NC STATE UNIVERSITY

Department of Nuclear Engineering

Consortsium for Nuclear Power
CNP
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Ninth COBRA-TF (CTF) User's Group Meeting and Training - CTF-9

Bologna, Italy
May 22-23, 2023

Hosted by ENEA, Italy

Announcement and Proposed Program

Sponsorship

The ninth COBRA-TF (CTF) User's Group (UG) Meeting (CTF-9) will be held on May 22, 2023 (*track 2*), in Bologna, Italy, in conjunction with fourteen Organization for Economic Cooperation and Development (OECD)/Nuclear Energy Agency (NEA) Working Party on scientific issues and uncertainty of Reactor Systems (WPRS) workshops, in order to facilitate co-ordination and share work, to combine efforts in common areas such as neutronics, thermal-hydraulics, multi-physics modelling and uncertainty analysis, and to make the participation more efficient. The OECD/NEA WPRS meetings/workshops/school concerned are:

- *May 22, 2023 (track 1 morning)* – Fourth OECD/NEA Multi-Physics Pellet Cladding Mechanical Interaction Validation Benchmark (MPCMIV-4) workshop;
- *May 22, 2023 (track 1 afternoon)* – First Burst-Fission-Gas Release Benchmark (BFGR-1) workshop;
- *May 23, 2023 (track 1)* - Sixteen OECD/NEA Light Water Reactor (LWR) Uncertainty Analysis in Modelling (UAM) Benchmark (LWR-UAM-16) workshop;
- *May 23, 2023 (track 2)* – OECD/NEA HTGR-TH Benchmark introductory presentation and discussions;
- *May 22*-23 (track 3), 2023 – OECD/NEA International School on Simulation of Nuclear Reactor Systems (SINUS);
- *May 24, 2023 (track 1 morning)* - OECD/NEA Task Force on Doppler Effective Fuel Temperature meeting;
- *May 24, 2023 (track 2 morning)* – Fourth OECD/NEA McMaster Core Thermal-Hydraulics (CTH) Benchmark (CTH-4) workshop;
- *May 24, 2023 (track 1 afternoon)* – OECD/NEA Task Force Artificial Intelligence & Machine Learning meeting;
- May 24, 2023 (track 2 afternoon – LFR neutronics) – May 25, 2023 (track 2 morning – LFR Thermal-hydraulics) – Second OECD/NEA Lead Fast Reactor (LFR) Benchmark (LFR-2) workshop;
- *May 24, 2023 (track 1 afternoon)* – *May 25, 2023 (track 1 morning)* - Eight OECD/NEA Time-Dependent Neutron Transport (C5G7-TD) Benchmark (C5G7-TD-8) workshop;
- *May 25, 2023 (track 2 afternoon)* – Second Liquid Metal Fast Reactor (LMFR) Thermal-Hydraulics (T/H) Benchmark workshop (LMFR T/H-2);
- *May 25, 2023 (track 1 afternoon)* – May 26*, 2023 (track 1 morning)* - Third meeting on OECD/NEA TVA Watts Bar 1 (WB1) Multi-Physics Multi-Cycle Depletion Benchmark (TVA-WB1-3) workshop.
- *May 26, 2023 (track 2)* - Eight OECD/NEA Sodium Fast Reactor (SFR) UAM Benchmark workshop and First Liquid Metal Fast Reactor (LMFR) Thermal-Hydraulics (T/H) Benchmark workshop (SFR-UAM-8);
- May 26, 2023 (track 1 afternoon) – Fifth benchmark meeting on Rostov-2 VVER-1000 multi-physics transient benchmark (Rostov2-5).

In conjunction with the CTF-9 meeting, hands-on CTF training sessions will be conducted on Monday afternoon, May 22, 2023 and Tuesday morning, May 23, 2023 (*track 2*).

CTF is a thermal-hydraulic subchannel and nuclear fuel modelling software package developed and maintained by North Carolina State University (NCSU) in collaboration with Oak Ridge National Laboratory (ORNL). A hands-on training session will be provided to introduce users to its capabilities through a series of example application problems.

Background and Purpose of 9th CTF User's Group Meeting

COBRA-TF is a thermal-hydraulic simulation code designed for Light Water Reactor (LWR) vessel and core analysis. It uses a two-fluid (hence the "TF" designation), three-field modeling approach. The original COBRA-TF code was developed as a thermal-hydraulic rod-bundle analysis code in 1980 by Pacific Northwest Laboratory under sponsorship of the Nuclear Regulatory Commission. It was subsequently implemented in the COBRA-TRAC code system and further validated and refined as part of the FLECHT-SEASET 163-Rod Blocked Bundle Test and analysis program. Over the past several decades, the COBRA series of codes has been used extensively throughout the nuclear industry, resulting in many variants of the code being created and validated.

CTF is the shortened name given to the version of COBRA-TF being developed and improved by the Reactor Dynamics and Fuel Modeling Group (RDFMG) initially at the Pennsylvania State University (PSU), and currently at NCSU in cooperation with ORNL. In the last decade, CTF has been extensively validated for Pressurized Water Reactor (PWR), Boiling Water Reactor (BWR), Water-Water Energetic Reactor (VVER), Small Modular Reactor (SMR), and research reactor applications. Improvements have included development of models, enhanced computational efficiency, as well as improving software quality and associated Quality Assurance procedures and documentation of CTF. Modifications and validation of CTF to analyze advanced reactors such as Molten Salt Reactor (MSR) designs and Sodium Fast Reactor (SFR) designs as well as spent fuel pools and dry storages have been implemented. As a result, CTF has become state-of-the-art subchannel code for reactor thermal-hydraulics bundle and core analysis.

CTF was included in two large projects – U.S. Department of Energy (DOE) Consortium for Advanced LWR Simulation (CASL) (as the basic thermal-hydraulic core feedback model) and European Commission (EC) NUclear REactor SAFEty simulation platform (NURESAFE) (as a BWR, PWR and VVER core thermal-hydraulic transient analysis tool). Within CASL, CTF become an important component of VERA, a "Virtual Environment for Reactor Applications", Core Simulator (CS) – VERA-CS. CTF is a part of the DOE Nuclear Energy Advanced Modeling and Simulation (NEAMS) program for LWR applications and VERA User's Group activities. Recently CTF was part also of DOE sponsored Advanced Nuclear Technology Project entitled "Modeling and Analysis of Exelon BWRs for Eigenvalue & Thermal Limits Predictability", which involved further high-fidelity development and application of VERA-CS, including CTF, to BWRs. The CTF capabilities have been expanded for modeling and simulation of Liquid Metal cooled Fast Reactor (LMFR) and solid fuel MSRs.

CTF have been distributed under code licenses to different organizations, which resulted in further improvements, modifications, verification & validation activities, and applications. In order to leverage and combine all non-proprietary developments, improvements, modifications and error fixes as well as the available verification and validation database and application experience of CTF from different organizations and activities, it was decided to establish a CTF User Group (UG) under the leadership of RDFMG/NCSU in order to provide and maintain the so-called "gold-standard" of CTF. RDFMG/NCSU is the keeper of the gold-standard CTF and taking on the

responsibility of maintaining and merging all developments and modifications. RDFMG/NCSU works to bridge the gap between different programs and activities related to CTF. Such unified and up-to-date code version, supplemented with extended verification and validation suite and application guidelines based on previous documented experience, will be useful to all CTF users in the future. RDFMG works to implement non-proprietary features developed in different projects in a single, gold-standard, and state-of-the-art version of CTF for the entire nuclear industry to benefit. The gold-standard version of CTF uses GIT source control and is hosted on RDFMG GitLab server to be accessible by all members of CTF UG. The code can be run in serial or parallel modes and is distributed via a code agreement/license to interesting parties. The information for CTF UG is provided at:

https://www.ne.ncsu.edu/rdfmg/cobra-tf/

The CTF-9 meeting will involve all interested users with objective to discuss on the progress in achieving a common version and to review the contributions from different organizations to the common version (including code development, improvement, verification and validation, uncertainty quantifications, and applications). CTF-9 will be conducted following the agreements reached at the first CTF UG meeting to have annual meetings to present, discuss and coordinate CTF related activities.

<u>Scope and Technical Content of the Meeting</u>

The topics to be addressed at the workshop include:
- Review of the CTF UG activities;
- Advances in reactor core thermal-hydraulics modeling;
- Discussion of status and recent additions to the CTF UG;
- Presentations and discussions on CTF/CTFFuel developments;
- CTF-Residual (CTF-R) updates;
- Presentations on multi-scale and multi-physics activities with CTF/CTFFuel;
- Discussion of updates of verification and validation (V&V) matrix as well as coverage matrix of CTF. Proposals for further expansion of V&V matrix and coverage matrix;
- Discussion of recent uncertainty quantification studies of CTF;
- Discussions of using high-fidelity models to inform low-fidelity models in CTF;
- CTF modifications and applications to PWRs;
- CTF modifications and applications to BWRs;
- CTF modifications and applications to VVERs;
- CTF modifications and applications to SMRs;
- CTF modifications and applications to research reactors;
- CTF modifications and applications to SFRs and MSRs;
- Discussions of transient applications of CTF;
- Presentations on other activities with CTF as well as experience and expertise of different organizations in CTF model developments, efficiency improvements, verification and validation efforts and applications;
- Defining a work plan and schedule for CTF UG activities.

The proposed meeting program is attached as Annex 1.

Organization of the Meeting

The meeting is organized around the discussion of CTF UG and its activities. The participants are requested to present their expertise and experience in CTF developments, improvements, verification and validation, uncertainty quantification and applications.

Participation in the Meeting

The participation in the meeting is open to all former, current, and future developers and users of COBRA-TF (CTF) for different applications.

Organization and Program Committee of the Meeting

An Organization and Program Committee has been nominated to make the necessary arrangements for the CTF-9 meeting and to draw up the final program, etc. The members of the Program Committee are:

Giacomo Grasso – *Co-Chair, and Local Host*
ENEA, Italy

Agustin Abarca – *Co-Chair*
North Carolina State University, USA

Maria Avramova
North Carolina State University, USA

Alessandro Petruzzi
NINE S.r.l., Italy

Yann Perin - *Coordinator of EC CTF activities*
Gesellschaft fuer Anlagen und Reaktorsicherheit (GRS) mbH, Germany

Proposed Program of the Meeting

The proposed program was drawn up by the Program Committee and is enclosed as Annex 1.

Language of the Benchmark Workshop

The official language of the CTF-9 meeting is English.

Proceedings of the Meeting

A summary of the CTF-9 meeting will be published by the RDFMG/NCSU after the meeting. The summary will be distributed free of charge to the participants in the meeting. The presentations will be available free of charge to the participants to download from participants' restricted area after the CTF-9 meeting.

Contacts and Registrations

The annual benchmark workshops/meetings **of** the [Working Party on Scientific Issues and Uncertainty Analysis of Reactor Systems](#) (WPRS) and CTF UG Meeting and Training will be hosted by ENEA in Bologna (Italy). The meetings will take place in three tracks in parallel during the week of May 22nd to May 26th, 2023 to exchange our results and lessons-learned for the different WPRS benchmark activities and to discuss future activities.

The link to registration page for the WPRS-related workshops/meetings, overall program, and local information for transportation and hotels is:

https://www.oecd-nea.org/jcms/pl_71612/wprs-benchmarks-workshop-2023

The link to registration page for the CTF-9 UG Meeting and Training is:
https://www.ne.ncsu.edu/rdfmg/cobra-tf/ninth-ctf-user-group-ug-meeting-and-training/

Workshops' Location

The meeting place for the ten meetings/workshops during the week of May 22nd to May 26th, 2023 in three tracks at the Zanhotel Europa, Via Cesare Boldini 11, Bologna, Italy (in-person meeting). As mentioned above the local information for transportation and hotels is given at:

https://www.oecd-nea.org/jcms/pl_71612/wprs-benchmarks-workshop-2023

The schedule for the incoming WPRS Workshops, SINUS school and CTF UG Meeting and Training is given in the table below:

Day	Track 1	Track 2	Track 3
Monday, 22 May 2023	MPCMIV	CTF User Group	OECD NEA International School on Simulation of Nuclear Reactor Systems (SINUS)
	Burst-Fission-Gas Release (EGRFP)	CTF Training	
Tuesday, 23 May 2023	LWR UAM	CTF Training	
		HTGR-TH	
Wednesday, 24 May 2023	EGMUP Task Force on Doppler effective fuel temperature EGMUP Task Force Artificial Intelligence & Machine Learning C5G7-TD	CTH	
		LFR Neutronics	
Thursday, 25 May 2023	C5G7-TD TVA-WB1	LFR Thermal-Hydraulics	
		LMFR T/H	
Friday, 26 May 2023	TVA-WB1	SFR-UAM	
	Rostov-2	SFR-UAM	

ANNEX 1

Ninth COBRA-TF User's Group Meeting (CTF-9)

Host Organization
Hosted by ENEA
Bologna (Italy)

May 22, 2023
Track 2

PROPOSED PROGRAM

CT01. Introduction and opening remarks.

CT02. Review of the CTF User's Group activities after the CTF-8 meeting.

CT03. Discussion of status and recent additions to the CTF User's Group – activities, coordination, agreements/licenses, distribution, etc.

CT04. CTF Version updates including CTF model developments and improvements/additions.

CT05. Presentations on CTFFuel model developments and improvements/additions.

CT06. Hi2Lo reconstruction models and capabilities in CTF and CTFFuel.

CT07. Updates on residual formulation implementation in CTF.

CT08. Presentations on recent verification, validation, and uncertainty quantification studies of CTF.

CT09. Presentations on recent verification, validation, and uncertainty quantification studies of CTFFuel.

CT09 Applications of machine learning techniques and artificial intelligence.

CT11. Presentations on coupling CTF with system thermal-hydraulics models.

CT12. Presentations on CFD informed models for CTF.

CT13. CTF modifications and applications to PWRs, BWRs, VVERs, SMRs, research reactors, SFRs, and MSRs.

CT14. Presentations on CTF applications to solve industry challenge problems.

CT15. Presentations on multi-physics and multi-scale activities involving CTF.

CT16. Presentations on CTF efficiency improvements and parallelization.

CT17. Presentations on other activities with CTF as well as experience and expertise of different organizations in CTF design and safety applications.

CT18. Defining a work plan and schedule for CTF UG activities.