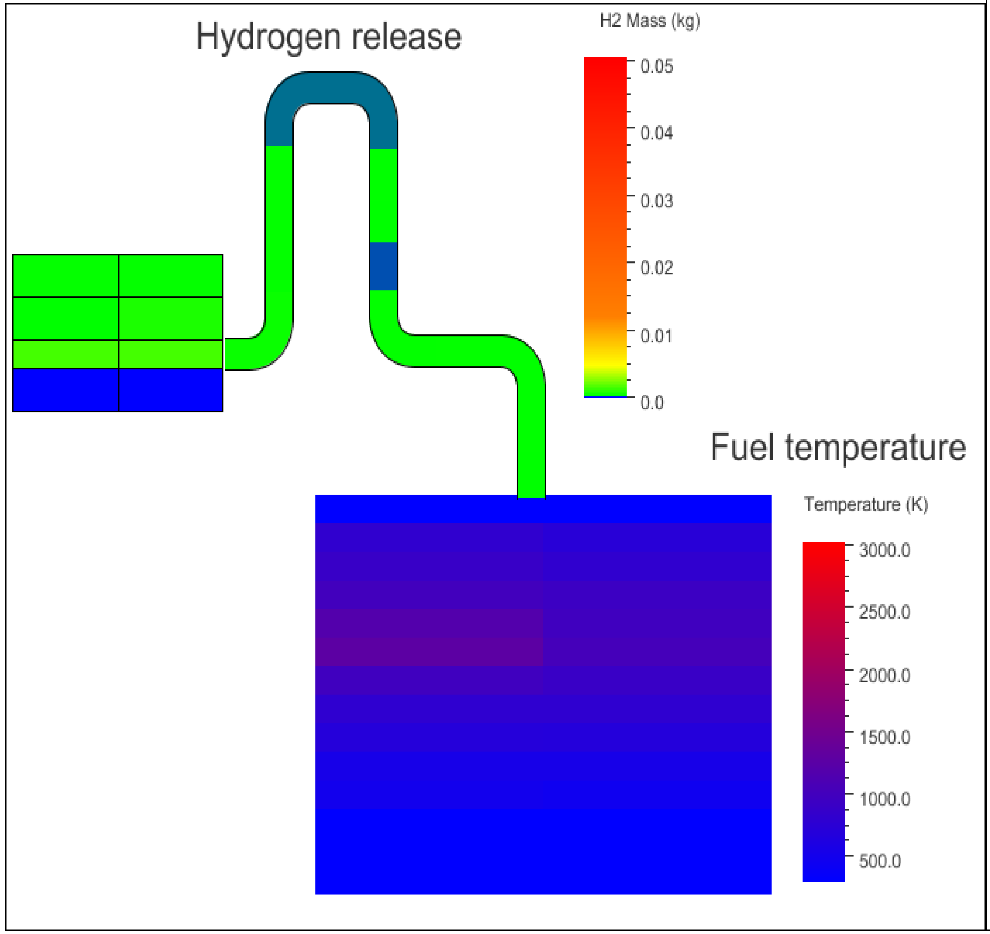


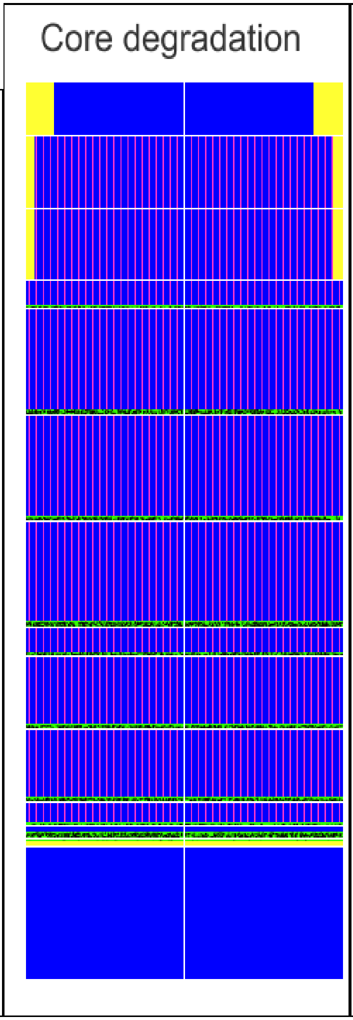


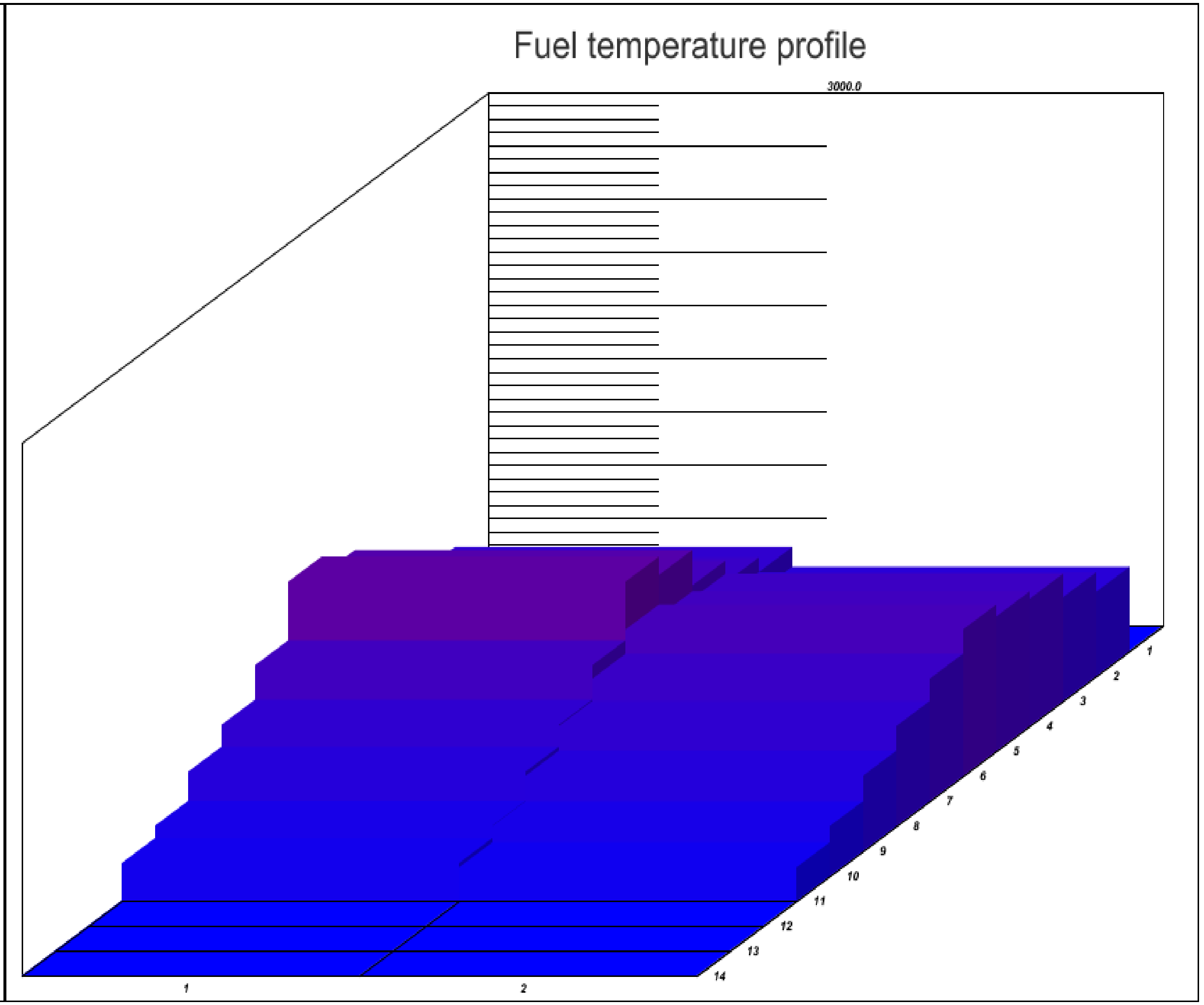

Calculation time: 4512.041 s
Hydrogen release
H2 Mass (kg)
0.05
0.04
0.03
0.02
0.01
0.0
Fuel temperature
Temperature (K)
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
Core degradation
Fuel temperature profile
3000.0

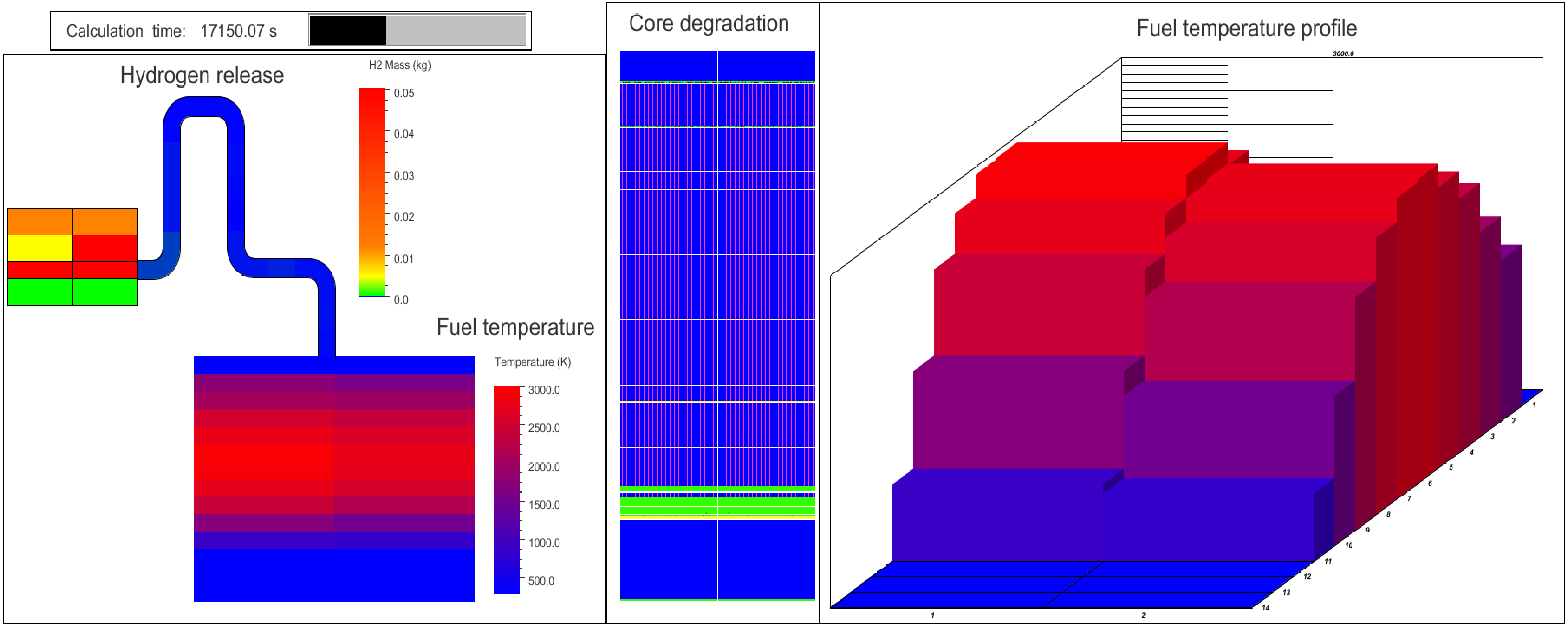

Calculation time: 4512.041 s
Hydrogen release
H2 Mass (kg)
0.05
0.04
0.03
0.02
0.01
0.0
Fuel temperature
Temperature (K)
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
Core degradation
Fuel temperature profile
3000.0

Calculation time: 4512.041 s

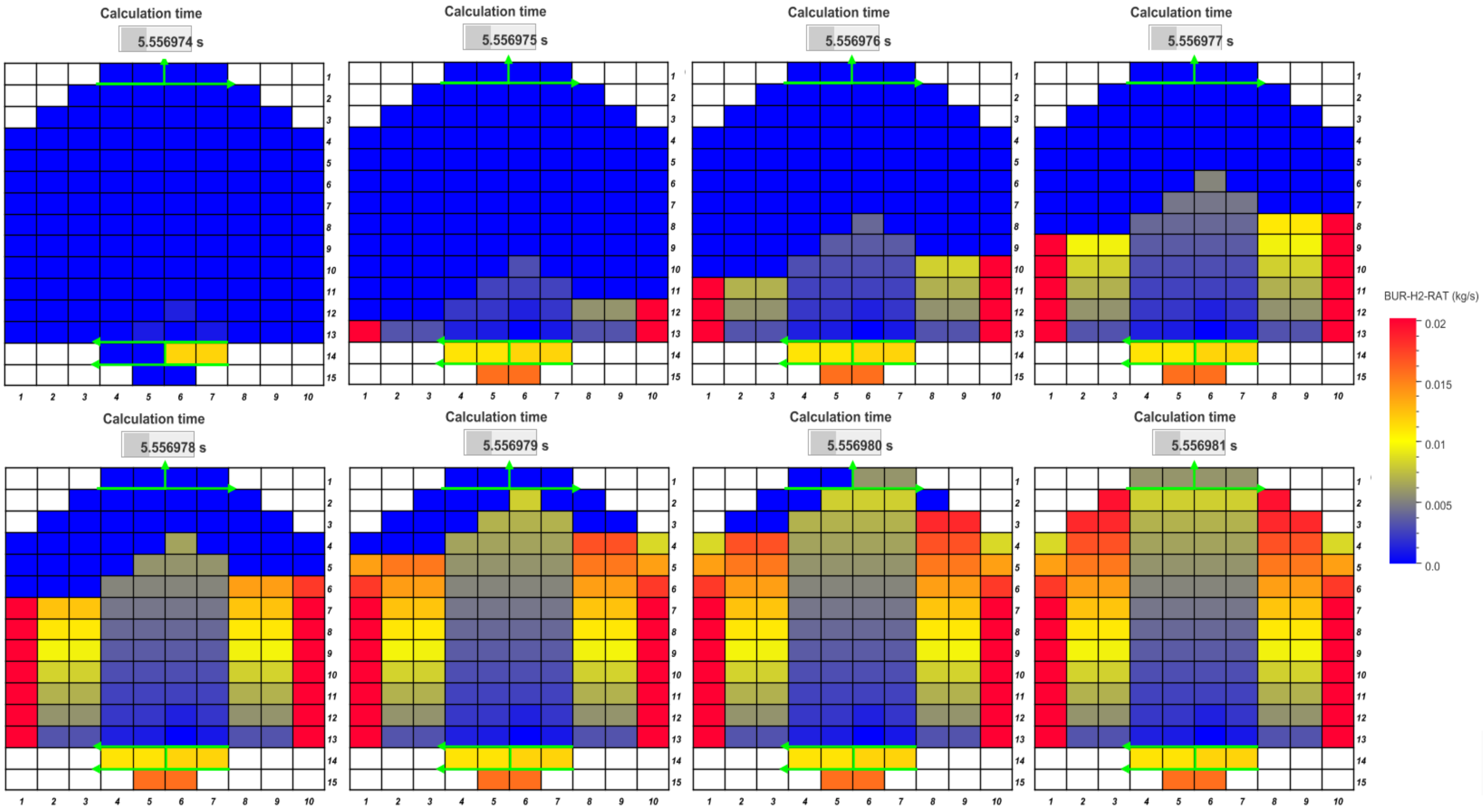








Calculation time: 17150.07 s
Hydrogen release
H2 Mass (kg)
0.05
0.04
0.03
0.02
0.01
0.0
Fuel temperature
Temperature (K)
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
Core degradation
Fuel temperature profile
3000.0


Calculation time
5.556974 s
Calculation time
5.556975 s
Calculation time
5.556976 s
Calculation time
5.556977 s
Calculation time
5.556978 s
Calculation time
5.556979 s
Calculation time
5.556980 s
Calculation time
5.556981 s
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
BUR-H2-RAT (kg/s)
0.02
0.015
0.01
0.005
0.0

2019

Conclusion

- The presentation describes the procedure for code qualification in the Czech Republic
- The procedure takes into account several different field areas such as: Reactor physic calculations, Thermohydraulic analyses, Calculations of nuclear fuel behaviour, Analysis of severe accidents, Strength calculations of components and piping systems, Calculations of radioactive products propagation and Probabilistic safety and reliability analyses.
- Some examples of the CVR codes qualification activities are presented using:
- SWAMUP-II test facility for ATHLET 3.1A Patch 1
- HEFUS-3 facility for TRACE 5 Patch 4
- THAI and PHEBUS FPT3 tests for MELCOR 2.1 v. 6342

Thank you for your Attention

Part of the work was done under the project of Ministry of Interion of the Czech Republic "More accurate prediction of radiological consequences of severe accidents at NPP aimed in identification of their risks" (VI20172020076).