IAEA
International Atomic Energy Agency

"Atoms for Peace and Development"

Technical Meeting on the Benefits and Challenges of
Fast Reactors of the SMR type
24-27 September 2019
Milano, Italy

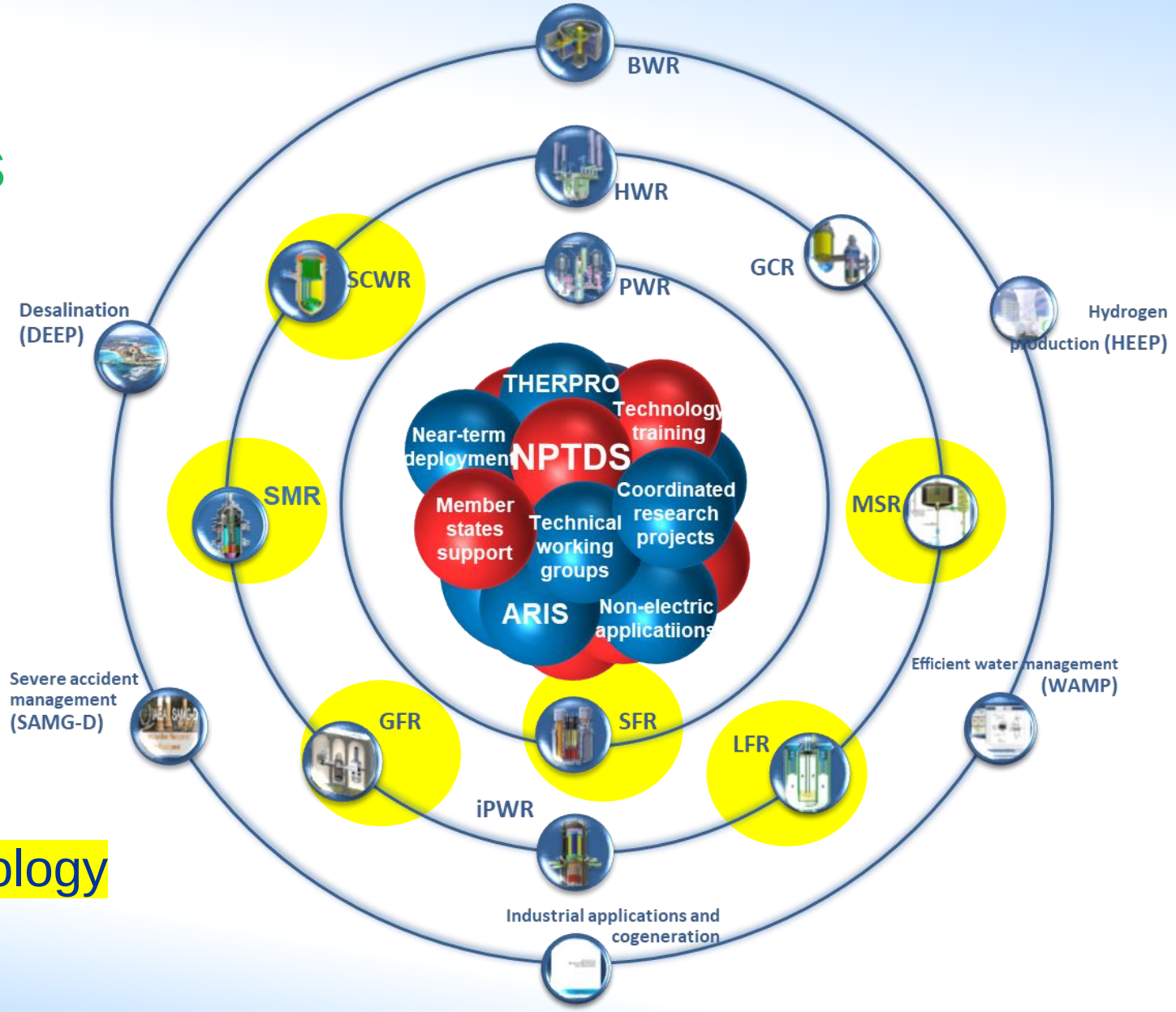
Status of NPTDS Activities on Fast SMRs

Vladimir Kriventsev, Frederik Reitsma, Chirayu Batra
Fast Reactor Technology Development Team
Nuclear Power technology Development Section
Division of Nuclear Power
Department of Nuclear Energy
International Atomic Energy Agency
https://www.iaea.org/topics/fast-reactors

email: FR@IAEA.ORG

Nuclear Power Technology Development

NPTDS:
Tasks & Activities



Fast Reactors Technology

Main IAEA Activities on Fast Reactor Technology in 2018 - 2019

CRPs/Benchmarks/Studies

- **NAPRO CRP** (2013 - 2018)
- 3 Ongoing CRPs:
  - **PSFR Source Term** (2016 - 2020)
  - **New CEFR Start-Up Tests** (2018 - 2022)
  - **New FFTF ULOF Test** (2018 - 2022)
- 2 New CRPs proposed (to start in 2021):
  - Modelling of Total Instantaneous Blockage of SFR F/A
  - Benchmarking LOF transient test in CLEAR-S HML Pool Facility
- Study on **Passive Shutdown Systems** for Fast Reactors (completed in 2017, NES to be published in 2019)
- TM on **Structural Materials for HLM Reactors** (2019)
- TM on **Benefits and Challenges of Fast SMRs** (2019)
- TM on Economic (or Industrial) Optimization of Liquid Metal cooled Fast Reactor Designs (2020)
- TM on Proliferation Resistant Features of Fast Reactors and Related Fuel Cycles (2020)

- Technical Working Group on Fast Reactors
  - 51st TWG-FR Meeting in Hefei, China, 21-25 May 2018
  - **52nd TWG-FR Meeting in Romania, 10-14 June 2019**
- Joint IAEA-GIF Workshops on LMFR Safety
  - 7th GIF-IAEA Workshop on LMFR Safety: 27-29 March 2018
  - **8th GIF-IAEA Workshop on LMFR Safety: 20-22 March 2019**
- LMFNS Experimental Facilities Database
- Training Courses and Workshops
  - Joint ICTP-IAEA Workshops on the Physics and Technology of Innovative Nuclear Energy Systems (2016, 2018 in Trieste, Italy)

IAEA Technical Working Group on Fast Reactors (TWG-FR)

"The Driving Force…"

- Provide advice and guidance
- Forum for information exchange and knowledge sharing
- Link between IAEA activities and national communities
- Provide advice in planning and implementing of CRPs
- Develop and review selected documents
- Contribute to status report, technical meetings, topical conferences
- Identify important topics for SAGNE
- Encourage participation of young professionals in IAEA activities

Members of the IAEA Technical Working Group on Fast Reactors

Full Members

Belarus	Brazil
China	**Belgium**
Czech Republic	France
Germany	India
Italy	Japan
Kazakhstan	Korea, republic of
Netherlands	Russian Federation
Slovakia	Sweden
Switzerland	Ukraine
UK	USA
European Commission	*OECD/NEA*

Observers

Argentina	~~Belgium~~
~~Czech Republic~~	Mexico
Romania	Spain
Generation-IV International Forum (GIF)	

52st TWG-FR Meeting, Pitesti, Romania, 10-14 June 2019

Fast Reactors: *Coordinated Research Projects*

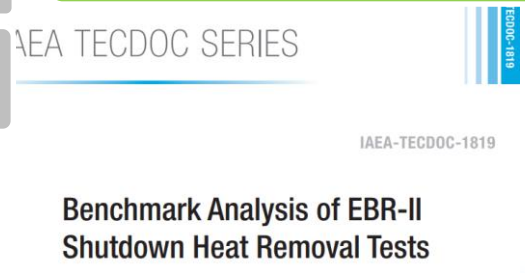
CRPs on Fast Reactors Technology

CRP recently completed

- **BN-600** MOX Core Benchmark
- Analytical and Experimental Benchmark Analysis of **ADS**
- **PHENIX** – EOL Tests
- **MONJU** – Na Natural Convection
- **EBR-II** Shutdown Heat Removal Tests

CRP currently on-going

- **NAPRO** – Na Properties and Safe Operations of Exp. Facilities
  Ended in Sept 2018
  2 TECDOCs in Publishing
- **PSFR Source Term** – Radioactive Release Under Severe Accident Conditions



New CRPs

- MONJU – Turbine Trip Test
- Neutronics Benchmark of **CEFR** Start-Up Tests (29 participants)
- Benchmark Analysis of **FFTF** Loss of Flow Without Scram Test (25 participants)

New Proposals

- Total Instantaneous Blockage of SFR Fuel Assembly
- Simulation of **CLEAR-S** Loss-of-Flow Experiment
- Benchmark Analysis of **STELLA-2** LOHS/LOF Tests

New IAEA CRPs on Fast Reactors (Started in 2018)

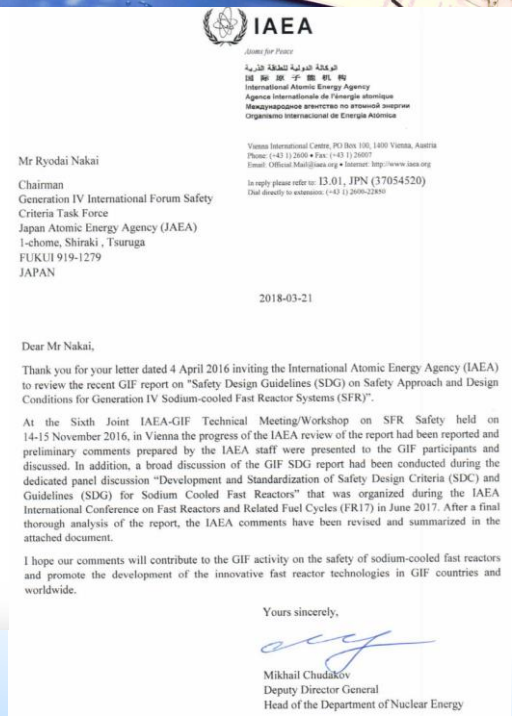
Neutronics Benchmark of **CEFR Start-Up Tests**

Country	Organization(s)
Belgium	SCK•CEN
China	CIAE, INEST, SNERDI, XJTU
France	CEA
Germany	KIT, HZDR, GRS
Hungary	BME, EK
India	IGCAR
Italy	NINE/UNIPI
Japan	JAEA
Rep. of Korea	KAERI, UNIST
Mexico	ININ
Romania	RATEN
Russia	IPPE, IBRAE, SSL, Kurchatov Inst.
Slovakia	VUJE
Switzerland	PSI
Ukraine	KIPT
UK	Cambridge
USA	ANL, NRC, INL
17 Countries	**29 Organizations**

Benchmark Analysis of **FFTF ULOF Test**

Country	Organization(s)
China	CIAE, NCEPU, INEST, XJTU
France	CEA
Germany	KIT, HZDR
India	IGCAR, ISSSA
Italy	NINE, Sapienza
Japan	JAEA
Rep. of Korea	KAERI
Netherlands	NRG
Russia	IPPE, IBRAE
Spain	CIEMAT
Sweden	KTH
Switzerland	PSI
USA	ANL, PNNL, TerraPower, NRC, TAMU
13 Countries	**25 Organizations**

Fast Reactors Safety: Joint GIF-IAEA Workshops on Safety of LMFRs



IAEA

Atoms for Peace

International Atomic Energy Agency

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Mr Ryodai Nakai

Chairman
Generation IV International Forum Safety
Criteria Task Force
Japan Atomic Energy Agency (JAEA)
1-chome, Shiraki , Tsuruga
FUKUI 919-1279
JAPAN

2018-03-21

Dear Mr Nakai,

Thank you for your letter dated 4 April 2016 inviting the International Atomic Energy Agency (IAEA) to review the recent GIF report on "Safety Design Guidelines (SDG) on Safety Approach and Design Conditions for Generation IV Sodium-cooled Fast Reactor Systems (SFR)".

At the Sixth Joint IAEA-GIF Technical Meeting/Workshop on SFR Safety held on 14-15 November 2016, in Vienna the progress of the IAEA review of the report had been reported and preliminary comments prepared by the IAEA staff were presented to the GIF participants and discussed. In addition, a broad discussion of the GIF SDG report had been conducted during the dedicated panel discussion "Development and Standardization of Safety Design Criteria (SDC) and Guidelines (SDG) for Sodium Cooled Fast Reactors" that was organized during the IAEA International Conference on Fast Reactors and Related Fuel Cycles (FR17) in June 2017. After a final thorough analysis of the report, the IAEA comments have been revised and summarized in the attached document.

I hope our comments will contribute to the GIF activity on the safety of sodium-cooled fast reactors and promote the development of the innovative fast reactor technologies in GIF countries and worldwide.

Yours sincerely,

Mikhail Chudakov
Deputy Director General
Head of the Department of Nuclear Energy

1st : June 2010
2nd : Dec 2011
3rd : Feb. 2013
4th : June 2014
5th : June 2015

6th GIF-IAEA Workshop on Safety of SFR
November 2016

7th Joint GIF-IAEA Workshop on LMFR Safety
March 2018

- Final Review of GIF Report on Safety Design Guidelines on Safety Approach & Design Conditions for GEN-IV SFRs

8th GIF-IAEA Workshop on LMFR Safety
20-22 March 2019

- Discussion of GIF Report on “Safety Design Guidelines on Structures, Systems and Components for Gen-IV SFRs”

9th GIF-IAEA Workshop on LMFR Safety
18-20 March 2020

LMFNS Experimental Facilities Catalogue

Experimental Facilities in support of Development and Deployment of Liquid Metal cooled Fast Neutron Systems

Includes an overview as well as detailed information on **190** experimental facilities under design, construction or operation

19 institutions from 14 IAEA Member States contributed

Updated August 2019!

Freely Available at iaea.org: Search for "IAEA LMFNS"

- A comprehensive Catalogue providing detailed information on experimental facilities currently designed, under construction or operating
- Facilities Designed to support the development and deployment of innovative liquid metal-cooled (sodium, lead and lead-bismuth) fast neutron systems (LMFNS), both critical and subcritical
- Identifies existing or future operational experimental facilities able to support innovative LMFNS
- Expected to facilitate cooperation using existing and planned experimental facilities for LMFNS, and enhance their utilization by providing end-users with detailed information
- Encourages international collaborations

LMFNS Experimental Facilities Catalogue

Experimental Facilities in support of Development and Deployment of Liquid Metal cooled Fast Neutron Systems

Includes an overview as well as detailed information on **150** experimental facilities under design, construction or operation

19 institutions from 14 IAEA Member States contributed

Freely Available at iaea.org: Search for "IAEA LMFNS"

Search Online Catalogue of LMFNS Facilities

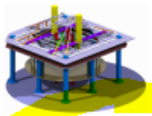
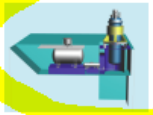
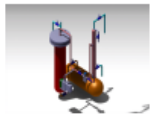
nucleus.iaea.org/sites/lmfns

Main research field(s)

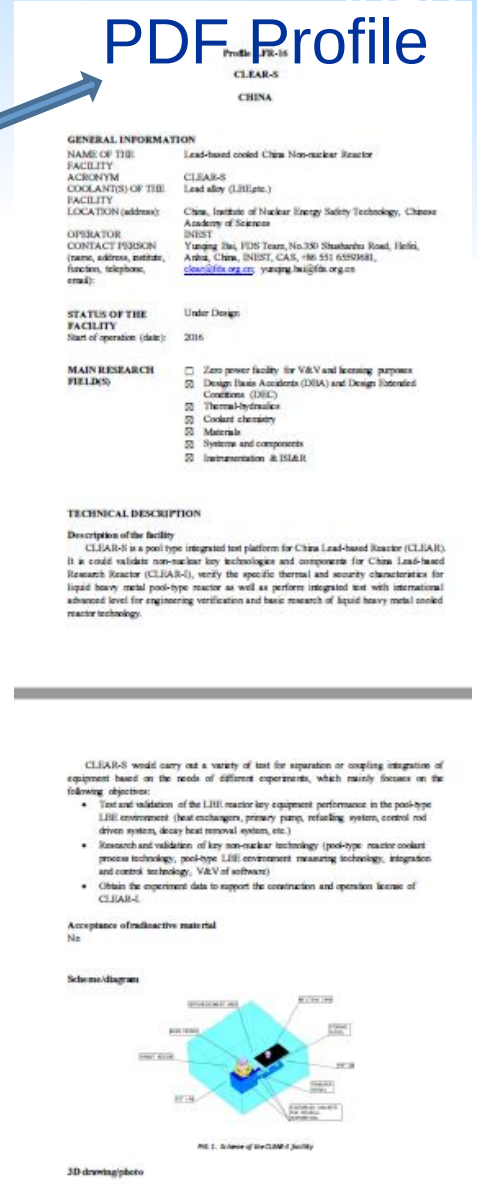
Reactor type

Country
China

Facility Country Profiles

✓	Picture	Facility name	Facility Profile	Reactor type	Country	Max Power (kW)	Coolant of the facility	Status	Main research field(s)	Max Operating Temperature (°C)	Max Operating Pressure (MPa)
		CLEAR - 0	China Lead-based Zero Power Reactor	LFR	China	0.01	Lead-bismuth eutectic (LBE),Other	under construction	Zero power facility for V&V and licensing purposes,Systems and components,Instrumentation & ISI&R		
		CLEAR -S	Lead-based cooled China Non-nuclear Reactor	LFR	China	3,000	Lead-bismuth eutectic (LBE)	under design	Design basis accidents (DBA) and design extended conditions (DEC),Thermal-hydraulics,Coolant chemistry,Materials,Systems and components,Instrumentation & ISI&R	500	2
		KYLIN II -M	KYLIN-II Materials Test Loop	LFR	China	300	Lead,Lead-bismuth eutectic (LBE)	in operation	Coolant chemistry,Materials	550	1.6
		KYLIN II -S	KYLIN-II Safety Test Loop	LFR	China	200	Lead,Lead-bismuth eutectic (LBE)	under construction	Design basis accidents (DBA) and design extended conditions (DEC),Systems and components,Instrumentation & ISI&R	500	25
		KYLIN II -TH FC	KYLIN-II Forced Circulation Thermal Hydraulics Test Loop	LFR	China	300	Lead,Lead-bismuth eutectic (LBE)	in operation	Thermal-hydraulics,Coolant chemistry,Systems and components,Instrumentation & ISI&R	400	1.2

PDF Profile



Profile_LFR-16

CLEAR-S

CHINA

GENERAL INFORMATION

NAME OF THE FACILITY: Lead-based cooled China Non-nuclear Reactor

ACRONYM: CLEAR-S

COOLANT(S) OF THE FACILITY: Lead alloy (LBE,etc.)

LOCATION (address): China, Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences

OPERATOR: INEST

CONTACT PERSON (name, address, institute, function, telephone, email): Yanqing Bai, FDS Team, No.350 Shushanhu Road, Hefei, Anhui, China, INEST, CAS, +86 551 65595681, clear@fds.org.cn; yanqing.bai@fds.org.cn

STATUS OF THE FACILITY: Under Design

Start of operation (date): 2016

MAIN RESEARCH FIELD(S)

- ☐ Zero power facility for V&V and licensing purposes
- ☒ Design Basis Accidents (DBA) and Design Extended Conditions (DEC)
- ☒ Thermal-hydraulics
- ☒ Coolant chemistry
- ☒ Materials
- ☒ Systems and components
- ☒ Instrumentation & ISI&R

TECHNICAL DESCRIPTION

Description of the facility

CLEAR-S is a pool type integrated test platform for China Lead-based Reactor (CLEAR). It is could validate non-nuclear key technologies and components for China Lead-based Research Reactor (CLEAR-I), verify the specific thermal and security characteristics for liquid heavy metal pool-type reactor as well as perform integrated test with international advanced level for engineering verification and basic research of liquid heavy metal cooled reactor technology.

CLEAR-S would carry out a variety of test for separation or coupling integration of equipment based on the needs of different experiments, which mainly focuses on the following objectives:

- Test and validation of the LBE reactor key equipment performance in the pool-type LBE environment (heat exchangers, primary pump, refuelling system, control rod driven system, decay heat removal system, etc.)
- Research and validation of key non-nuclear technology (pool-type reactor coolant process technology, pool-type LBE environment measuring technology, integration and control technology, V&V of software)
- Obtain the experiment data to support the construction and operation license of CLEAR-I.

Acceptance of radioactive material

No

Scheme/diagram

FIG. 1. Scheme of the CLEAR-S facility

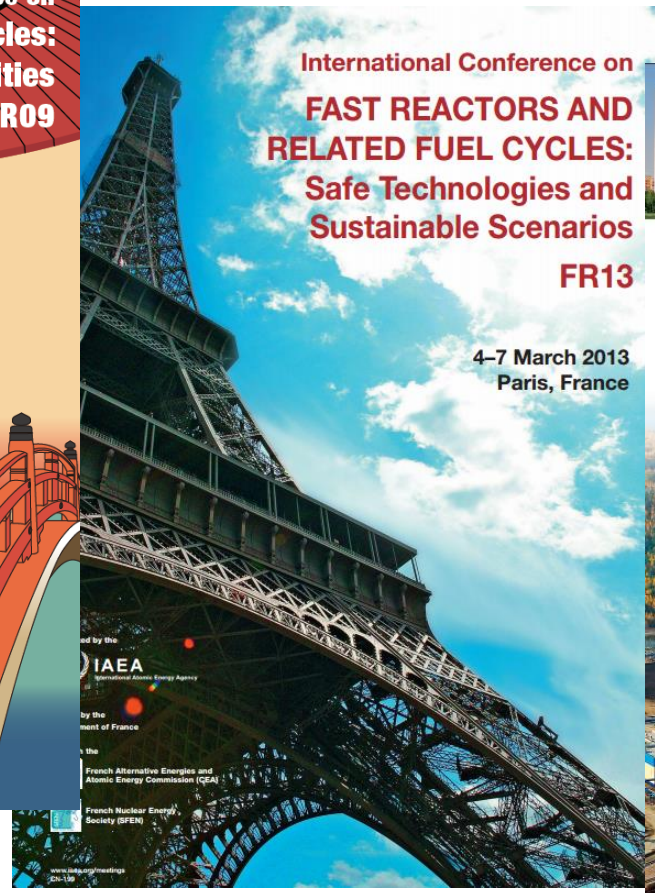
3D drawing/photo

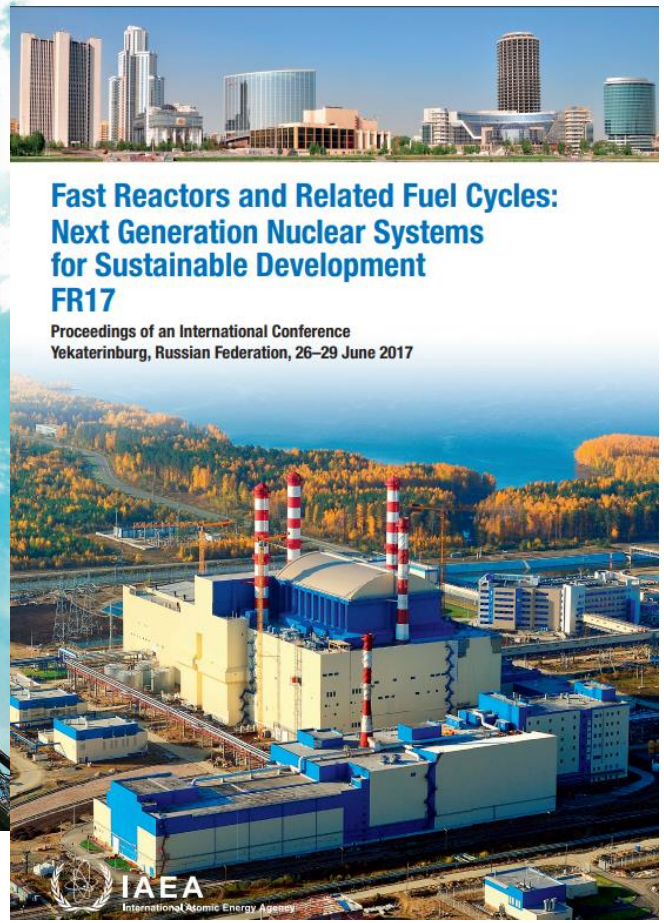
Joint ICTP-IAEA Workshops on Innovative Nuclear Energy Systems

- In **2016** and in August **2018** Trieste, Italy
- Contributed by NPTDS, INPRO, GIF, and other external experts
- Next Workshop: 13-17 July 2020

FR09 >> FR13 >> FR17 >> FR21 Conferences

IAEA International Conferences on
Fast Reactors and Related Fuel Cycles



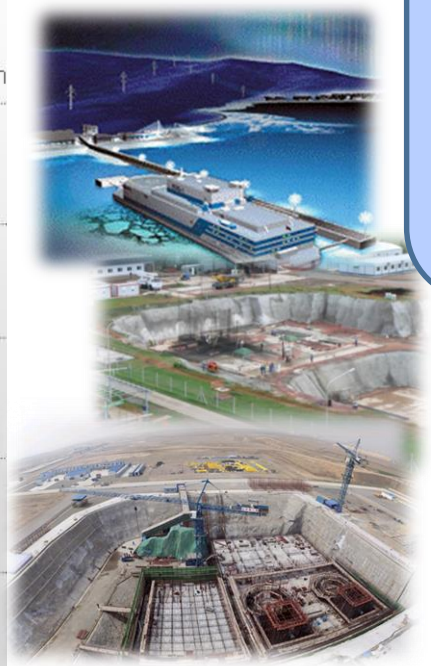


FR21
June 2021

Yekaterinburg 2017
~600 Participants from
27 IAEA Member States
6 International Organizations
460 Technical Papers
10 Invited Plenary Speeches

IAEA Activities on Small and Medium Sized or Modular Reactors

– All advanced technologies included



Information Exchange

ARIS database and SMR booklet

Scientific Secretary:
Mr Frederik Reitsma
F.Reitsma@iaea.org

Coordinate Research Projects

1. Development of Approaches, Methods and Criteria for Determining Technical Basis for EPZ for SMR Deployment
2. Design and Performance Assessment of Passive Engineered Safety Features in Advanced SMRs.

Education and Training

iPWR Simulator

HTGR under development

Training courses; ICTP events

Publications

SMR Instrumentation and Control Systems

Technology Roadmap

SMR and Hybrid Energy Systems

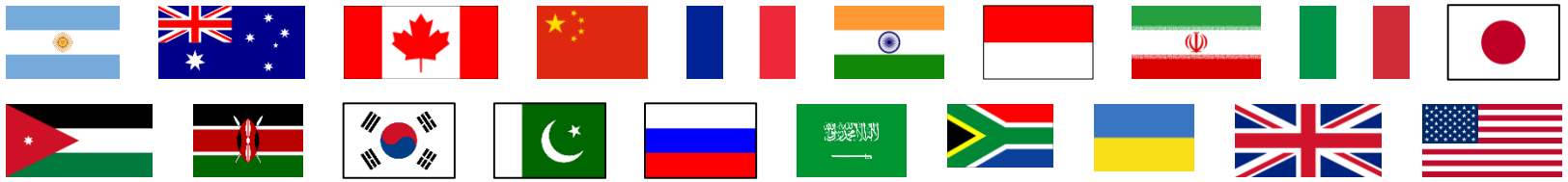
SMR Environment Impact Assessment

Deployment Indicators

Published and Upcoming

IAEA Technical Working Group on SMR

- To advice and support IAEA programmatic planning and implementation in areas related to technology development, design, deployment and economics of SMRs
- 1st meeting in 2018 with 14 Member States
- Now 20 Member States and two International Organizations: European Commission and OECD-NEA as invited observers:



- Three technical subgroups established in 2018 / 2019:
  - **SG-1:** Development of Generic Users Requirements and Criteria (GURC)
  - **SG-2:** Research, Technology Development and Innovation; Codes and Standards
  - **SG-3:** Industrialization, design engineering, testing, manufacturing, supply chain, and construction technology
- TWG also address SMR for Non-Electric Applications and coupling with renewables
- 1st TWG Meeting held on 23 - 26 April 2018 in Vienna
- 2nd Meeting : 8 – 11 July 2019 in Vienna
- 3rd scheduled for 29 June – 2 July 2020 in Vienna

TWG-SMR Chair:
Mr Marco Ricotti
President of CIRTEN

New Studies on Fast Reactors: Technical Meeting on

Benefits and Challenges of Fast Reactors of SMR Type

Action	Date
Announcement and Call for Papers	March 2019
Abstract submission Deadline Extended	~~15 May 2019~~ 30 May 2019
TWG-FR review abstracts at its 52nd Meeting and IAEA accepts 15-20 abstracts	*10-14 June 2019*
Full paper submission deadline; Start of peer-review	15 August 2019
Technical Meeting in Milano, Italy	**24 - 27 September 2019**
Final Papers Deadline; Draft TM Report	November 2019
Publication of the IAEA TECDOC	2020

Structural Materials for Heavy Liquid Metal Cooled Fast Reactors

Action	Date
Announcement and Call for Papers	March 2019
Abstract submission Deadline Extended	~~15 May 2019~~ 30 May 2019
TWG-FR review abstracts at its 52nd Meeting and IAEA accepts 15-20 abstracts	10-14 June 2019
Full paper submission deadline; Starting peer-review	1st September 2019
Technical Meeting in Vienna	15 - 17 October 2019
Final Papers Deadline; Draft TM Report	December 2019
Publication of the IAEA TECDOC	2020

International Advisory Group (for both meetings)

Name	Org	Country
Mr Alessandro Alemberti	Ansaldo Nucleare S.p.a	Italy
Mr Didier DE BRUYN	SCK•CEN	Belgium
Mr Donghui Zhang	CIAE	China
Mr Ferry Roelofs	NRG	Netherlands
Mr Georgy Toshinsky	IPPE	Russia
Mr Giacomo Grasso	ENEA	Italy
Mr Haileyesus Tsige-Tamirat	JRC	EC
Mr Jaehyuk Eoh	KAERI	Korea, Rep. of
Mr Joel Guidez	CEA/GIF	France
Mr Kamil Tucek	JRC	EC
Mr Karl-Fredrik Nilsson	JRC	EC
Mr Luciano Cinotti	Hydromine	Luxembourg

Name	Org	Country
Mr Mariano Tarantino	ENEA	Italy
Mr Paul Schuurmans	SCK CEN	Belgium
Mr Pietro Agostini	ENEA	Italy
Mr Sergii Fomin	KIPT	Ukraine
Mr Yican Wu	INEST	China
Mr Zhao Chen	CGN	China
Mr Zoltan Szaraz	JRC	EC

IAG reviewed submitted abstracts and advised the IAEA on selection of contributions, speakers and sessions' allocation

Accepted Abstracts

Country	Abstracts
Belgium	1
China	3
France	2
India	1
Italy	5
Japan	2
Korea, Rep. of	4
Luxembourg	1
Netherlands	1
Russia	5
Slovakia	1
Switzerland	1
Sweden	1
Ukraine	1
USA	1
Total	**30**

17 Member States and 1 International Organization

TM on HLM Materials: 22

Country	Abstracts
Belgium	1
China	4
Czech Republic	1
EC	1
Germany	1
Italy	4
Korea, Rep. of	1
Romania	2
Russia	3
Slovakia	1
Sweden	2
Ukraine	1
Total	**22**

TM on Fast SMRs: 30 (23 full papers submitted)

TM on HLM Materials: 15 - 17 October 2019

General Chair: ***Daniela Gugiu***

Session	Session Title	Chair	Abstracts
1	HLM Compatibility with Structural Materials: Phenomena, Modelling and Operational Experience	Mr Kamil Tucek	8
2	Corrosion Mitigation Measures: Coating, New Structural Materials, Environmental Conditioning	Mr Peter Szakalos	8
3	Qualification Programmes of Structural Materials for HLM Fast Reactors	Mr Bin Long	6

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Technical Meeting on the Benefits and Challenges of Fast Reactors of the SMR Type

hosted by

Government of Italy

through

Interuniversity Consortium for Nuclear Technology Research (CIRTEN)

24 - 27 September

Politecnico di Milano

https://www.iaea.org/events/evt1803539

TM on Fast SMRs: Summary

- The TM on **Benefits and Challenges of Fast Reactors of SMR Type** was initiated by the TWG-FR in 2018
- **47 participants** have been nominated by their national authorities to participate from 17 IAEA Member States and 1 Intl organization (EC/JRC) (40 confirmed attendance)
- **32 abstracts** were submitted
- For review, the IAEA organized International Advisory Group who advised the IAEA to **accept 30 abstracts**
- **23 full papers** have been submitted and reviewed by 20+ independent experts who provided their comments and recommendations
- Papers are split in **six technical sessions**
- After this meeting, authors are expected to submit revised papers to be included in the IAEA publication (TECDOC)

TM on Fast SMRs: Organization

- General Chair: *Pietro Agostini*
- Honorary Chair: *Georgy Toshinsky*
- Chair of Local Organizing Committee: *Marco Ricotti*
- IAEA Secretariat: *Vladimir Kriventsev, Frederik Reitsma, Chirayu Batra*

TM on Fast SMRs: Sessions

	Session Title	Chair(s)	Final Papers
1	Sodium Cooled Fast SMRs	Vladimir Kriventsev, Akira Yamaguchi	4
2	HLM Cooled Fast SMRs	Didier de Bruyn, Janne Wallenius	8
3	Molten Salt and Gas Cooled Fast SMRs	Jiri Krepel	1
4	Economic Aspects & Fuel Cycle of Fast SMRs	Georgy Toshinsky	2
5	Safety Aspects of Fast SMRs	Paul Gauthe, Hiroki Hayafune	4
6	Technology and Research in Support of SMR Development	Lixia Ren, Iurii Ashurko	4

TM on Fast SMRs: Group Discussion

Group Discussion	Title	Chair
I	In-factory construction (Tuesday, 24 September, 16:10)	Janne Wallenius
II	Technological challenges to be resolved (Wednesday, 25 September, 15:50)	Vladimir Kriventsev
III	Benefits of fast SMRs including market needs (Friday, 27 September, 09:30)	Marco Ricotti

TM on Fast SMRs: Tasks and Outputs (1/2)

- Meeting Chair:
  - Chair the meeting
  - Draft summary and conclusions of the whole meeting for the TECDOC
  - Compile the final TECDOC with the help of IAEA secretariat
  - Perform the final review of the TECDOC
- Session Chairs:
  - Conduct peer review and provide comments to the author
  - Chair the session during the meeting
  - Draft session summary for the TECDOC
  - Collect final revised papers (in proper format) and submit to the IAEA
  - Perform the final review of the TECDOC

TM on Fast SMRs: Tasks and Outputs (2/2)

- Group Discussion Leaders:
  - Moderate group discussions
  - Draft summary and conclusions of group discussions for the TECDOC
  - Perform the final review of the TECDOC
- Authors:
  - Present their works at the meeting
  - In conclusion, highlight Benefits/Challenges of Fast SMRs
  - Submit the final revised papers before 1st December 2019
- All Participants:
  - Participate in discussions
  - Propose highlights for Benefits/Challenges of Fast SMRs
- Main Outcome:
  - **Benefits and Challenges** of Fast SMRs

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Thank you!