Nuclear Research Reactors

Seminar on

Nuclear Science and Technology

for Diplomats

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Nuclear Research Reactors (RR)

Outline of Presentation

- Introduction to RR principles, components
- RR types and features
- RR utilization: Techniques and Applications
- RR issues & needs: perceptions and concerns
- Agency assistance on RRs
- Some Stories of Success

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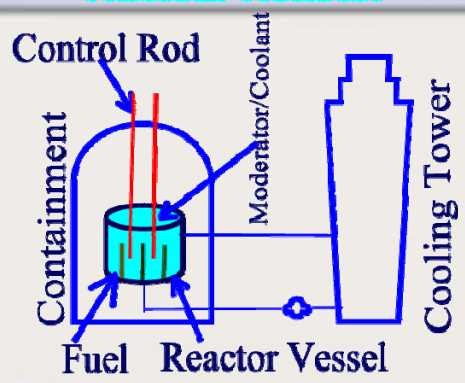
Nuclear Reactor



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Nuclear Research Reactors – Typical Features

- **Typical power levels 30kW to 10MW**
- **Intense source of neutrons. Typical steady-state neutron flux: 10^{11} to 10^{14} neutrons/cm^2·s**
- **Vertical and horizontal channels to avail neutrons**
- Various coolants / moderators
  - light water, heavy water, organic liquids
- Various types of fuel
  - plates, rods, tubes, liquid in homogeneous RR
  - metallic, hydrides, silicides
- Natural and forced circulation cooling

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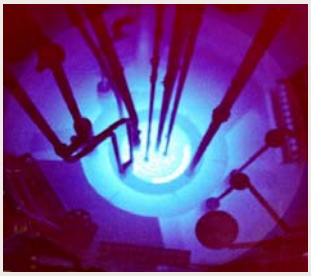
Research Reactors: Some Typical Characteristics

- Small volume cores
- 90% have power level less than 10 MW(t)
- Generally higher enrichment fuel than in power reactors (though some RRs use natural uranium fuel)
- Natural and forced cooling
- May have pulsing capability



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Research Reactor (RR) Types

- Miniature neutron source reactor (MNSR) of 30kW(t) to about 100MW(t) RR (1–10 MW more common)
- Industrial manufacturer supplied RR to custom-built indigenous RR
- Neutron flux ranging from 10^{11} to 10^{14}
  - Neutron beam facilities
  - Sample irradiation facilities (radioisotope production, material testing)
  - Rabbit facility for NAA
  - Analytical and other services facilities

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Research Reactor Data according to the Agency's RR Database (RRDB)

• Reactors in operation	242
HEU → LEU converted	62
HEU → LEU planned	39 + 28
• Total reactors listed	671
• Reactors Shut down	246
• Decommissioned	172
• Under Construction	7
• Planned	4

(LEU <20% ^{235}U; HEU >20 to 93% ^{235}U)

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Research Reactor Utilization Techniques and Purposes

- **Education & Training**
- **Fuel testing and qualification**
- **Supporting power reactor programmes**
- **Radioisotope Production**
- **Neutron Scattering**
- **Material science investigations**
- **Neutron Activation Analysis (NAA)**
- **Neutron transmutation doping**
- **Neutron Radiography**

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Research Reactor (RR) Utilization - Applications

Neutron Irradiation for Radioisotope Production

- *Principle*: Target element's activation in RR for specified period to induce radioactivity
- *Typical Uses*: Production of radioisotopes for a variety of applications in medicine, industry, agriculture, biology and research
- e.g. ANSTO, BARC/Dhruva, HANARO, Safari-1 etc

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Radioisotope Production in RR

- Low n flux: $<10^{13}$ ^{24}Na, ^{32}P, ^{82}Br
- Medium n flux: 2-8 X 10^{13} ^{82}Br, ^{99}Mo, ^{125}I, ^{35}S, ^{131}I, ^{153}Sm, ^{177}Lu, $^{186/188}Re$, ^{192}Ir
- High n flux: $>10^{14}$ ^{60}Co, ^{192}Ir, ^{75}Se, ^{89}Sr, ^{177}Lu, ^{99}Mo, ^{188}W

- **Medicine**
  - Diagnosis
  - Treatment
- **Industry**
  - Radiography
  - Tracer Techniques
  - Radiation Technology
- **Food and Agriculture**
  - Tracer Techniques
  - Mutants - Productivity
  - Disinfestation – Safety, Shelf-life

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Research Reactor (RR) Utilization - Applications

Neutron scattering

- *Principle*: RR neutrons incident on sample and record the angular and energy distribution of scattered neutrons.
- *Typical Uses*: order and dynamics of atoms and molecules in condensed matter, non-destructive testing of materials – residual stress in engineering components; surface studies - thin films, polymers and biological materials, magnetic specimen
- e.g. ILL, Grenoble; HMI, Berlin; HFIR, ORNL; HFR, Petten etc.

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Research Reactor (RR) Utilization - Applications

Neutron Radiography

- *Principle*: Transmission of neutron through selective absorption and scattering results in photograph with details of material contents and defects in specimen.
- *Typical Uses*: Investigation of bulk materials; explosives,
- e.g. PSI, MIT, IPEN, HMI etc.

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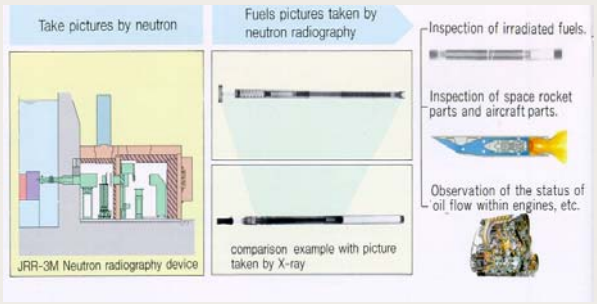
NDT-Neutron Radiography



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Research Reactor (RR) Utilization - Applications

Neutron transmutation doping

- *Principle*: Irradiation of Si by neutron transmutes some of the Si atoms to P➔ change in electrical conduction
- *Typical Uses*: Semiconductor devices
- e.g. Safari-1, HANARO etc.

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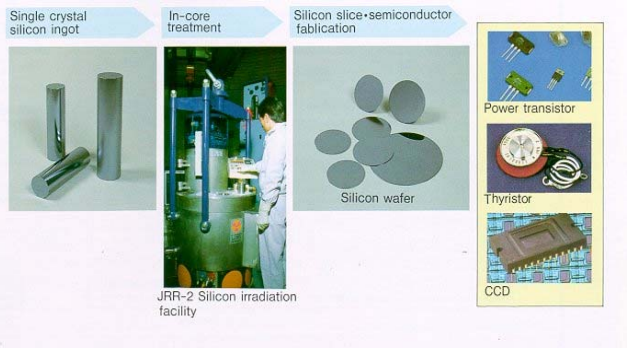
Neutron Transmutation Doping



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Research Reactor (RR) Utilization - Applications

Neutron Activation Analysis *NAA*

- *Principle*: Sample exposed to neutron fluence for a specified time ➔ induced activation products characteristic of the elements and the quantity
- *Typical Uses*: Assessment of elemental composition of chemical, geological, biological, environmental, forensic samples and art objects
- Most centres, even in small reactor e.g. in Ghana, Jamaica and medium size reactor e.g. in Hungary

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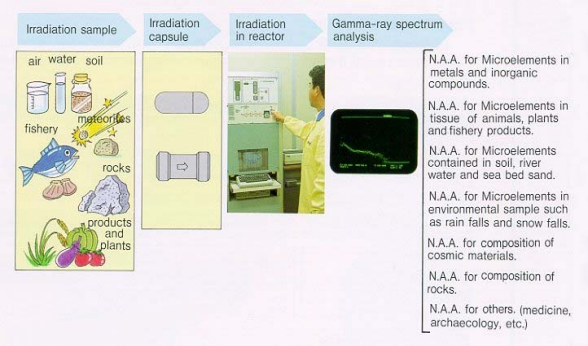
Neutron Activation Analysis



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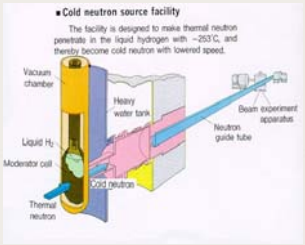
Cold Neutron Source



- Useful for large particle sizes / low energy transfers—diffusion of atoms & molecules.
- Study of Bio-molecules, Polymers, Paints
- Precipitation, phase separation in alloy synthesis
- Surface studies, thin films, bio membranes

e.g. in ILL, Grenoble; HMI, Berlin

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Research Reactor (RR) Utilization - Applications

Neutron irradiation for materials testing

- *Principle*: Target material's irradiation by neutrons and exposure to radiation field in RR for specified period leading to changes/damages
- *Typical Uses*: Understanding and assessment of radiation induced damage
- Modification to material characteristics, structure

➔Utility for new reactor designs and concepts; Data for plant life-extension studies and decommissioning/disposal purposes

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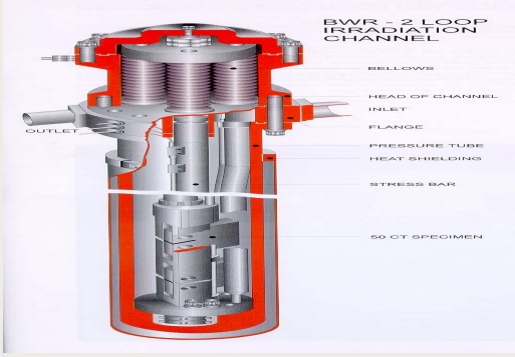
Applications – Irradiation Testing



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Research Reactor (RR) Utilization - Applications

Post-irradiation examination (PIE)

Principle: Fuel & related material's exposure to RR ambience (radiation, temperature, pressure, neutron flux) for specified period

- *Typical Uses*: Reactor fuel testing and development, validation/qualification, trouble-shooting. Understanding fuel behaviour in various conditions

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Research Reactor (RR) Utilization - Applications

Education and Training for HRD

- Science teachers & students
- Engineering teachers & students
- Nuclear power plant operator trainees
- Operational health physicists
- Regulators
- Public awareness

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RR issues and needs: perceptions and concerns *(1 of 2)*

- RR as the *stepping stone* to or *symbol* of nuclear science and technology
- RR as the *cradle* of all development and availability of nuclear technology
- RR utilisation needs and requirements for safety & security upgrades vis-à-vis resources availability and national support/ priorities/ policies

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RR issues and needs: perceptions and concerns *(2 of 2)*

- RR fuel issues – conversion of HEU fuel to LEU fuel; development & qualification of high density LEU fuels
- Decommissioning of shut-down RR – Strategy and technology support needs

RR type classification desirable to facilitate utilisation plans *and address the above concerns.*

'***Need exists for beneficial utilisation***' to be the basis for operation & utilisation of RR in safe and secure manner.

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IAEA Assistance on Research Reactors

- The Agency is ready to assist Member States in all RR related issues:
- Utilization
- Safety and Security
- RR operation, maintenance, reliability and availability
- RR nuclear fuel cycle issues
- RR spent fuel management
- New RRs and refurbishment and modernization
- RR ageing
- RR decommissioning

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Story of Success: Instrument development / Regional collaboration

- Neutron beam applications: Small Angle Neutron scattering and Reflectometry are important for R & D and industrial applications.
- IAEA-TC project for RR utilization
- Greece installing instruments for neutron scattering and establish a Regional Centre. Expected to complete this year
- South Africa to establish a SANS centre in South Africa, which is expected to be used by researchers and industries
- Facilities expected to be installed/operational 2007

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Story of Success: Conversion of TRIGA 14-MW (Romania)

- TC project ROM/4/024
- Contract to supply LEU fuel between the IAEA, Romania and CERCA/TRIGA International (November 2003)
- IAEA officials together with officials from CNCAN and the Institute for Nuclear Research (ICN), Pitesti, jointly carried out all the QA audits and acceptance inspections
- Final lot of LEU delivered to Pitesti on March 30, 2006
- Mid-May 2006 full-core conversion to LEU completed
- All irradiated HEU removed prior to May 12, 2006 will be shipped to the US

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Story of Success: Development of National Capacity for RR fuel Fabrication (Chile)

- TC Project CHI/4/021
- Development of domestic capacity to fabricate LEU silicide fuel with IAEA assistance
- Chile qualified as a supplier of silicide fuel elements through an irradiation and post irradiation qualification programme
- Chilean fabrication capacity used to fabricate LEU fuel to convert RECH-1
- RECH-1 fully converted to LEU in May 11 2006

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…atoms for peace.

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