RESEARCH REACTORS FOR THE DEVELOPMENT OF MATERIALS AND FUELS FOR INNOCATIVE NUCLEAR ENERGY SYSTEMS

F. M. Marshall, A. Borio di Tigliole, M. Khoroshev
International Atomic Energy Agency

Presented by M.Khoroshev

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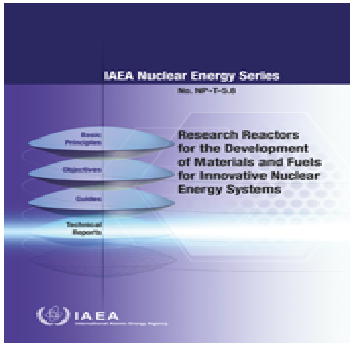

Research Reactors for the Development of Materials and Fuels for Innovative Nuclear Energy Systems

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This publication presents an overview of research reactor capabilities and capacities in the development of fuels and materials for innovative nuclear reactors, such as GenIV reactors. The compendium provides comprehensive information on the potential for materials and fuel testing research of 30 research reactors, both operational and in development. This information includes their power levels, mode of operation, current status, availability and historical overview of their utilization. A summary of these capabilities and capacities is presented in the overview tables of section 6. Papers providing a technical description of the research reactors, including their specific features for utilization are collected as profiles on a CD-ROM and represent an integral part of this publication. The publication is intended to foster wider access to information on existing research reactors with capacity for advanced material testing research and thus ensure their increased utilization in this particular domain. It is expected that it can also serve as a supporting tool for the establishment of regional and international networking through research reactor coalitions and IAEA designated international centres based on research reactors.

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IAEA Nuclear Energy Series

No. NP-T-5.8

Research Reactors for the Development of Materials and Fuels for Innovative Nuclear Energy Systems

Technical Reports

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Bookmarks

PROFILES SUMMARY

The 30 profiles on the CD-ROM accompanying this publication provide a technical description of the research reactors, including their specific features for utilization (see Table 1). The profiles describe research reactors according to the template which was agreed among a broad group of international experts contributing to this publication. Most of the profiles were provided to the IAEA by Member State institutions in response to requests to complete the template. Although some profiles do not follow exactly the requested contents and format, they have been included for completeness.

The profile remains true to the original report submitted. The views expressed do not necessarily reflect those of the IAEA. The use of particular designations of countries or territories does not imply any judgement by the IAEA as to the legal status of such countries or territories, of their authorities and institutions or of the delimitation of their boundaries.

TABLE 1. RESEARCH REACTORS INCLUDED IN THE PROFILES ON THE CD-ROM

Profile No.	Country	Research reactor	Readiness[a]	Table[b]
1	Argentina	Argentine multipurpose reactor (RA-10)	Planned	A–2
2	Belgium	Belgium Reactor 2 (BR-2)	Operational	A–1
3	China	China Experimental Fast Reactor (CEFR)	Operational	A–1
4	China	China Advanced Research Reactor (CARR)	Operational	A–1
5	Egypt	Experimental Training Research Reactor 2 (ETRR-2)	Potential	A–3
6	France	Jules Horowitz Reactor (JHR)	Planned	A–2
7	Hungary	Budapest Research Reactor (BRR)	Potential	A–3
8	India	DHRUVA	Operational	A–1
9	India	High Flux Research Reactor (HFRR)	Potential	A–2
10	Indonesia	Reaktor Serba Guna G.A. Siwabessy (RSG-GAS)	Operational	A–3
11	Japan	Japan Materials Testing Reactor (JMTR)	Operational	A–1
12	Japan	Experimental Fast Reactor (JOYO)	Potential	A–3
13	Kazakhstan	Impulse Graphite Reactor (IGR)	Operational[c]	A–4
14	Republic of Korea	High-flux Advanced Neutron Application Reactor (HANARO)	Operational	A–1
15	Netherlands	High Flux Reactor (HFR)	Operational	A–1
16	Norway	Halden Boiling Water Reactor (HBWR)	Operational	A–1
17	Poland	MARIA	Potential	A–3
18	Romania	TRIGA II Pitești	Operational[c]	A–1, A–4
19	Russian Federation	Fast Pulse Graphite Reactor (BIGR)	Operational[c]	A–4
20	Russian Federation	IR-8	Operational	A–1

Introduction

- Project Background, Link to Nuclear Power Development
- Motive for the Compendium
- Role of Material Test Reactors (MTRs) for Reactor Material Development
- Future R&D Needs
- Structure of Compendium
- MTR Information Included in Compendium
  - Reactors
    - Unique designs
    - Transient testing
    - Experimental capabilities
  - Ancillary Facilities

Contact: F.Marshall@iaea.org

Project Background

- Overall Activity on “Research Reactor Support Needed for Innovative Nuclear Power Reactors and Fuel Cycles”
  - Identify innovative nuclear research and development (R&D) activities that require RR support
  - Identify existing (or soon to be operational) RR facilities capable of supporting innovative nuclear development
  - Quantify the capabilities of the identified facilities within the context of the required research support
  - Promote the experience and resources of the identified facilities
  - Identify significant challenges or constraints potentially limiting a facility’s ability to provide support
  - Quantify technical capability gaps between identified facilities and research requirements
  - Recommend measures to address the capability gaps identified above

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Contact: F.Marshall@iaea.org

Origin of the Compendium

- IAEA Published *Utilization Related Design Features of Research Reactors: A Compendium*, Technical Reports Series No. 455, in 2007
  - Included some information about MTRs, but not many details, nor did it include a wide variety of MTRs
  - Decided that more detailed information about specific experiment capabilities was required.
- Communication to Nuclear Energy R&D Organizations about RR Capabilities
- Motivated by Interest in Increasing Utilization of Existing RRs
- Useful for Newcomer Member States in Understanding Existing Capabilities – Eliminate Duplication and Enhance Cooperation between RR Facilities in Networks
- Supported by Technical Working Group on Research Reactors, 2013

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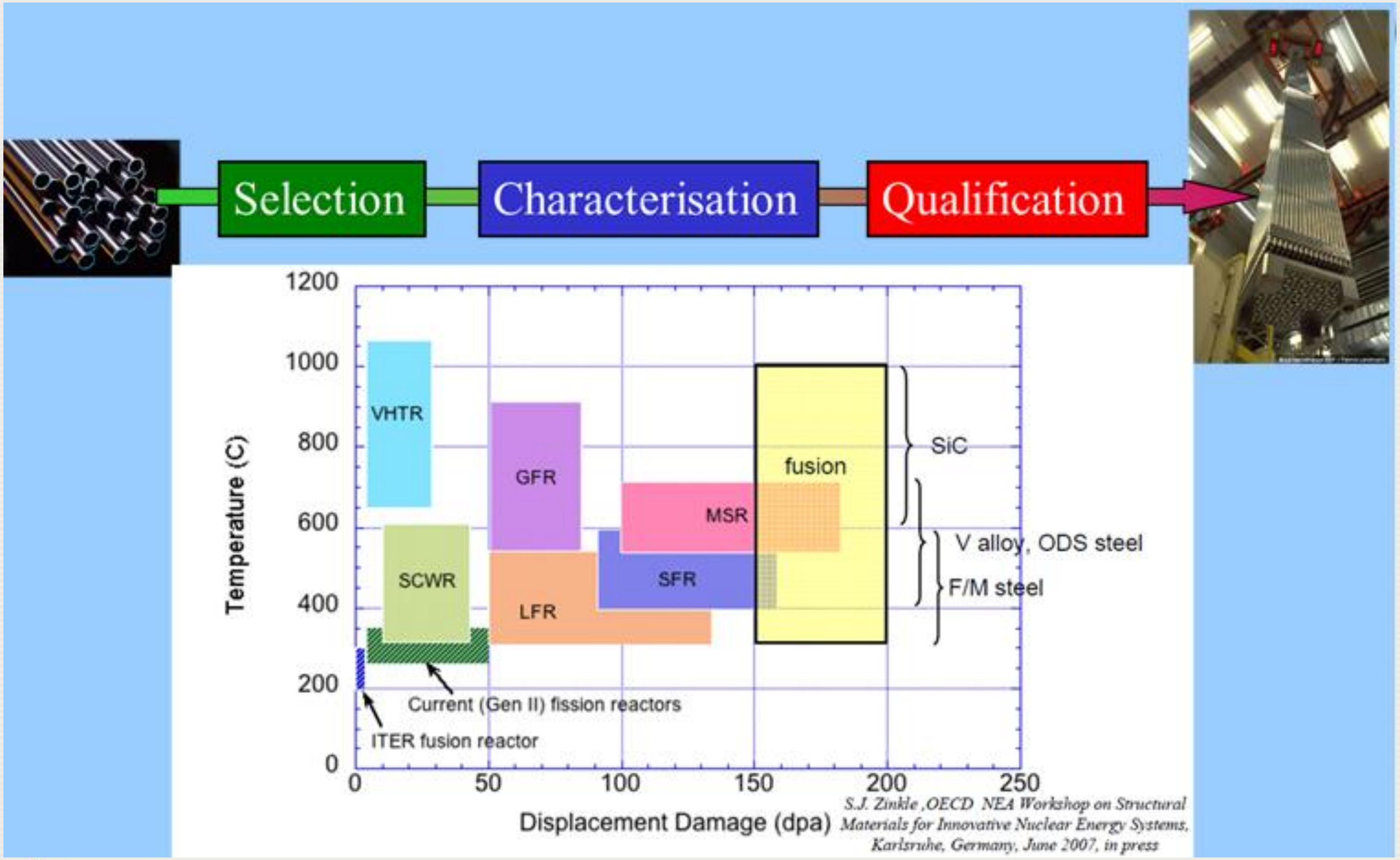
Contact: F.Marshall@iaea.org

Material Development in Nuclear Industry



RR Applications, from IAEA RR Database

Application	Number of Reactors	Number of Countries Represented
Education and Training	162	52
Neutron Activation Analysis	115	51
Radioisotope Production	82	41
Neutron Radiography	68	39
Material/Fuel Testing and Irradiation	61	26
Neutron Scattering	44	29
Nuclear Data Measurements	2	2
Gem Coloration	18	10
Silicon Doping	23	15
Geochronology	26	23
Neutron Therapy	16	13
Other	118	34

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http://nucleus.iaea.org/RRDB/

Contact: F.Marshall@iaea.org

Compendium Users

- Governmental and Private Sector Organizations Responsible for the Development and/or Deployment of Innovative Nuclear Energy Systems
  - Designers
  - Manufacturers
  - Vendors
  - Research institutions
  - Universities
- Other Organizations Directly Involved in the Development of Materials and Fuels for Nuclear Energy Industry
- Regulators

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Contact: F.Marshall@iaea.org

Compendium Contents

- Overview of MTRs Included, Categorized by
  - Operational status (operation, planned, or potential)
  - Operational mode (steady state, pulsed)
  - Power levels (high, medium, low)
  - Neutron spectrum (fast, thermal)
  - Unique design impacting experimental capability
  - Experiment configurations
  - In-situ instrumentation
  - Loop coolant options (molten metal and salts, supercritical water, gas)
- Summary of Capabilities for Included Reactors, Including Access Information for Researchers
- Detailed Profiles for Each Reactor Included
- More Profiles Expected for Future Revisions

Contact: F.Marshall@iaea.org

High Power MTRs Included (P≥20 MW)

Country	Reactor Name	RR Full Name	Status
Argentina	RA-10	Argentinian Multipurpose Reactor	Planned
Belgium	BR-2	Belgium Reactor - 2	Operational
China	CARR	China Advanced Research Reactor	Operational
China	CEFR	China Experimental Fast Reactor	Operational
Egypt	ETRR-2	Experimental Training Research Reactor - 2	Potential*
France	JHR	Jules Horowitz Reactor	Planned
India	DHRUVA	DHRUVA	Operational
India	HFRR	High Flux Research Reactor	Potential
Indonesia	RSG-GAS	Reaktor Serba Guna G.A. Siwabessy	Operational
Japan	JMTR	Japan Materials Test Reactor	Operational

* Operational reactor, but new capability to be added

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Contact: F.Marshall@iaea.org

High Power MTRs Included (cont.)

Country	Reactor Name	RR Full Name	Status
Japan	JOYO	Experimental Fast Reactor	Operational
Korea	HANARO	High-flux Advanced Neutron Application Reactor	Operational
Netherlands	HFR	High Flux Reactor	Operational
Norway	HBWR	The Halden Boiling Water Reactor	Operational
Poland	MARIA	The MARIA Reactor	Operational
Russian Federation	SM-3		Operational
Russian Federation	BOR-60	Experimental Fast Sodium Reactor	Operational
Russian Federation	MIR.M1	The Research Reactor MIR.M1	Operational
United States	ATR	Advanced Test Reactor	Operational
United States	HFIR	High Flux Isotope Reactor	Operational

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Contact: F.Marshall@iaea.org

Medium Power MTRs Included (5<u><</u>P<20 MW)

Country	Reactor Name	RR Full Name	Status
Hungary	BRR	Budapest Research Reactor	Potential*
Romania	TRIGAII-PITESTI	Training, Research, Isotope General Atomics Steady State Research Reactor	Operational
Russian Federation	IVV-2M	Water-moderated, Water-cooled, Multipurpose Nuclear Research Reactor	Potential*
Russian Federation	IR-8	IR-8 Pool Type Reactor	Operational
Russian Federation	RBT-6	Thermal Neutron Pool Type Reactor	Operational
United States	MITR	Massachusetts Institute of Technology Reactor	Operational

* Operational reactor, but new capability to be added

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Contact: F.Marshall@iaea.org

Low Power Reactor Contributions

- Typically MTRs have High Power/Flux
- Some Low Power Reactors were Included in Compendium to Support Material Testing Without Requiring Long Irradiation Durations and High Fluxes
  - Instrumentation testing and calibration for experiment capability development
  - Basic neutron damage testing prior to longer duration test in high flux reactor
  - Nuclear data collection, such as cross section measurements
  - Non destructive analysis to support material testing
    - Neutron radiography
    - Small angle neutron scattering

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Low Power MTRs Included (P<5 MW)

Country	Reactor Name	RR Full Name	Status
Italy	RSV TAPIRO	The TAPIRO Nuclear Reactor	Planned
Italy	TRIGA RC-1	The TRIGA RC-1 Research Reactor	Operational
Slovenia	TRIGA	Training, Research, Isotope General Atomics Mark II Reactor	Operational
Russian Federation	BFS	Critical Stands BFS-1&2	Operational
Russian Federation	SM-3	Critical Facility at SM-3	Operational

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Contact: F.Marshall@iaea.org

Pulsed Reactors Included

Country	Reactor Name	RR Full Name	Status
Kazakhstan	IGR	Impulse Graphite Reactor	Operational
Romania	TRIGAII-PITESTI	Training, Research, Isotope General Atomics Pulsed Reactor	Operational
Russian Federation	BIGR	Fast Pulsed Graphite Reactor	Operational

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Contact: F.Marshall@iaea.org

Unique Experimental Capabilities

- ATR – Geometry shaped like 4-leaf clover and can operate with different conditions in the four corner regions of the core in one operating cycle
- BR2 – Can achieve very high fluxes in the center of the core due to the twisted hyperboloidal shape
- HBWR – Initially licensed as a prototype BWR, so there can be up to 30 fuelled experiments at a time.
- HFIR – Concentrated high flux in the center of the core facilitating practical long term irradiation programs.
- MIR – Can accommodate up to 11 loop tests, and has a combination of high flux (5E14 n/cm^2-s)and large diameter irradiation channel (148.5 mm)
- Loop Coolant Options
  - Current NPP conditions – LWR, WWER, CANDU, RBMK
  - Liquid metal
  - Gas-cooled
  - Sodium (planned)

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Contact: F.Marshall@iaea.org

In-Core Experiment Instrumentation

- New Reactor Conditions Require New Material Performance
- Existing Instrumentation Insufficient for New Operating Parameters
- Instrument Development Efforts Include Instruments that can Withstand Harsher Conditions and Test More Complex Material Irradiation Phenomena
  - Higher temperature
  - Strain loading during irradiation
  - Higher pressure
  - Potentially corrosive coolants
  - Miniature neutron detectors embedded in the experiments
  - Ultra-sonic transducers
  - Irradiation-resistance video monitors in the experiment regions

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Contact: F.Marshall@iaea.org

Post Irradiation Examination Capabilities

Standard Post Irradiation Examination (PIE) Facilities for MTRs Include A Variety of Testing Capabilities

Non-Destructive PIE

- Geometry measurements, elongation, straightness
- Visual examinations
- Gamma scanning
- Eddy-current testing
- Ultrasonic examinations
- Neutron radiography
- X ray radiography

Destructive PIE

- Metallography and ceramography
- Micro-hardness
- Density and porosity
- Burn-up measurement
- Fission products release
- Thermal conductivity and electric resistance
- Transmission electron microscope (TEM)
- Scanning electron microscope (SEM)
- Quantitative elemental micro-analysis EPMA
- Secondary ion mass spectrometry (SIMS)
- Mechanical testing (tensile, compression, bending, impact, etc.)

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Contact:
F.Marshall@iaea.org

International Centres Based on Research Reactors (ICERR)

- IAEA Member States (MSs) increasing need for access to RR facilities
- Accessing these facilities can be both expensive and not timely
- IAEA designated “International Centre based on Research Reactor” (ICERR) program is intended to help IAEA MSs gain timely access to relevant nuclear infrastructure based on RRs
- Principal ICERR Objective is to Recognize and Incentivise the Following Outcomes:
  - To **make available** existing RRs to IAEA MSs
  - To provide a **scientific hub** for IAEA MSs to support nuclear R&D
  - To **improve accessibility** of existing RRs
  - To **facilitate joint activities** of IAEA MSs
  - To **enhance utilization** of existing RRs
- Process is for MS to apply for ICERR designation, IAEA to perform evaluation.
- CEA first organization to be designated as ICERR – Cadarache and Saclay

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Contact: F.Marshall@iaea.org

Summary

- In response to Member State need and request, IAEA has developed a Catalogue of material testing reactors (MTR) capabilities
- It contains detailed information on about 30 MTRs (“Profiles”), provided by Member State MTR representatives
- For each MTR included, there is Information about experiment capabilities, loop testing conditions, experiment instrumentation, post irradiation examination (PIE) facilities, and access to the facility
- IAEA designated “International Centre based on Research Reactor” (ICERR) program supports efforts for MTRs to work collaboratively and facilitate access to the research facilities

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Contact: F.Marshall@iaea.org

Thank You For Your Attention!

A.Borio@iaea.org, F.Marshall@iaea.org, M.Khoroshev@iaea.org

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