IAEA Activities on Super-Critical Water Cooled Reactors

13th GIF-IAEA Interface Meeting
VIC
18 – 19 March 2019

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INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)
OUTLINE

1. WCR Team Activities

2. Projects and Activities on SCWRs
   - Coordinated Research Projects
   - Publications
   - Meetings and Training Courses

3. Summary
OUTLINE

1. WCR Team Activities

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3. Summary
IAEA’s key functions “to foster the exchange of scientific and technical information on peaceful uses of atomic energy”

- Modelling & Simulations
- Development of Methodologies
- Education & Training
- Data Bases & Toolkits
- Technology Support Safety Systems

CRPs, TCs, TMs
RTA
eLearning & Tools
ARIS, THERPRO, HOPS
CRPs, TMs
**2018 Technical Meetings & Courses**

**Technology development for water cooled reactors**

### Technical Meetings

1. Develop a New IAEA Nuclear Energy Series Report on Nuclear Power Plant Simulators as Tools for Education and Training (23–27 April, China)
2. Challenges and Opportunities in Construction Management of Advanced Nuclear Power Plant, with NPES (27–30 August, China)
3. Multi-Physics Benchmark for Pressurized Heavy Water Reactors (4–7 September, VIC)
4. Hydrogen Management in Severe Accidents (25–28 September, VIC)
6. Workshop on Development of Severe Accident Management Guidelines with the IAEA SAMG-D Toolkit (29 October–1 November, VIC) with NSNI/SAS
7. Reactor Technology Assessment: Testing the IAEA’s Reactor Assessment Methodology (12–16 November, VIC)

### Training Courses

1. Advanced WCRs: Physics, Technology, Passive Safety, and Basic Principle Simulators [Islamabad, Pakistan, 22–26 January]
2. Regional Training Course on Pressurized Water Reactor (PWR) Technology Using PC Based Basic Principle and GlassTop Nuclear Power Plant Simulators [Sharjah, UAE, 19–23 February]
3. Workshop on Small Modular Reactors Technology Assessment in Jordan [Video conference from VIC, Vienna to Amman, Jordan, 10–12 April]
4. Workshop on Reactor Technology Assessment Training for Large Water Cooled Reactors in Saudi Arabia [Riyadh, Saudi Arabia, 15–19 April]
5. Nuclear Infrastructure Training Course [Vienna, from 02-11 May]
7. Interregional Training Course on Nuclear Power Plant Contract Specifications and Reactor Technology Assessment [Vienna, Austria, 8–12 October]
8. JOINT ICTP-IAEA 1st COURSE ON SCIENTIFIC NOVELTIES IN THE PHENOMENOLOGY OF SEVERE ACCIDENTS IN WATER COOLED REACTORS [Trieste, Italy, 22–26 October]
9. Regional Training Workshop on Phenomenology and Numerical Simulations of Severe Accidents in Advanced WCRs [New Delhi, India, 3–7 December]
Coordinated Research Projects (CRPs)


Technology development for water cooled reactors

2018 Activities

Development of Methodologies

Technical Meetings and Workshops

- Workshop on Nuclear Reactor Technology Assessment for Ghana, VIC, Vienna, 14 – 17 November 2017
- Workshop on Small Modular Reactors Technology Assessment in Jordan, videoconference from VIC, Vienna to Amman, Jordan, 10 – 12 April 2018
- Workshop on Reactor Technology Assessment Training for Large Water-Cooled Reactors in Saudi Arabia, Riyadh, Saudi Arabia, 15 – 19 April 2018
- Reactor Technology Assessment: Testing the IAEA’s Reactor Assessment Methodology, VIC, Vienna, 12 – 16 November 2018

1st CM on the IAEA RTA Methodology Refinement, VIC, Vienna, May 2019
Technology development for water cooled reactors

Human capacity building in MSs on advanced reactor technologies with train-the-trainer and learning-by-doing integrated approach (supported with educational simulators)

Technical Meetings & Publications


Education & Training

Training Courses [TC supported]

IAEA training courses and workshops at national, regional and interregional levels in supporting human capacity development and sustainable learning

1999 – 2019

>40 education and training courses Hosted by 15 Member States

Develop a New IAEA TECDOC on Nuclear Power Plant Simulators as Tools for Education and Training, 23 – 27 April, Wuhan, China
E-Learning Modules

The IAEA Advanced Water Cooled Reactor E-Learning Module: Boiling Water Reactors

**Overview**

The Advanced Water Cooled Reactor E-Learning Modules are developed as tools for education on various water cooled reactor technologies. The Boiling Water Reactor E-Learning Module is the first of a series of such modules and consists of the following submodules:

- Submodule 1: Introduction
- Submodule 2: Basic Concepts
- Submodule 3: History
- Submodule 4: Global Deployment
- Submodule 5: Advanced Designs

Each submodule includes multiple choice questions and a random quiz is included at the end of the module to reinforce learned information.

**Submodule 1: Introduction**

This submodule introduces the topics which are covered in the module as well as describes how to navigate use and interact with the module. There are several buttons for navigation and which can be used to read information about it and introduces Water Cycle.

**Submodule 2: Basic Concepts**

This submodule provides necessary background information on boiling water reactor technology. This information includes a basic description of basic nuclear reactor physics, major boiling water reactor systems and components, and a description of advanced reactor technologies.

**Submodule 3: History**

**Submodule 4: Global Deployment**

**Submodule 5: Advanced Designs**

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**BWR (complete)**

**PWR General (~Feb 15 2019)**

- **VVERs (~Mar 15 2019)**
- **AP1000 (~Mar 30 2019)**
- **APR1400 (~Apr 15 2019)**

**PHWR (~Jun 30 2019)**

- **EPR (~Apr 30 2019)**

**SCWR (~Aug 15 2019)**

- **HPR1000 (~May 15 2019)**
Technology development for water cooled reactors

The IAEA Advanced Water Cooled Reactor E-Learning Module: Boiling Water Reactors

Overview
The Advanced Water Cooled Reactor E-Learning Modules are developed as tools for education on various water cooled reactor technologies. The Boiling Water Reactor E-Learning Module is the first of a series of such modules, and consists of the following five submodules:

Submodule 1: Introduction
Submodule 2: Basic Concepts
Submodule 3: History
Submodule 4: Global Deployment
Submodule 5: Advanced Designs

Each submodule includes multiple choice questions and a review quiz is included at the end of the module to reinforce learning information.

Submodule 1: Introduction
This submodule introduces the topics which are covered in the module as well as describes how to navigate, use, and interact with the module. There are several buttons for navigation and which can be used to read information aloud. It also introduces Walter!

Submodule 2: Basic Concepts
This submodule provides necessary background information on boiling water reactor technology. This information includes a basic description of basic nuclear reactor physics, major boiling water reactor systems and components, and a description of advanced reactor technologies.

Basic Concepts: Neutron Energy
- Critical mass: a sufficient amount of fissionable material that can sustain a nuclear chain reaction.

Basic Concepts: Advanced Reactors
- Advanced reactor designs include: pressurized water reactors (PWR), boiling water reactors (BWR), gas-cooled reactors (GCR), and fast breeder reactors (FBR).

Submodule 3: History
This submodule describes the history of boiling water reactor technology. This includes a description of initial prototypes, summaries of major reactor and containment designs, and discussions of major developments.

Submodule 4: Global Deployment
This submodule describes the global deployment of boiling water reactors, including advanced technologies. This submodule details the relevant information which can be found on two IAEA databases: the Power Reactor Information System (PRIS) [https://pris.iaea.org/PRIS/Home.aspx] and the Advanced Reactors Information System (ARIS) [https://aris.iaea.org/].

Submodule 5: Advanced Designs
This submodule describes technical information for each of the five advanced boiling water reactor technologies included in the ARIS database. The description of each includes an overview of the design, the reactor core, the reactor coolant system, safety systems, and other main features.

*as of August 2018.*
Technology development for water cooled reactors

**Database Bases & Toolkits**

THERPRO provides systematically organized and verified thermo-physical properties of nuclear materials. More than 11,000 property data sets for more than 1,600 materials.

**Database on Advanced Nuclear Power Reactors**

THERPRO provides systematically organized and verified thermo-physical properties of nuclear materials. More than 11,000 property data sets for more than 1,600 materials.

Modernization required: CM 3 – 5 July, VIC, Vienna

New template

Contacts to designers and vendros URGENT for some designs
OUTLINE

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3. Summary
Technology development for water cooled reactors

- Continuous interest in R&D and conceptual designs of SCWRs in a number of the IAEA Member States
- IAEA started its activities on SCWRs in 2006, and launched the first formal project in 2008
- Many project and technical meetings were held facilitating collaboration and information exchange among the Member States

![Diagram of pressure vs. temperature with various reactor types and critical points]
Technology development for water cooled reactors

Most of these R&D needs are common to all SCWR concepts

SCWR design concept development:
- Conceptual design [operating P/T exceed those of conventional WCRs]
- Performance & safety assessment

Thermal-hydraulics (T/H) of supercritical pressure fluids:
- Heat transfer;
- Flow instability;
- ...

Materials and chemistry:
- In-core materials (fuel cladding);
- Water chemistry;
- ...

Most of these R&D needs are common to all SCWR concepts
Technology development for water cooled reactors

Goal of the IAEA projects on SCWRs is to facilitate technology development in Member States mainly by:

- Providing forums for researchers and engineers to collaborate in R&D
- Promoting information exchange of advanced technology for SCWR development
- Educating newcomers interested in science and technology of SCWRs

- **Coordinated Research Projects (CRP)**
  - International collaborative project to coordinate R&D on a selected topic of common interest

- **Technical Meetings (TM)**
  - Specialist meeting to collect and exchange technical information on specific topics and to explore or build consensus

- **Training Courses**
  - Education and training to provide a comprehensive and up-to-date review of the science and technology in a specific area
1) Coordinated Research Projects (CRPs):
   - “Understanding and Prediction of Thermal-Hydraulics Phenomena Relevant to SCWRs”, 2014-2019

2) Technical Meetings (TMs):

3) Training Courses:

4) Cooperation in international symposia/meetings.

Collaboration among 16 institutes from 10 Member States and 2 international organizations

Comprehensive and reliable database for thermal-hydraulics of supercritical fluids
Technology development for water cooled reactors

**CRP on Understanding and Prediction of Thermal-Hydraulics Phenomena Relevant to SCWRs (2014-2019)**

- Overall objective to:
  - Improve the understanding of T/H phenomena and prediction accuracy of T/H parameters related to SCWRs
  - Benchmark numerical toolsets for SCWR T/H analyses
  - 12 Institutes from 10 Member States (Canada, China, Germany, Hungary, India, Italy, Russia, Ukraine, UK, USA) and OECD/NEA hosting the database for the CRP; and
  - 2<sup>nd</sup> RCM held at BARC, India, November 2015
  - 3<sup>rd</sup> RCM held in U. Wisconsin-Madison, USA, June 2017
  - 4<sup>th</sup> RCM held in IAEA HQ, Austria, Jan. 2019 (also 1<sup>st</sup> 2014)

**TECDOC 2019**

- Improved understanding of SCWR thermal-hydraulic phenomena;
- Improved accuracy of SCWR thermal-hydraulic predictions;
- Coordinated strategy for SCWR thermal-hydraulic R&D;
- Enhanced interactions and cooperation among participating institutes; and
- Enhanced education and knowledge management
- Recommendations for future activities (2022/23)
Comprehensive and objective overview of SCWR R&D based on the outcomes from Technical Meetings on:

- *Heat Transfer, Thermal-Hydraulics and System Design for SCWRs*, hosted by the Government of the UK through the University of Sheffield, August 2016
- *Materials and Chemistry for SCWRs*, hosted by the Government of the Czech Republic through the Research Centre Řež, October 2016
Technology development for water cooled reactors

Training Courses on Science and Technology of SCWRs

• 1st Course joint IAEA - International Centre for Theoretical Physics (ICTP), Trieste, Italy, June 2011.

• 2nd and 3rd Courses in cooperation with IAEA at:
  – McMaster University, Hamilton, Canada, July 2012
  – Shanghai Jiao Tong University (SJTU), Shanghai, China, August 2013

• 4th Course held at University of Ontario Institute of Technology (UOIT), Oshawa, Canada, July 2016

The purpose of the event is to provide a comprehensive training on physics and technology of evolutionary and innovative WCRs and introduce various conceptual designs of SCWRs
Technology development for water cooled reactors

eLEARNING MODULES

- PWRs
  - Introduction
  - Basic Principles
  - Simulators
- Early PWR History
- Advanced Design Concepts
  - Safety Systems (Active/Passive)

VVERs
- Gidropress
- Development History (full series)
- Technical Information
- Deployment (PRIS)
- VVER 300 (ARIS)
- VVER 600 (ARIS)
- VVER 640 (ARIS)
- VVER 1000 (ARIS)
- VVER 1200 (ARIS)
- VVER 1500 (ARIS)
- VVER TOI/1300

AP1000
- Westinghouse
- Development History
- Technical Information (ARIS)
- Deployment (PRIS)

APR1400
- KEPCO
- Development History
- Technical Information (ARIS)
- Deployment (PRIS)

EPR
- Framatome, AREVA, EDF
- Development History
- Technical Information (ARIS)
- Deployment (PRIS)

HPR1000
- CNNC, CGNPC
- Development History
- Technical Information (pre-ARIS)
- Deployment (PRIS)

SCWRs

Possibly in co-operation with GIF-SCWR

Education & Training
1. WCR Team Activities

2. Projects and Activities on SCWRs
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3. Summary
IAEA Projects/Activities on SCWRs

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Summary

• 13 years has passed since the IAEA started its activities on SCWRs in 2006.

• IAEA has held so far:
  - Two Coordinated Research Projects (CRPs) on Thermal-Hydraulics;
  - Two Technical Meetings (TMs) on Thermal-Hydraulics;
  - Three TMs on Materials and Chemistry;
  - Four Training Courses jointly with the host organizations.

• IAEA will continue to facilitate fundamental research and technology development for SCWRs in Member States.
Thank you!