

**IAEA Technical Meeting on
Commercial Products and Services of Research Reactors
28 June – 2 July 2010**

**under the IAEA project on
Enhancement of Utilization and Applications of Research Reactors**

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Physics Section

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IAEA

International Atomic Energy Agency

Outline

- **Background**
- **Key Issues and challenges**
- **IAEA related activities**
 - **Networks and coalitions**
 - **Coordinated Research Projects**
 - **Technical Cooperation Projects**
 - **Research Reactor Data Base**
 - **Meetings and workshops**
 - ...
- **Objectives of this TM**

Background

Source: IAEA RRDB, March 2010

TOTAL:	672
Operational	234
Temp. shutdown	11
Under construction	6
Planned	2
Shutdown/Decommissioned	419



Operational RRs are distributed over 56 countries

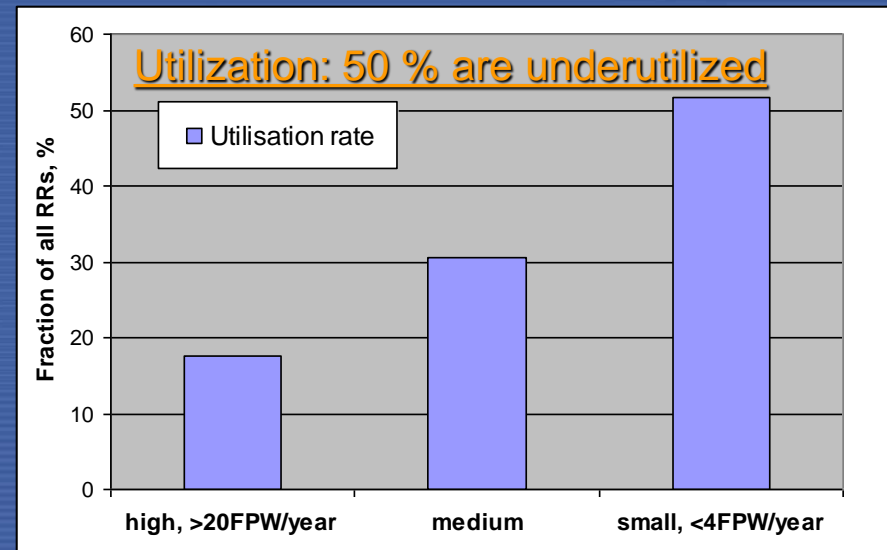
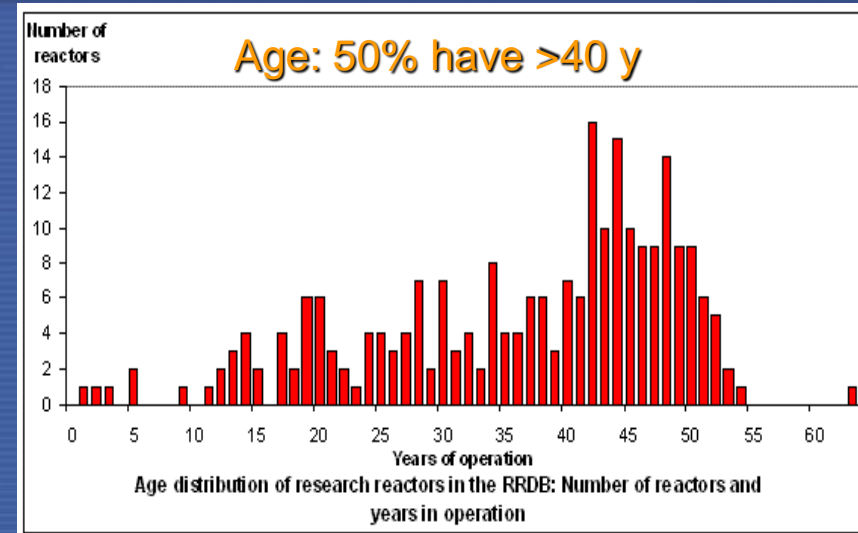
Russia	~44
USA	~41
China	~16
Japan	~13
France	~11
Germany	~10

Region	Operational RRs
Africa	9
Americas	66
Asia/Pacific	59
Europe (with Russia)	100

Key issues and challenges

Source: IAEA RRDB, March 2010

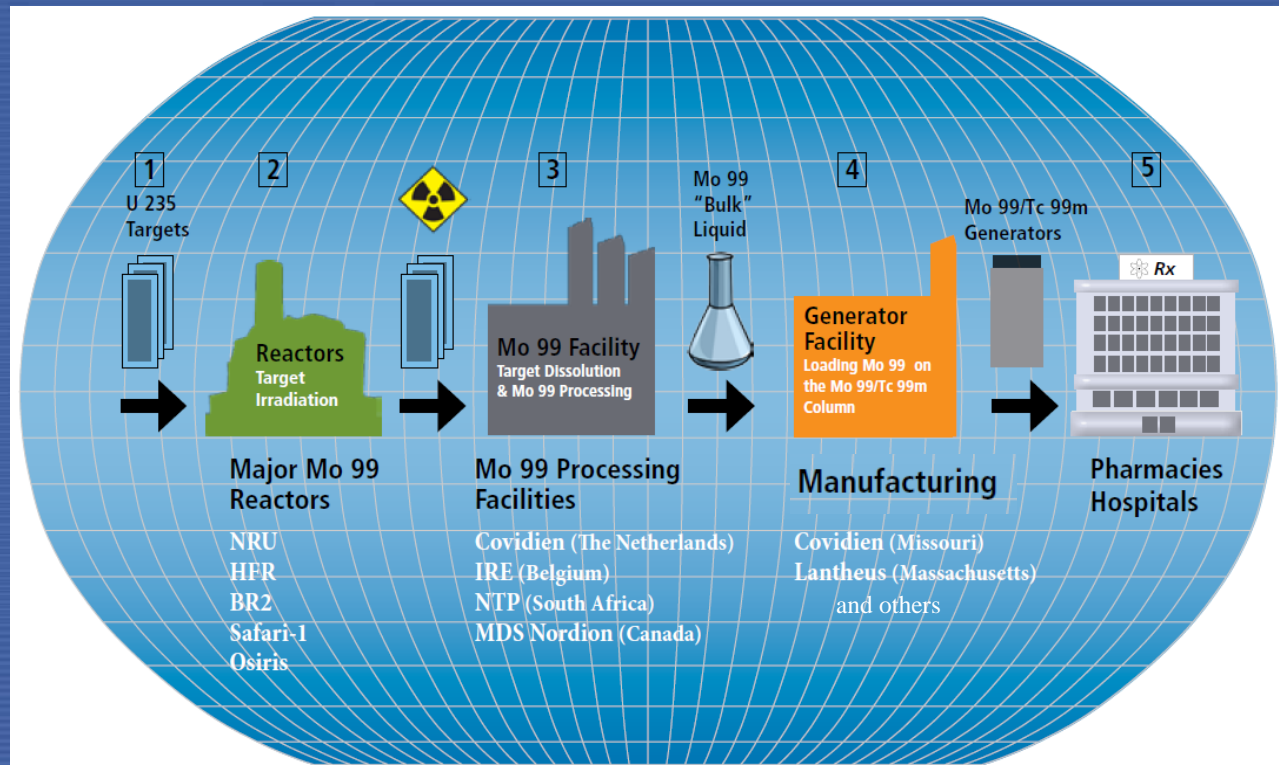
- RR underutilization
- Ageing & needs for refurbishment
- Fuel cycle and safety issues
- Requests for new RRs
- ...



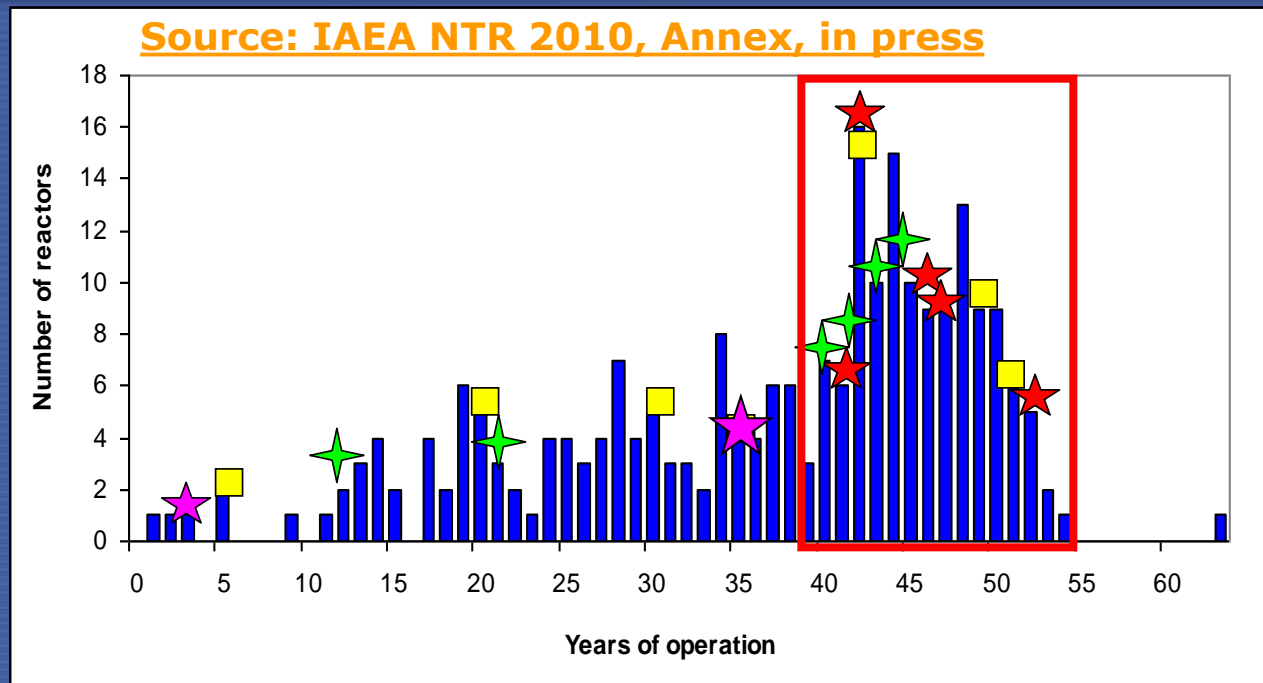
Key issues and challenges: **supply of Mo-99**





- Over 80% of diagnostic nuclear medical imaging uses radiopharmaceuticals containing technetium-99m (^{99m}Tc), entailing over 30 million investigations per year
- Over 95% of the ^{99}Mo required for ^{99m}Tc generators is produced by the fission of uranium-235 targets in nuclear research reactors

Source: IAEA NTR 2010, Annex, in press



Key issues and challenges: **supply of Mo-99**



-  • The five major RR currently producing more than 95 % of ⁹⁹Mo
-  • The OPAL (Australia) and Maria (Poland)
-  • Existing RR that are already used by regional ⁹⁹Mo producers or for which commissioning is underway
-  • Existing RR which are now studying the feasibility of providing irradiation services.

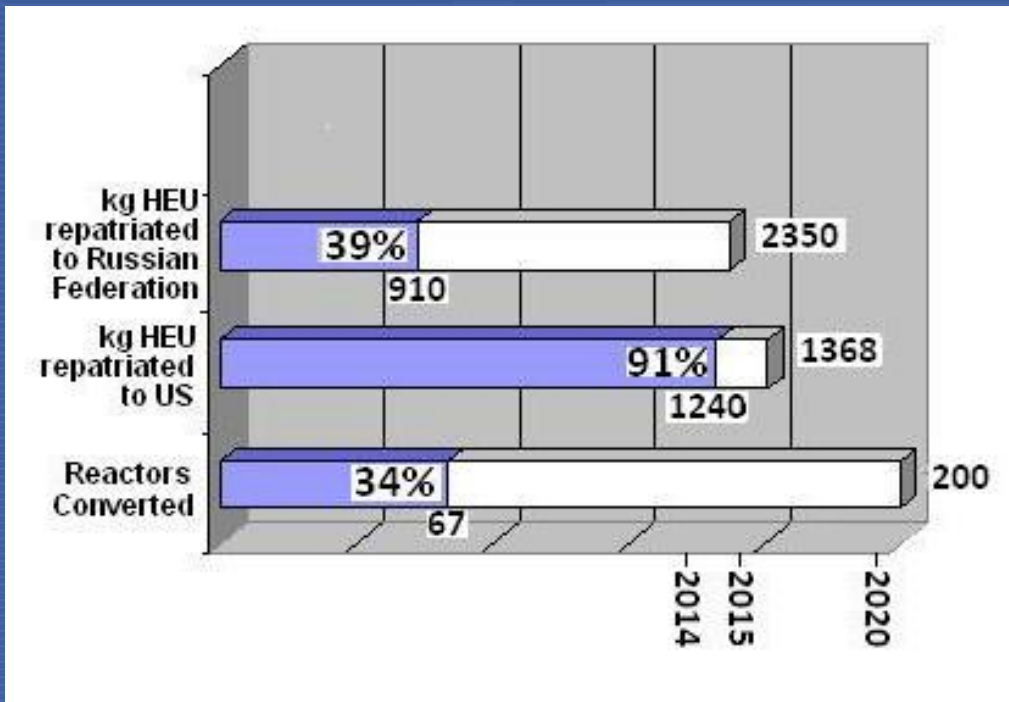
Latest news:

NRU (Canada) and HFR (Netherlands) are shutdown

Maria (Poland) and LVR-15 are entering the production as new important players

Key issues and challenges: **reduction of HEU**

- Reduction of HEU through the Global Threat Reduction Initiative (GTRI)
 - **67 RR cores converted to LEU**, 27 RR are expected/ongoing
 - Spent and fresh fuel take back programmes



Latest news from South Africa:

→ **SAFARI-1 core is entirely LEU since last year!**



RR related efforts within the IAEA programmes

→ Cross cutting activities on RRs: NA, NE, NS, TC, ...

To address

- RR underutilization
- Ageing and needs for refurbishment
- Fuel cycle and safety issues
- Requests for new RRs
- ...

Major Programme D: Nuclear Science

Sub-programme D2: Research Reactors (RR)

Project D2.01:
Enhancement of utilization
& applications of RRs

- Activity 1
- Activity 2
- Activity 3
- ...

Project D2.02:
RR infrastructure, planning
& innovation

Project D2.03:
Addressing RR fuel cycle
issues

Project D2.04:
Research Reactor
operation

Project (D2.01) - Enhancement of RR utilization and applications

List of major activities:

- **RR coalitions & networks**
- **Research Reactor Data Base (RRDB)**
- **Coordinated Research Projects**
- **Technical Meetings (TM), Consultancy Meetings (CM), Schools**
- **International RR Conference, Workshops**
- **Support of national & regional TC projects**
- **Publications, technical reports, brochures**

More information:

http://www-naweb.iaea.org/napc/physics/research_reactors/

Activity: Networks and Coalitions (1)

Objective:

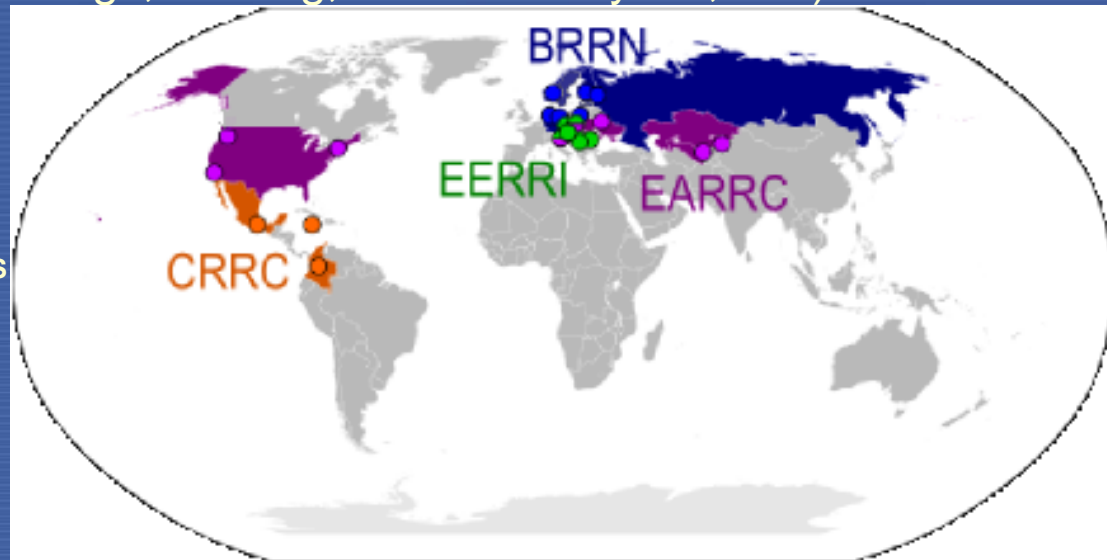
enhanced utilisation and sustainability through regional grouped entities, provision of new products & services, access for countries without RRs, ...

Role of the IAEA:

“facilitator” & “catalyst”- generate and coordinate ideas/proposals/ventures, provide initial support (meetings, training, studies/analyses, etc.)

Status, March 2010:

BRRN – Baltic Research Reactor Network, multipurpose, 10MS
EARRC – Eurasian RR Coalition, isotope production, 5Ms
EERRI – Eastern European RR Initiative, multipurpose, 6MS
CRRC – Caribbean RR Coalition, mainly NAA, 3 MS



Future:

- Strengthen and consolidate the existing 4 RR coalitions
- Assist in developing common strategic and business plans
- Provide support towards maturation, self-reliance and sustainability
- Ensure access to countries without RRs

Activity: Networks and Coalitions (2)

ARRN – African RR Network, NAA and Education & Training, 16 MS

Status:

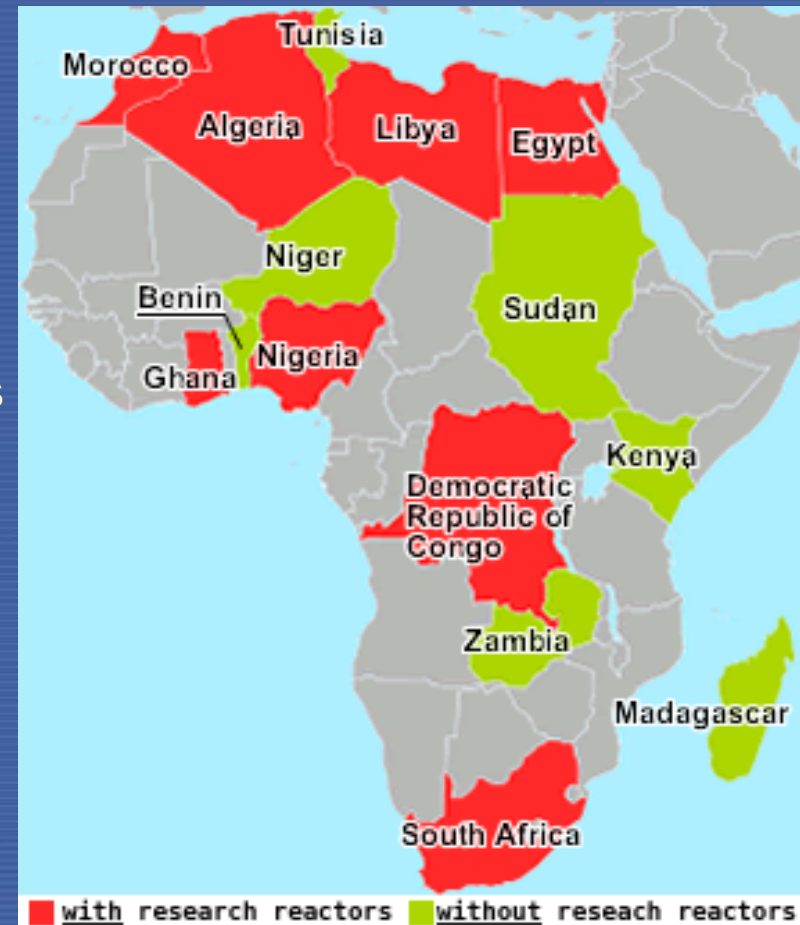
Initiated in 2009 and supported through RAF4022

Activities:

- RR safety related issues
- Proficiency tests in NAA and other techniques
- Education and training

Future:

- regional rather than continental network might be the right approach



Activity: Networks and Coalitions (3)

MRRUN – Mediterranean RR Users' Network, multipurpose, 6 MS

Status:

Created in 2008 in Vienna,
supported through RB

Activities:

little/no due to absence of regional TC projects

Future:

- Through RER4032 and RAF4022 support will be ensured
- New meeting is planned in July 2010 in France, 20 MS are expected
- Formulation of a new interregional (?) TC project



Activity: Networks and Coalitions (4)

APRRN – Asia-Pacific RR Network, neutron scattering, 11 MS

Status:

Discussed in 2009, supported through RB

Activities:

- research and applications with neutron beams
- ANSTO as an IAEA CC
- existence of AONSA

Future:

- 2nd meeting is planned in October (Korea)
- formulation of a new regional TC project



Activity: Coordinated Research Projects (1)

Closed CRP 1314 (2006-2009):

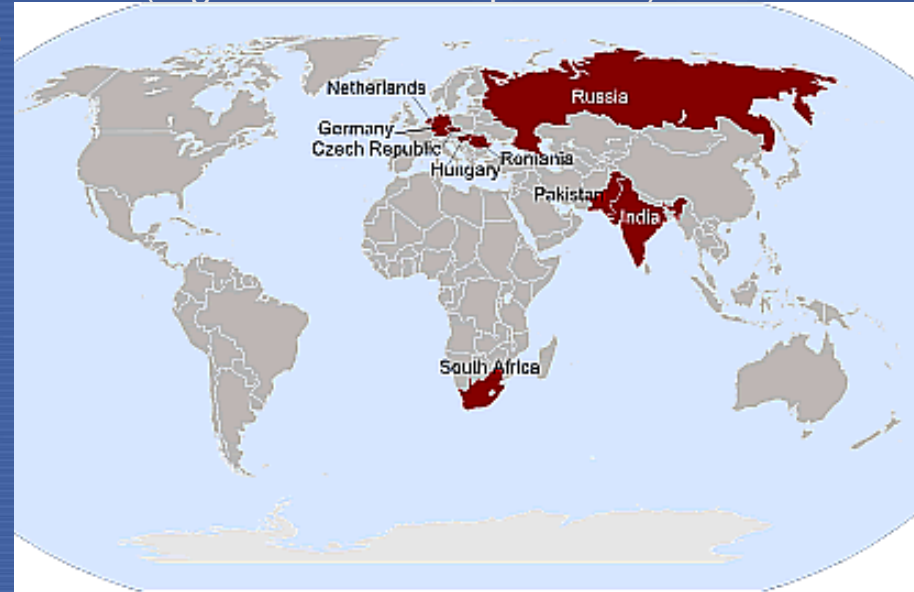
- Development and application of the techniques of residual stress measurements in materials

Objectives:

- characterization, tests and development of materials
- development of new instruments & upgrade of existing facilities
- advanced analysis of material stresses – links to industrial partners
- harmonisation and standardization procedures (e.g. round robin experiment)

• 5 Research Contracts + 4 Research Agreements

1. Czech Republic
2. Germany
3. Hungary
4. India
5. The Netherlands
6. Pakistan
7. Romania
8. Russian Federation
9. South Africa



Main achievements/outlook:

- Creation of network on residual stress
- Transfer of know-how from RA holders to RC (developed → developing)
- Round Robin experiments are ongoing (+USA, +Australia, +UK)
- Project report for Technical Report Series is in preparation

Activity: Coordinated Research Projects (2)

Active CRP 1496 (2008-2011), jointly coordinated and supported by NA, NE and NS:

- Innovative methods in RR Analysis: Benchmark against Experimental Data on Neutronics and Thermalhydraulic Computational Methods & Tools for Operation & Safety Analysis of RRs

Objectives:

- encourage cooperation and exchange of information in the area of RR related numerical analysis
- facilitate and support RR design, operation, and safety
- benchmark against experimental data existing neutronics and thermalhydraulic computational methods and tools that are routinely utilized for operation and safety analysis of RRs

8 Research Contracts + 7 Research Agreements + 2 Observers

1. Argentina
2. Australia
3. Bangladesh
4. Canada
5. Egypt
6. France
7. Germany
8. Ghana
9. Nigeria
10. Pakistan
11. Romania
12. South Africa
13. Syrian Arab Republic
14. USA
15. Uzbekistan



Expected output:

- report on comparison of experimental and theoretical results
- **data base of RR characteristics, experiments and data used for benchmarks**
- recommendations on open issues for future R&D activities involving RRs
- increased cooperation in RR related experiments and modelling

Activity: Coordinated Research Projects (3)

Active new CRP 1575 (2009-2012):

- Development, Characterization and Testing of Materials of Relevance to Nuclear Energy Sector Using Neutron Beams (SANS, diffraction and neutron radiography)

Objectives:

- investigation and characterization of materials relevant to nuclear energy applications
- optimization and validation of experimental and modelling methods
- creation of a database of reference data for nuclear materials research
- enhancement of the capacity of research reactors for nuclear materials research

→ 8 Research Contracts + 9 Research Agreements (with Australia in final approval stage)

1. Argentina
2. Australia
3. Brazil
4. China
5. Czech Republic
6. France
7. Germany
8. Hungary
9. Indonesia
10. Italy
11. Japan
12. Korea
13. The Netherlands
14. Romania
15. Russian Federation
16. Switzerland
17. USA



Expected output:

- Materials characterized, experimental/modelling methods optimized
- Creation of multilateral network in the field of advanced nuclear materials research
- Creation of an experimental reference database for models and calculations
- Final project publication

Activity: Technical Cooperation Projects (1)

In addition to the “usual” support through the TC projects (16),

assistance in planning and building the 1st RR

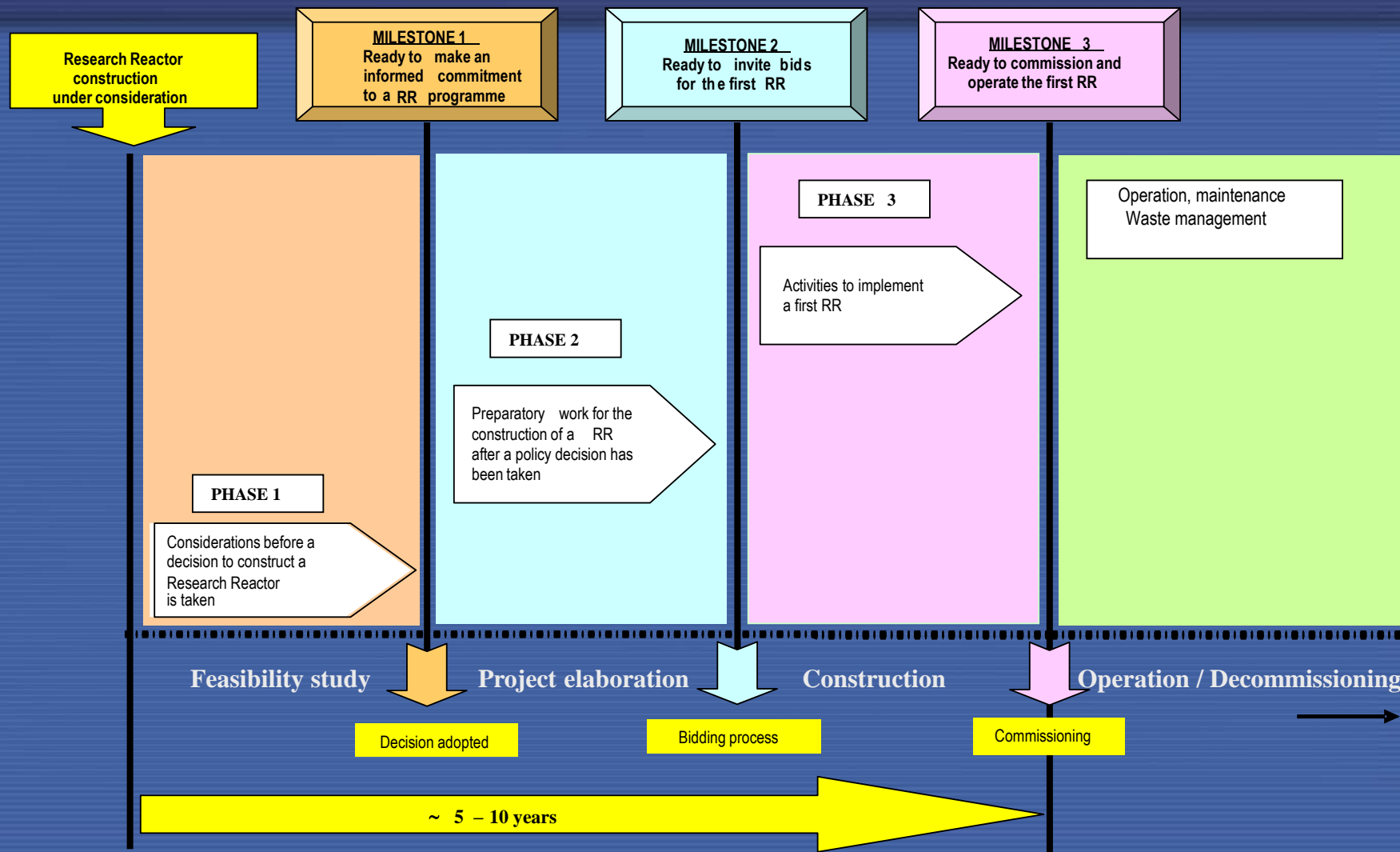
<u>Country</u>	<u>Title</u>	<u>Year Started</u>
Algeria	Development and Improvement of Experimental and Analysis Techniques for the Es Salam Reactor	2005
Azerbaijan	Conducting a Feasibility Study for Planning and Establishing a Research Reactor	2009
China	Residual Stress Measurement using Neutron Diffraction for Industrial Application	2007
Egypt	Development of Neutron Irradiation and Beam Line Facilities for Effective Use of the Research Reactor	2005
Jordan	Establishing a Research Reactor	2009
Kazakhstan	Introducing High Performance Neutron Activation Analysis for Industrial Needs	2009
Libya	Utilizing the Research Reactor	2009
Malaysia	Capability Building in Planning for a High-power Reactor and its Application	2009
Morocco	Use of the Lateral Channels of the TRIGA Mk. II Research Reactor, Phase III	2007
Peru	Modernizing and Improving the Utilization of the RP10 Reactor	2009
South Africa	Upgrading of the Neutron Beam Line Facilities of the SAFARI-1 Research Reactor	2007
Sudan	Sudan Nuclear Research Reactor Project	2010

<u>Region</u>	<u>Title</u>	<u>Year Started</u>
Africa	Enhancing Research Reactor Utilization and Safety	2009
GCC	Developing a Regional Nuclear Training Centre for Capacity Building and Research	2009
Europe	Enhancement of the Sustainability of Research Reactors and Their Safe Operation Through Regional Cooperation, Networking and Coalitions	2009
Latin America	Supporting a Sustainable Increase in the Use of Research Reactors in the Latin American and Caribbean Region through Networking, Exchange of Experiences, Knowledge Preservation and Training of Human Resources	2009

Activity: New RRs (1)

Azerbaijan, Jordan, GCC and Sudan

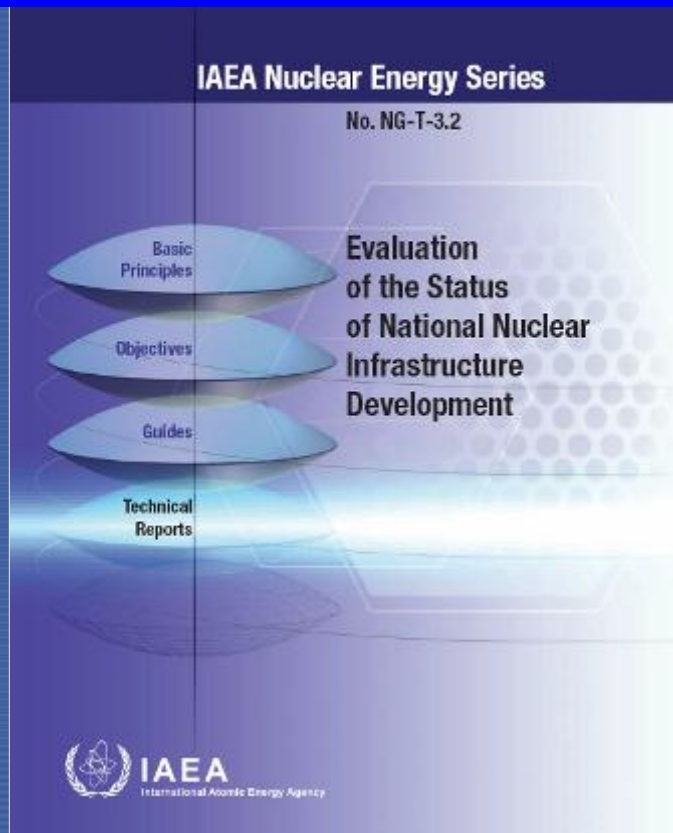
Building a RR: phases



Approach for the 1st RR: similarity to NPP

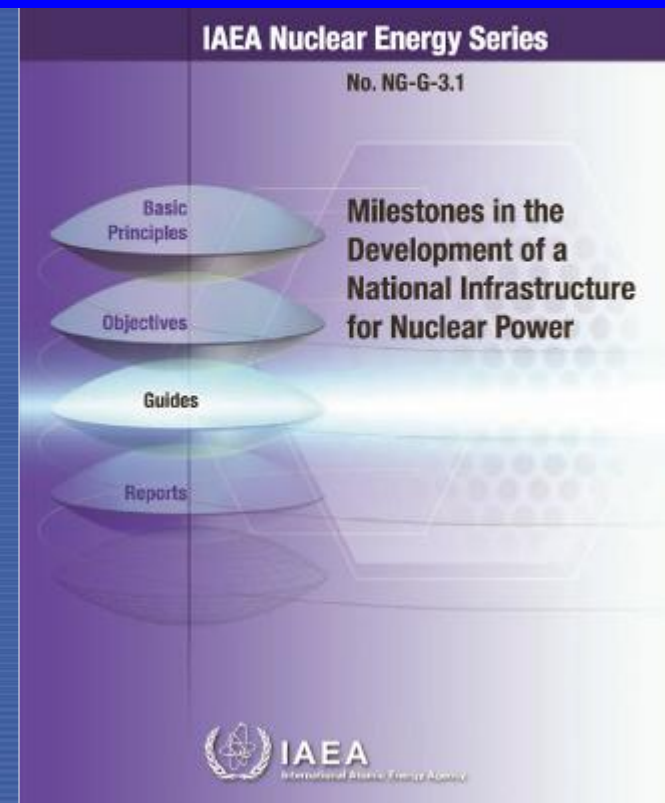
Guidelines document (available):

Guidelines and questionnaires for preparation of country status reports

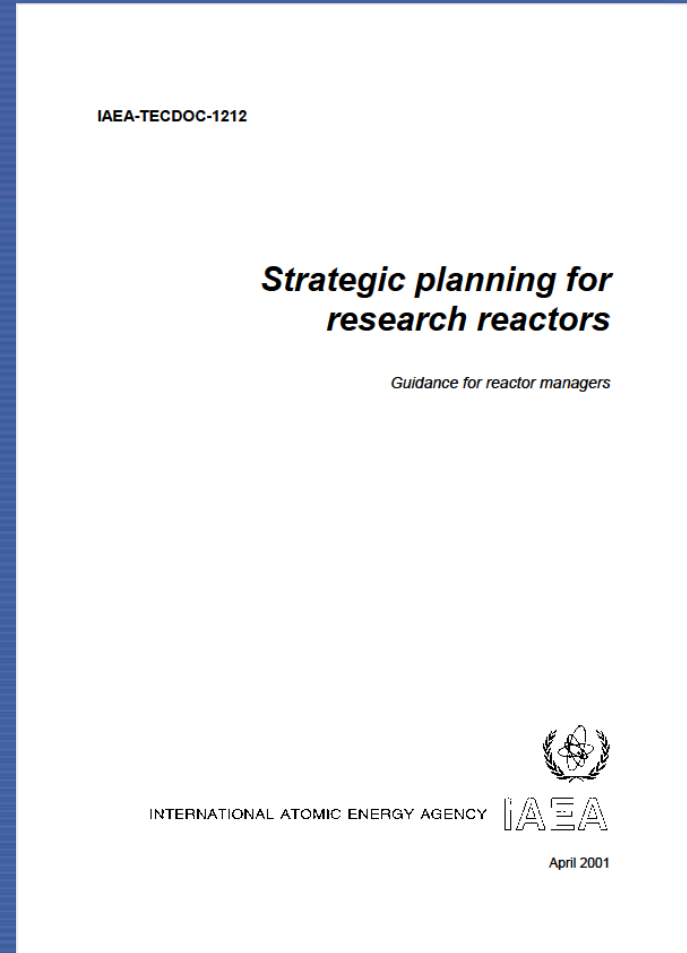
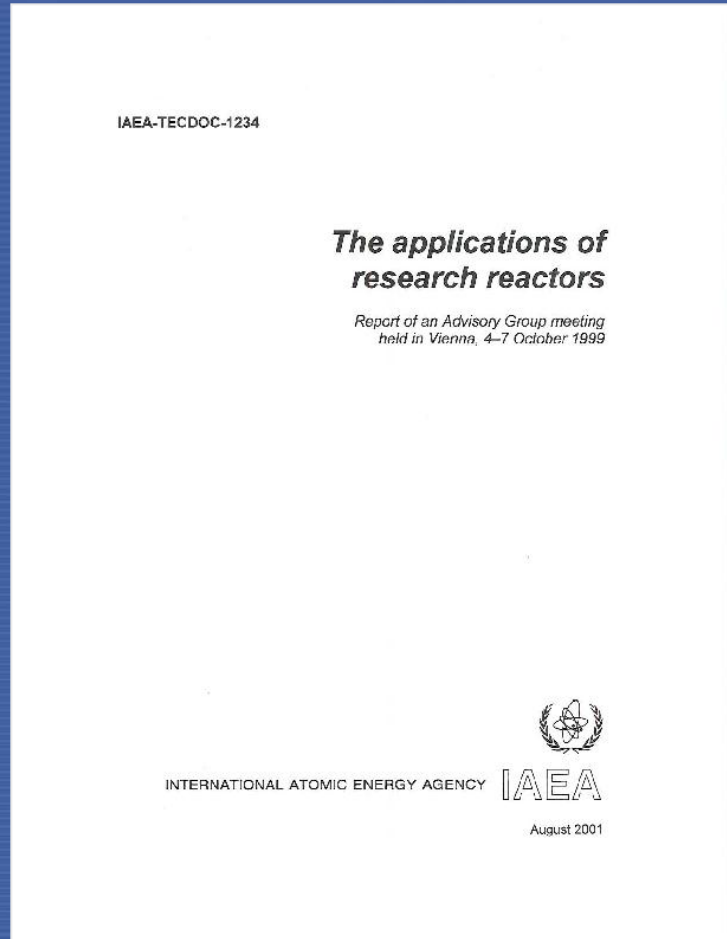


Milestones document (in progress):

Milestones in the Development of a National Infrastructure for a Research Reactor Programme



Preparation of Strategic and Business Plans

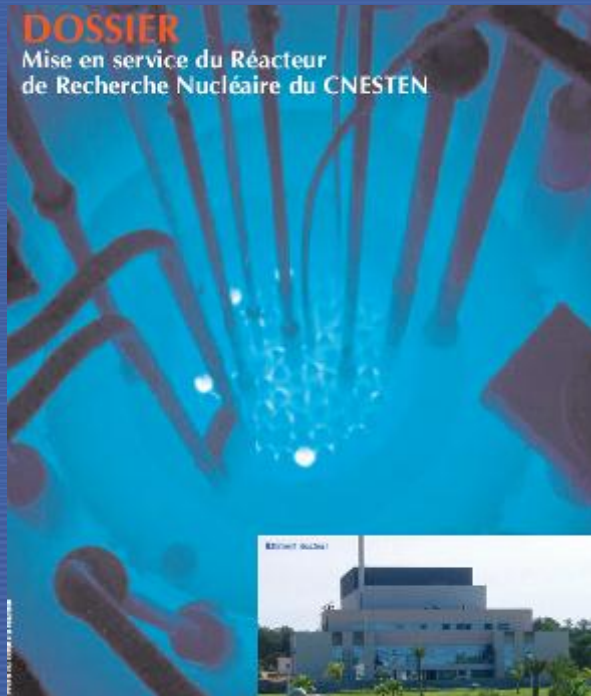


Activity: **New RRs (4)**

Recently licensed RR

TRIGA Mark II, Morocco; 2007 **support through national and regional TC**

- 2 MW, in core flux $4 \cdot 10^{13}$ n/(s cm²)
- Fuel: UZrH, LEU 19% U-235, Coolant: H₂O, Moderator: H₂O+ZrH
- Reflector: graphite, Control: B₄C
- Support to nuclear power, education & training, basic research
- Material research, isotope production, activation analysis, radiography, etc.



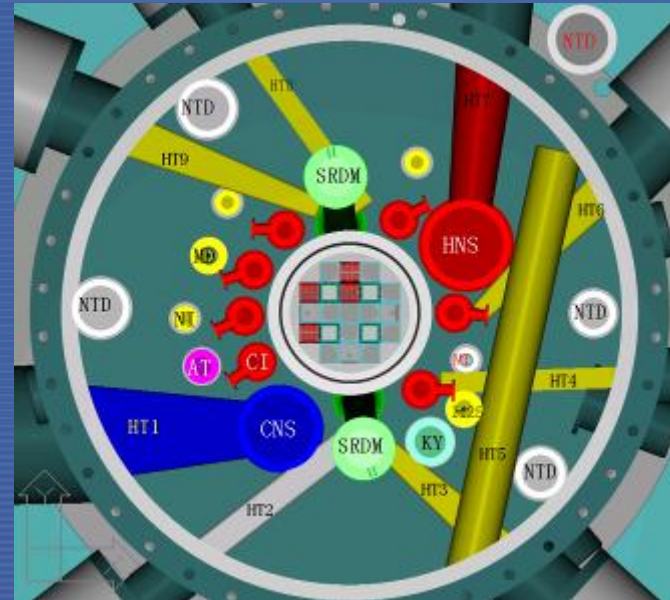
Activity: **New RRs (5)**

Last licensed RR

CARR, China, 1st criticality on 13 May 2010

support through national TC

- 60 MW, in core flux $\sim 1 \cdot 10^{15}$ n/(s cm²)
- Fuel: 19% U-235, Moderator: H₂O, Reflector: D₂O
- Replacement for 10MW HWRR (2007)
- Multipurpose RR with the main objectives in basic research
- Open to users from universities, governmental laboratories, industry

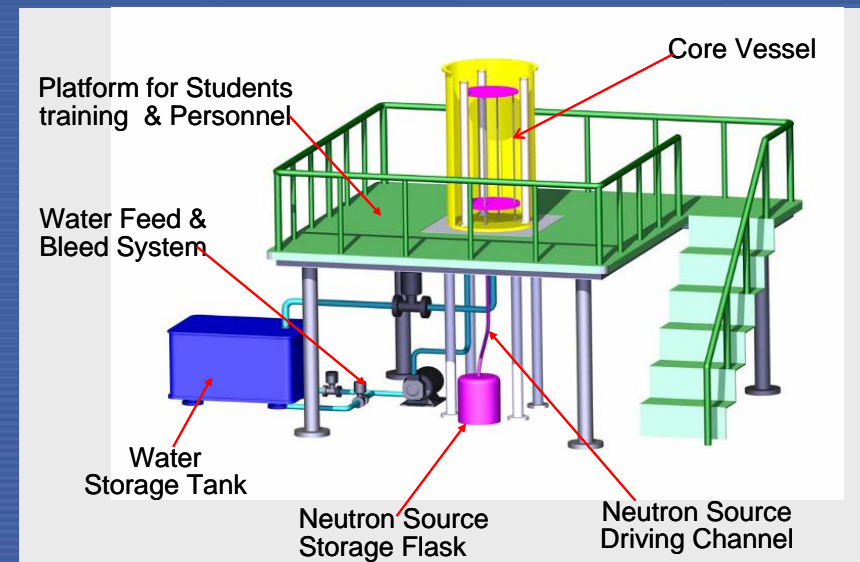


Activity: **New RRs (6)**

Next licensed sub-critical facility

Jordan Sub-Critical Assembly - JSA, Jordan, expected in 2010
support through national TC

- Zero power ($k_{\text{eff}}=0.94$), light water moderated
- Fuel: PWR-structure pattern fuel rods, UO_2 , 3.4% U-235
- Dedicated educational tool for teaching, training and experimental research
- **In support of the future multipurpose RR (~5MW)**



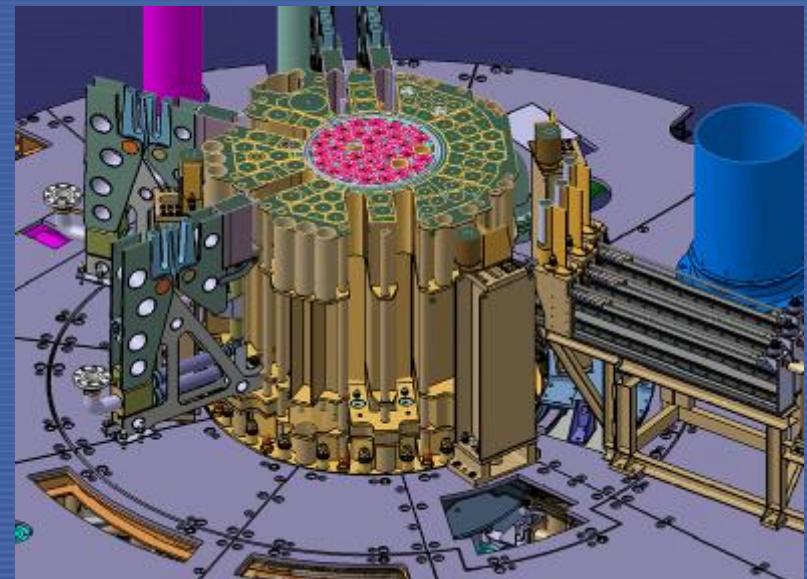
IAEA

Activity: **New RRs (7)**

RR under construction

JHR, France, operation expected in 2014

- MTR pool, 100 MW, in core flux $\sim 1 \cdot 10^{15}$ n/(s cm²)
- Fuel: Ref. UMo LEU, Backup: U₃Si₂ 27 % U-235
- In support of future nuclear power, Gen3+ & Gen4
- Dedicated for material/fuel irradiation and testing
- Other applications envisaged (isotope production)
- International consortium



The IAEA RRDB: since April on-line updates by designated RR managers are possible!

Header Information - RRDB - IAEA - Microsoft Internet Explorer provided by IAEA

http://rrsf-dev.iaea.org/RR/HeaderInfo.aspx?RID=8

File Edit View Favorites Tools Help

Header Information - RRDB - IAEA

Research Reactors

Home Reports Administrator

Reactor Fuel Cycle Data Providers

Reactor **TRIGA II VIENNA** IAEA Code **AT0002** Workflow Status **FDP Update needed** Current | Updated Search

Header Information General Information Technical Data Experimental Facilities Utilization Decommissioning

Country Name * Austria Facility Name * / Number * TRIGA II VIENNA

Status OPERATIONAL

Status Comment: status comment

Category RESEARCH URL www.atf.ac.at

Info Date * 2006-03-25 (YYYY-MM-DD) Geographical Location Latitude: Longitude:

Cancel Save Submit

Reactor Data - RRDB - IAEA - Microsoft Internet Explorer provided by IAEA

http://rrsf-dev.iaea.org/SF/ReactorData.aspx?RID=8

File Edit View Favorites Tools Help

Reactor Data - RRDB - IAEA

Research Reactors

Home Reports Administrator Nucleus

Reactor Fuel Cycle Data Providers

Reactor **TRIGA II VIENNA** IAEA Code **AT0002** Workflow Status **Data Up to Date** Start Data Update Search Reactors

Reactor data Fuel Data Fuel & Inventory Storage Concerns Management Contacts

Country Austria Information provided on 2006-03-25 (yyyy-mm-dd)

Storage site away from reactor Power level (KW) 250.0000

Status OPERATIONAL

Status Comments status comment

General Comments

Comments

GTRI Do you agree to share information with GTRI?

Save



Contact: E. Bradley or D. Ridikas

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RRDB of operational RRs World Wide: in support of RR coalitions!

Operational RRDB			
Geographical Distribution	Reactor Category	Reactor Utilisation	Foreword (Home)
<p>Home</p> <p>Summary Graphs</p> <p>Editorial Note</p>	<p>Home</p> <p>Summary Graphs</p> <p>Editorial Note</p>	<p>Home</p> <p>Summary Graphs</p> <p>Editorial Note</p>	<p>Home</p> <p>Summary Graphs</p> <p>Editorial Note</p>
<p>Geographical Distribution:</p> <ul style="list-style-type: none"> ■ All Reactors ■ Africa ■ Americas ■ Asia / Pacific ■ Europe ■ Russia ■ USA 	<p>Reactor Category:</p> <ul style="list-style-type: none"> ■ Reactor by Status: <ul style="list-style-type: none"> - Operational - Temporary Shutdown - Under Construction / Planned ■ Reactor by Power: <ul style="list-style-type: none"> - Power < 1kW - 1 kW ≤ Power < 1MW - Power ≥ 1MW ■ Reactor by Flux: <ul style="list-style-type: none"> - High Flux - Medium Flux - Low Flux ■ Reactor by Age: <ul style="list-style-type: none"> - Less than 40years - Over 40years 	<p>Reactor Utilisation:</p> <ul style="list-style-type: none"> ■ Utilisation Rate: <ul style="list-style-type: none"> - High Utilisation - Medium Utilisation - Low Utilisation ■ Isotope Production <ul style="list-style-type: none"> - All Isotopes ■ Neutron Scattering ■ Neutron Radiography ■ Material/fuel Irradiation ■ Transmutation: <ul style="list-style-type: none"> - Silicon Doping - Gemstone Coloration ■ Teaching/Training ■ NAA ■ Geochronology ■ BNCT ■ Nuclear Data Provision ■ Other Applications 	<p>Foreword (Home)</p>

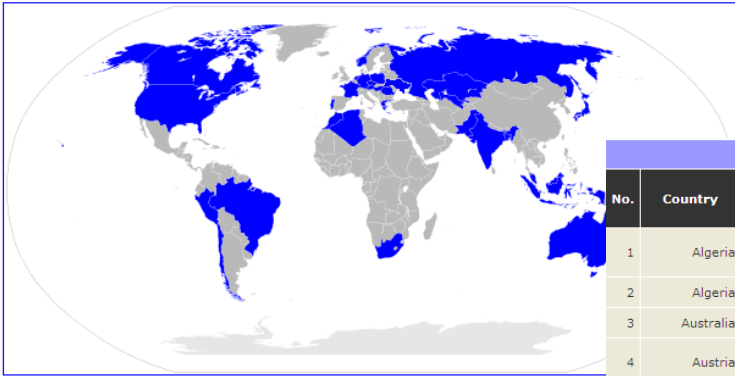
RRDB of operational RRs is available at:

http://www-naweb.iaea.org/naweb/physics/research_reactors/

or **USB Memory Stick, <10MB, no internet is needed!**

RRDB of operational RRs World Wide: in support of RR coalitions!

Neutron Scattering Facilities - "Click here for details"



44 RRs employ neutron beams; they are distributed over 30 MSs

This database contains 44 research reactors performing Neutron Scattering distributed over 30 MSs

Neutron Scattering Facilities							
No.	Country	Name	Reactor Type	Thermal Power, kW	Thermal Flux, n/cm ² /s	Fast Flux, n/cm ² /s	Criticality Date
1	Algeria	ES-SALAM	HEAVY WATER	15000	2.1E14	4.2E12	1992-02-17
2	Algeria	NUR	POOL	1000	5.9E12	4.0E12	1989-03-24
3	Australia	OPAL	POOL	20000	3.0E14	2.1E14	2006-08-12
4	Austria	TRIGA II VIENNA	TRIGA MARK II	250	1.0E13	1.7E13	1962-03-07
5	Bangladesh	TRIGA MARK II	TRIGA MARK II	3000	7.5E13	3.8E13	1986-09-14
6	Brazil	IEA-R1	POOL	5000	4.6E13	1.3E14	1957-09-16
7	Canada	MNR MCMMASTER UNIV	POOL	3000	1.0E14	4.0E13	1959-04-04
8	Canada	NRU	HEAVY WATER	135000	4.0E14	4.5E13	1957- Temp
9	Chile	RECH-1	POOL	5000	7.0E13	5.0E13	1974-
10	Czech Republic	LVR-15 REZ	TANK WWR	10000	1.5E14	3.0E14	1957-
11	France	HFR	HEAVY WATER	58300	1.5E15		1971-
12	France	ORPHEE	POOL	14000	3.0E14	3.0E14	1980-
13	Germany	BER-II	POOL	10000	2.0E14	1.4E13	1973-
14	Germany	FRG-1	POOL	5000	1.4E14	4.5E13	1958-
15	Germany	FRM II	POOL	20000	8.0E14	5.0E14	2004-
16	Greece	DEMOKRITOS (GRR-1)	POOL	5000	1.0E14	4.5E13	1961- Temp
17	Hungary	NUCL. BUDAPEST RES.	TANK WWR	10000	2.5E14	1.0E14	1959-

Utilization

Hours per Day	24
Days per Week	7
Weeks per Year	21
MW Days per Year	2160
Materials/fuel test experiments	NO
Isotope Production	99Mo, 131I, 192Ir, 32P
• Total Activity (GBq)	33741
Neutron Scattering	HRPD, NRF, HRSANS, FCD/TD, SANS, PD
• On-line beam hours	2100
Neutron Radiography	On-line beam hours: N/A
Neutron capture therapy	NO
Activation Analysis	INAA
• number of samples irradiated	300
Transmutation	NO
Geochronology	NO
Teaching	Number of students: N/A
Training	Number of operators/experimenters trained: 13
Other Uses	NO

RRDB of operational RRs is available at:

http://www-naweb.iaea.org/napc/physics/research_reactors/

or **USB Memory Stick, <10MB, no internet is needed!**



Meetings, Workshops and Conferences (2010 -)

2010: IAEA Technical Meetings

Q4	IAEA, Vienna	Research Reactor Applications for Materials in the Energy Sector
June 28 - 2 July	IAEA, Vienna	Commercial Products and Services of Research Reactors
June 14 - 18	IAEA, Vienna	Assessment of Core Structural Materials and Surveillance Programme of Research Reactors

2011: IAEA RR Conference

International Conference on Research Reactors: Safe Management and Effective Utilisation, Rabat, Morocco, from 14 to 18 November 2011

More information on RR utilization and applications related events:

http://www-naweb.iaea.org/naweb/physics/research_reactors/

You are in : Home » Our Work

Our Work

- Promoting Safeguards & Verification
- Promoting Safety & Security
- Promoting Science & Technology

Pillars of Nuclear Cooperation



The IAEA works for the safe, secure and peaceful uses of nuclear science and technology. Its key role is to contribute to international peace and security, and to the World's Millennium Goals for social, economic and environmental development.

Three main pillars - or areas of work - underpin the mission:

Safeguards & Verification



The IAEA is the world's only nuclear inspectorate, with more than four decades of verification experience. Inspectors work to verify that safeguarded nuclear materials and activities are not used for military purposes. The Agency is additionally responsible for the nuclear file in Iraq as mandated by the UN Security Council. [More >](#)

Safety and Security



The IAEA helps countries to upgrade nuclear safety and security, and to prepare for and respond to emergencies. Work is keyed to international conventions, standards and expert guidance. The main aim is to protect people and the environment from harmful radiation exposure. [More >](#)

Science & Technology



The IAEA helps countries mobilize peaceful applications of nuclear science and technology. The work contributes to goals of sustainable development in fields of energy, environment, health, and agriculture, among others, and to cooperation in key areas of nuclear science and technology. [More >](#)

Programmatic Web

- Safeguards
- Safety & Security
- Nuclear Science & Applications
- Nuclear Energy
- Technical Cooperation
- Legal Affairs

Laboratories

- Seibersdorf & Vienna
- Monaco
- Research and Projects
- Coordinated Research
- Knowledge Management
- International Centre for Theoretical Physics (ICTP), Trieste, Italy
- Technical Cooperation Projects

Programme Areas

Direct Links to IAEA's Departmental Websites:

- [Nuclear Energy](#)
- [Nuclear Safeguards](#)
- [Nuclear Safety and Security](#)
- [Nuclear Sciences and Applications](#)
- [Technical Cooperation](#)

RR@IAEA?

- RR @ Nuclear Energy: http://www.iaea.org/OurWork/ST/NE/NEFW/rrg_home.html
- RR @ Nuclear Safety: <http://www-ns.iaea.org/tech-areas/research-reactor-safety/>
- RR @ Nuclear Applications: http://www-naweb.iaea.org/napc/physics/research_reactors

Overall objectives of this TM are:

- Promotion and development of commercial applications of RRs
- Enhancement of RR utilization in Member States for practical applications
- Strengthened regional and international cooperation between RR from developing and developed countries with special emphasis on the transfer of knowledge and good practices

→ Preparation of the IAEA publication

Specific objective of this TM is

To assess the status and future potential for commercial applications of RRs in the following areas:

- Nuclear education and training
- Production of medical and industrial radioisotopes
- Irradiation services for neutron transmutation doping (NTD) of Si, gem coloration, tests of electronic devices, food and goods sterilization, etc.
- Analytical techniques such as instrumental neutron activation analysis (INAA), prompt gamma neutron activation analysis (PGNAA), delayed neutron activation analysis (DNAA), fission track dating, etc., with emphasis on complementary services when compared to non RR based methods
- Neutron beam techniques such as neutron imaging, small angle neutron scattering (SANS), neutron diffraction, etc.
- Support of R&D relevant to present nuclear power reactors (e.g., ageing management, development and qualification of new fuels, etc.)
- Support of R&D relevant to future advanced nuclear systems, both fission and fusion reactors (e.g., development and qualification of fuel and structure materials, reactor design and licensing, validation of modelling tools, nuclear data provision, etc.)
- Other potentially revenue generating applications



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Thank you for your attention!