AER Benchmark Specification Sheet

1. Test ID: AER-CFD-001

2. Short Description:

In the VVER-440/213 type reactors, the core outlet temperature field is monitored with in-core thermocouples, which are installed above 210 fuel assemblies. These measured temperatures are used in determination of the fuel assembly powers and they have important role in the reactor power limitation. For these reasons, correct interpretation of the thermocouple signals is an important question. In order to interpret the signals in correct way, knowledge of the coolant mixing in the assembly heads is necessary. Computational fluid dynamics (CFD) codes and experiments can help to understand better these mixing processes and they can provide information which can support the more adequate interpretation of the thermocouple signals.

This benchmark deals with the 3D CFD modeling of the coolant mixing in the heads of the profiled fuel assemblies with 12.2 mm rod pitch. Two assemblies of the 23rd cycle of the Paks NPP's Unit 3 are investigated. One of them has symmetrical pin power profile and another possesses inclined profile.

3. Submitted by: Attila Aszódi, Sándor Tóth (Budapest University of Technology and Economics)

Date: September 21, 2009.

4. Reviewed by: (name)

Date:

5. Accepted by: (name)

Date:

6. Objective:

The objective of this benchmark is detailed investigation of the coolant mixing in the head parts of the profiled VVER-440 fuel assemblies using CFD codes. The goal is comparison of the participants' results with each other and with in-core measurement data of the Paks NPP in order to test the different CFD codes and applied CFD models (used mesh, turbulence models, difference schemes, etc.). Measured data will not be published preliminary so this is a blind benchmark.

7. Rationale for Test Setup:

In the last few years, some members of the VVER community investigated the coolant mixing in the VVER-440 assembly heads with CFD codes [1]-[6]. Common conclusion of these investigations is that the coolant mixing is imperfect in the assembly heads therefore the thermocouple signals and the outlet average coolant temperatures of the assemblies generally differ. In these calculations, several VVER-440 fuel assemblies (different geometries with different boundary conditions) were investigated with various CFD codes (CFX, FLUENT, etc.) and with various models (different meshes, difference schemes, turbulence models etc.). For these reasons, the results of the individual models were not comparable. In this benchmark, the same fuel assemblies are investigated by the participants thus the results calculated with different codes and models can be compared with each other.

8. Input:

Two profiled fuel assemblies of the 23rd cycle of the Paks NPP's Unit 3 are investigated in this benchmark. One of them is in its second burnup cycle (223 EFPD in the second cycle) and it is located in the inner region of the reactor core. The other assembly is in its first burnup cycle (110 EFPD) and it is in the periphery of the core. The main characteristics of the selected assemblies are summarized in Table 1.

Table 1. Main characteristics of the selected fuel assemblies

Notation	Characteristics	Burnup cycle	Operational time in cycle [EFPD]	Power [MW]	Mass flow rate [kg/s]	Inlet temperature [°C]	Pressure [bar]
323_17	Internal	2	223	4.565	23.76	265.30	123.12
323_34	Peripheral, 5 neighbours	1	110	3.826	23.76	264.98	123.12

a, Geometry

The model geometry of the assembly heads is provided for the participants in *.iges and *.tin (ICEM CFD geometry format) file format. The *.iges and *.tin files will be distributed directly to the participants. Please write an e-mail to aszodi.attila@reak.bme.hu and toth.sandor@reak.bme.hu to require the files.

The model is based on the technical documentation of the profiled VVER-440 fuels with 12.2 mm rod pitch. It contains the upper part of a fuel assembly from the end of the rod bundle's active part and a channel of the protective tube unit's lower plate, which includes an in-core thermocouple.

b, Boundary conditions

The inlet temperature and velocity fields of the assembly heads are given at the ends of the active rod bundles (Figures 1 and 2). The entrance fields were determined with the COBRA subchannel code using the nodal pin powers from cycle following calculations with C-PORCA code, the mass flow rates and the inlet coolant temperatures of the assemblies [7]. The temperature and velocity data are given in MS Excel files (323_17.xls and 323_34.xls files) as subchannel average values according to the COBRA subchannel code numbering (Figure 3).

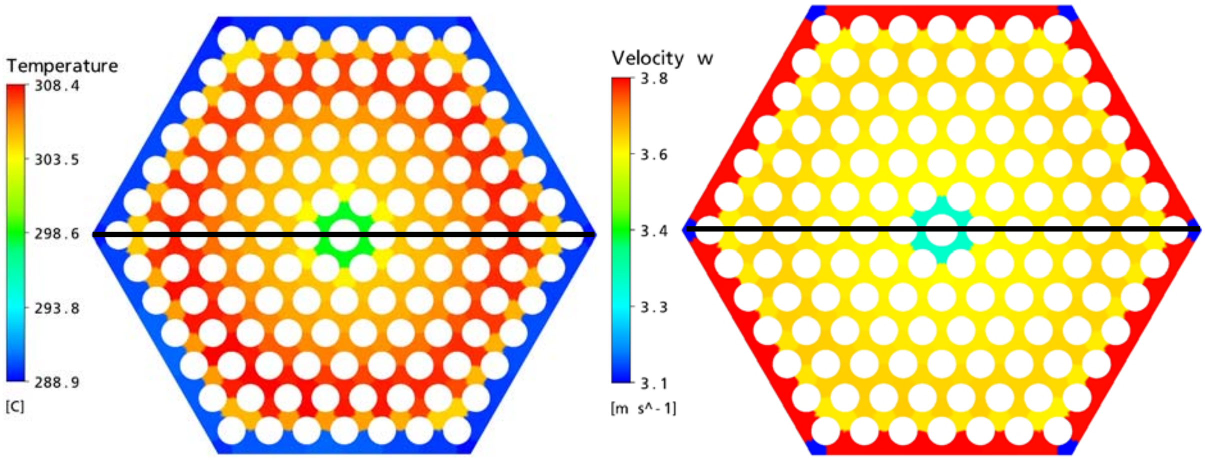

Figure 1. Inlet temperature and velocity fields of assembly head model (323_17 fuel assembly).

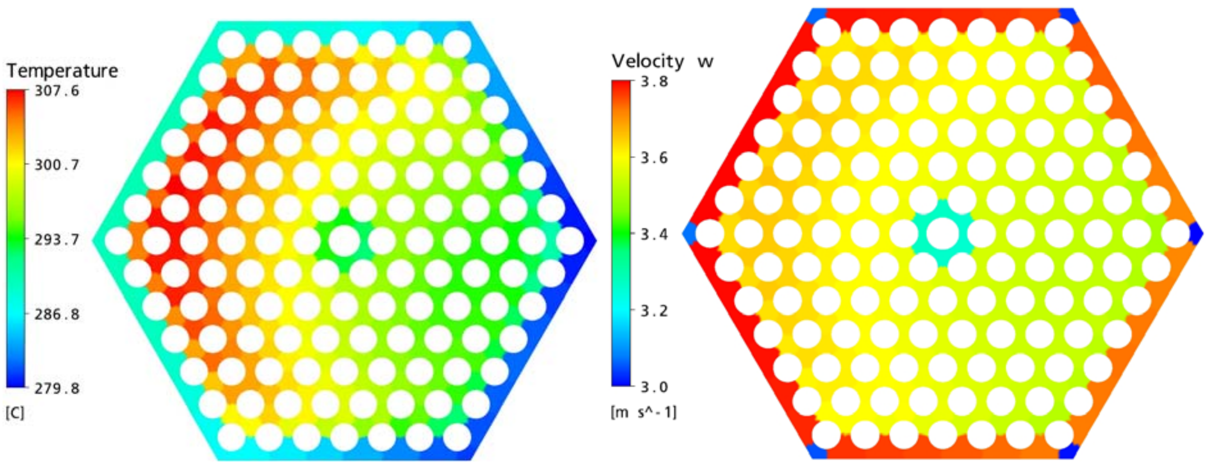

Figure 2. Inlet temperature and velocity fields of assembly head model (323_34 fuel assembly).

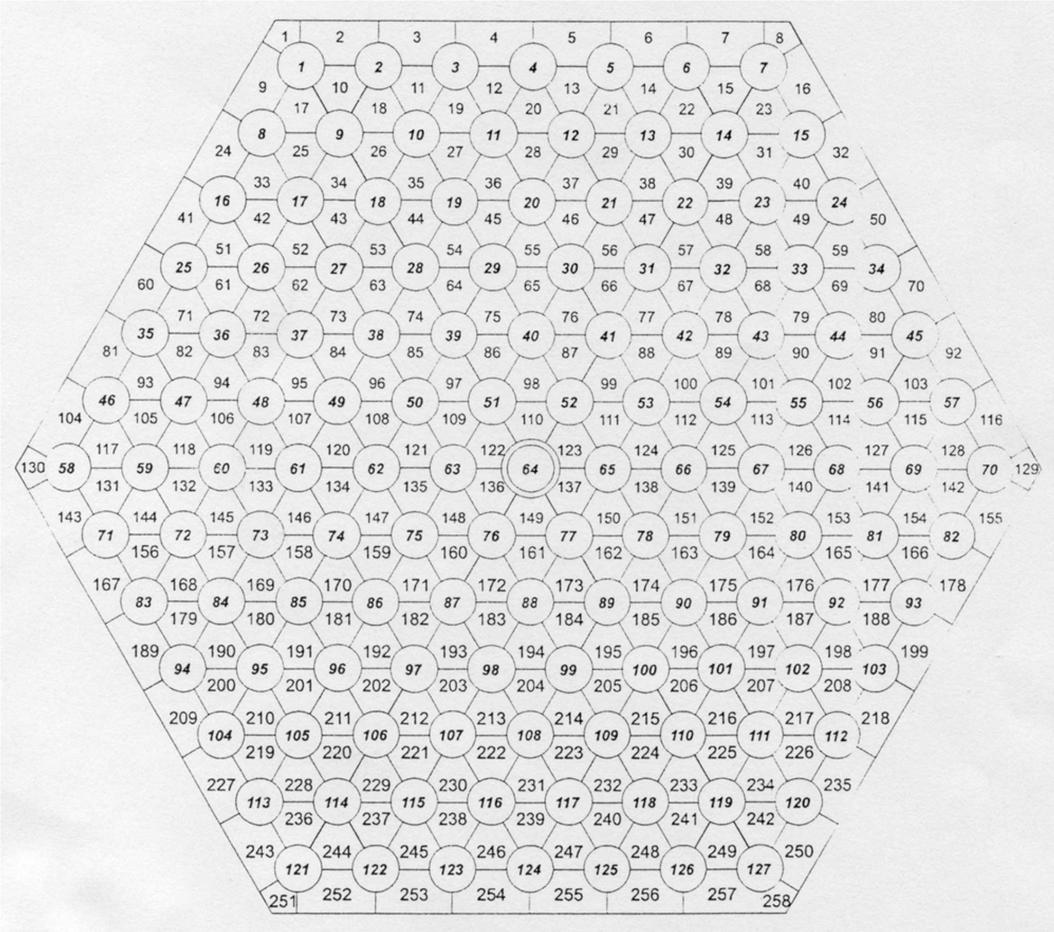

Figure 3. Subchannel numbering in the COBRA code.

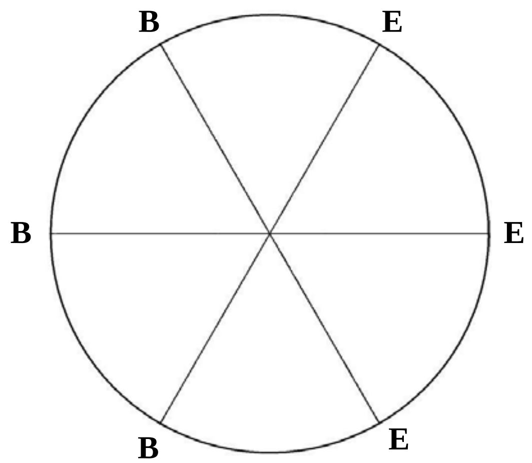

Figure 4. Diameters at the thermocouple level (Z=0.443) for the evaluation (B: beginning of the lines, E: end of lines).

9. Hardware and Software Requirements: memory, files, appr. comp. time

Hardware requirements strongly depend on the complexity of the applied model (resolution of the mesh, used turbulence model etc.). For the calculations, a 3D CFD code (e.g. CFX, FLUENT, STAR CD, etc.) is needed.

10. Output:

a, Expected Results

- In-core thermocouple signals above the selected assemblies
- Deviations between the in-core thermocouple signals and the outlet average coolant temperatures of the assemblies
- Axial velocity and temperature profiles along three diameters (Figure 4) at the level of the thermocouple
- Axial velocity and temperature distributions in the cross section at the level of the thermocouple (plane at the level Z=0.443 m)
- Axial velocity and temperature distributions in the center plane of the assembly head model (planes are marked by black lines on Fig. 1.)

b, Files, Format

The numerical data and the profiles are recommended to send in text or MS Excel files. The distributions should be printed in some kind of image files (e.g. *.jpg, *.png, *.bmp).

11. Time schedule

Preliminary announcement of benchmark:	10.07.2009.
Reflections for preliminary announcement:	10.08.2009.
Official announcement of benchmark:	on 19th SYMPOSIUM of AER, 21-25.09.2009
First comparison of participants' results:	on AER Working Group C and G joint meeting in 2010
Publication of participants' results:	in proceedings of 20th Symposium of AER in 2010 and in journal paper

12. References

1. Petényi, V.; Klučárová, K.; Remiš, J.; Chapčak, V.: Fuel Assembly Outlet Temperature Profile Influence on Core By-pass Flow and Power Distribution Determination in VVER-440 Reactors. Proc. Int. Conf. 13th Symposium of Atomic Energy Research on VVER Reactor Physics and Reactor Safety, Dresden, Germany, September 22-26, 2003, p. 695
2. Légrádi, G.; Aszódi, A.: Detailed CFD Analysis of Coolant Mixing in VVER-440 Fuel Assembly Heads Performed with the Code CFX-5.5. Proc. Int. Conf. 13th Symposium of Atomic Energy Research on VVER Reactor Physics and Reactor Safety, Dresden, Germany, September 22-26, 2003, p. 773
3. Toppila, T.; Lestinen, V.; Siltanen P.: CFD Simulation of Coolant Mixing Inside the Fuel Assembly Top Nozzle and Core Exit Channel of a VVER-440 Reactor. Proc. Int. Conf. 14th Symposium of Atomic Energy Research on VVER Reactor Physics and Reactor Safety, Helsinki, Finland, September 13-17, 2004, p. 331
4. Tóth S.; Aszódi, A.: Preliminary Validation of VVER-440 Fuel Assembly Head CFD Model. Proc. Int. Conf. 17th Symposium of Atomic Energy Research on VVER Reactor Physics and Reactor Safety, Yalta, Crimea, Ukraine, September 23-29, 2007, p. 449

5. Tóth S.; Aszódi, A.: CFD Study on Coolant Mixing in VVER-440 Fuel Assembly Head. Proc. Int. Cong. on Advances in Nuclear Power Plants, Anaheim, CA, USA, June 8-12 2008, Paper 8278
6. Farkas, I.: CFD Calculations of the Fuel Assembly of VVER-440 Type PWR Reactors. Proc. Int. Cong. on Advances in Nuclear Power Plants, Anaheim, CA, USA, June 8-12 2008, Paper 8264
7. Szécsényi, Zs.; Beliczai, B.; Parkó, T.: Personal communication from Paks NPP, Paks, Reactor Physics Department, Hungary, 2008.