The Research Reactor IRT-Sofia

50 years after first criticality

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IAEA: International Conference on Research Reactors: Safe Management & Effective Utilization,
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Research Reactor Refurbishment :

- Fresh and Spent Fuel Removal
- Partial Dismantling of Aged Reactor Systems
- Mounting of New Reactor Systems

PART of the Nuclear Power Program

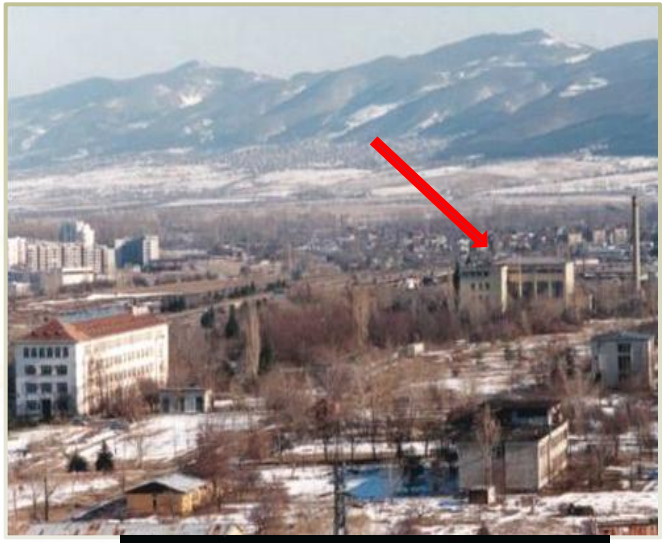
“Kozloduy” Nuclear Power Plant:
4 units 440 MW each (2 shut down, 2 stand by state)
2 units 1000 MW each (33% of electricity supply)
Spent Fuel Pool Storage, Dry Fuel Storage

“Belene” Nuclear Power Plant:
2 units 1000 MW each (WWER type)

Research Reactor IRT - Sofia

Nuclear Scientific Experimental and Educational Center

- located in the eastern part of Sofia
- water-moderated & water-cooled pool type reactor
- put into operation 1961 (design: 1958-1960 (Kurchatov Institute of Atomic Energy, Moscow)
- Initial criticality 3.37 kg ^{235}U, 19 Sept. 1961
- Power levels (MW): 0.5 (1961), 1 (1962), 1.5 (1965), 2.0 (1970): fuel EK-10 (enrichment 10%)
- 1980: Mixed core : K-10(LEU-10%,) C-35 (HEU-36%)
- 12 vertical channels, 11 horizontal channels
- Maximum thermal neutron flux 3,2 10^{13} n/(cm^{2}s)
- Shutdown June 1989 (28 years, 4189 starts-up)
- Two projects for upgrading: 5-8 MW (1986-1989) and 2MW (1998-2001); fuel IRT-2M, 36%
- Passed a process of nuclear fuel conversion HEU (IRT-2M) - LEU (IRT-4M) (DOE-ANL, INRNE)
- IRT-2M returned to Russia; IRT-4M (19.7%±0.3%)
- Undergoing refurbishment to 200 kW
- June 15, 2011, MEW&INRNE actions "Environment Impact Assessment Report" approved by the Administrative court



Research Reactor IRT - Sofia

IRT - 2000

Pool type: 63 m^3 water

Core: up to 48 fuel and graphite assemblies

Fuel - EK-10, C-36; 14, 15, or 16 fuel pins per assembly

Reflector - 13 graphite blocks (graphite assemblies)

Safety and control system

- 2 safety rods, 4 shim rods
- 1 automatic regulating rod

Cooling system

- 3 pumps, special ejector pipe,
- 2 heat exchangers,
- 4 ion exchange columns and 2 mechanical filters

- Secondary cooling system: open air sprinkling in pool

Storage pool - capacity: 108 fuel assemblies;

Experimental channels: 11 horizontal, 12 vertical (1-in core center; 3 – in core, 7 in pool)

Hot cells and a production line of radioisotopes

IRT -2000
Problems with pool lining (1987-1988)

- K. Krezhov. *Operational Experiences and Coping with Ageing Effects of the IRT-Sofia Research Reactor*.

Proc. International Workshop on "*Management of Ageing of Research Reactors*", GKSS/Hambourg, Germany, May 7-14, 1995, TECDOC IAEA--SR--190/12, International Atomic Energy Agency, Vienna, 1996, pp. 123-137

- Description of the planning and the implementation of the work program for reparation of Al lining of the pool

- Seismicity hazard assessment and measures taken

The Project "IRT – Sofia" – brief history

Bulgarian Nuclear Regulatory Body: prescription on 19 July, 1989 to stop temporarily the operation of IRT-2000

Motivation: to implement the final stage of the project for upgrading to 5-8 MW and modernize systems relevant to radiation and nuclear safety

Financing: 1991 stopped due to political issues; but IRT-2M fuel delivered

- Governmental decision No.332/May, 1999 to shut down the RR IRT-2000 in Sofia;
- Governmental decision № 552 / July, 2001 to refurbish and convert IRT-2000 into a civil reactor with low power (200 kW)
- Coping with Fuel Problems:
  - Shipment of HEU IRT-2M
  - Shipment of spent fuel
  - Core conversion to IRT-4M

The IRT - 200 Project

Permission № 2751/December 17, 2002 for design, issued by the Bulgarian Nuclear Regulatory Agency (BNRA).

INTERATOM

Contract № 40 / July 24, 2002

- **Atomenergoproekt Ltd. Bulgaria**
- **Skoda JS a.s. Czech Republic**
- **RRC "Kurchatov Institute"**, Russian Federation - Scientific **supervisor**

Conceptual Design

Safety Analyses Report:

- Edition 1 – March 2003, IRT-2M (36%) Fresh Fuel
- Edition 2 – revised edition 1 - 2004
- Edition 3 - October 2005, IRT-4M (20%) Fresh Fuel

Detailed Design

LEGAL AND FINANCIAL FRAMEWORK

Starting from 2004 the whole Bulgarian legislation including the issues concerning nuclear energy has been updated in accordance with the EUROPEAN UNION legislation:

Act on the Safe Use of Nuclear Energy (ASUNE)
Regulations in the field of nuclear energy use
Radiation protection normative documents
Normative documents associated with environmental protection

- Implementation of the Partial Dismantling activities started in August 2009 and finished successfully with submission of the Final Report in February 2010.

- Financing based on the regular Bulgarian budget
  - US DOE partial financial support
  - IAEA expert missions

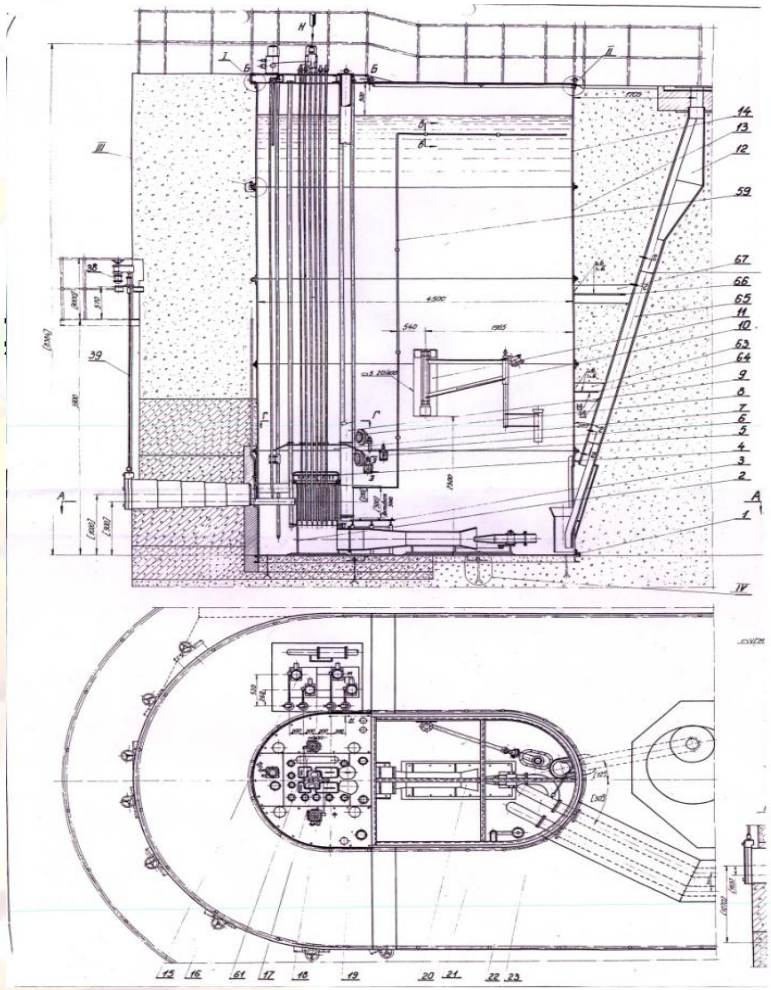
The IRT – 200 Project

- **Reactor of thermal power 200 kW;**
- LEU fuel (19.7% ^{235}U ; IRT–4M);
- Six vertical experimental channels;
- Seven horizontal experimental channels;
- maximum fast neutron flux : 3.10^{12} n/cm^{2}s
- maximum thermal flux: 8.10^{12} n/cm^{2}s
- **Quality Assurance of Management**

INRNE was certified:

2003 Integrated System of Management (ISO 9001:2008, quality assurance)

2004 ISO 14001:2004 (environment)



Decommissioning /planning/

The Partial Dismantling activities were considered as a part of the general process for reconstruction of the research reactor IRT-Sofia. The final stage of the research reactor after the Partial Dismantling was thought to become the initial stage of mounting the new reactor systems and equipment.

General Plan /GP/

- IAEA Expert Mission #1 (February 2004)
- IAEA Expert Mission #2 (March 2005)
- General Plan Submitted October 2005 ✓

Detailed Plan /DP/ incl. RAW and personnel doses

- IAEA Expert Mission #3 (December 2007)
- Detailed Plan Submitted February 2009 ✓

Safety Analysis Report for Dismantling /SAR/

- IAEA Expert Mission #4 (June 2008)
- Report Submitted February 2009 ✓

RADIATION SAFETY DURING IRT-2000 PARTIAL DISMANTLING

The operating organization shall develop and achieve agreement with the competent state authorities to implement programs :

- for radiation protection of the Research Reactor (RR) personnel
- for radiation monitoring of the environment
- periodically review and update of these programs on the basis of the operational experience

The basic goal of the radiation control program is :

- Assessment of the possible sources of irradiation of the RR personnel when carrying out the reactor equipment dismantling
- Provision of the necessary work conditions – devices, personal means of protection, measuring appliances for overall dosimetry control, RR personnel conduct, instructions, etc., so that the obtained doses are in the *permissible limits* determined by the Provision for the basic norms of radiation protection (BNRP), the internal regulations for work with sources of ionizing radiation in accordance of the ALARA principle.

BASIC POINTS

The programs shall include requirements to:

- 1. Classification of areas in compliance with the regulations and access control of personnel and materials;
- 2. Co-operation in establishing operating and maintenance procedures and experimental programs for activities when radiological hazard is anticipated;
- 3. Instrumentation and equipment for monitoring;
- 4. Means for collective and individual personnel protection;
- 5. On-site radiological monitoring;
- 6. Decontamination of structures and systems;
- 7. Environment radiological monitoring;
- 8. Monitoring of radioactive liquid and gaseous discharges;
- 9. Radiation control of radioactive substances and irradiated sources taken out of RR;
- 10. Control to limit the extent of radioactive release outside the RR site.

INTERNATIONAL COOPERATION

- **General Plan**
  - IAEA Expert Mission #1 (February 2004)
  - IAEA Expert Mission #2 (March 2005)
  - General Plan Submitted October 2005
  - **Detailed Plan** incl. rad. waste and personnel doses
  - IAEA Expert Mission #3 (December 2007)
  - Detailed Plan Submitted February 2009
- **Safety Analysis Report for Dismantling**
  - IAEA Expert Mission #4 (June 2008)
  - Report Submitted February 2009

Current state of the execution of the Project

- **Partial dismantling of reactor equipment**

  - Dismantling of 1st cooling loop equipment
  - Reactor vessel equipment dismantling
  - Dismantling of grid situated on the bottom of the spent fuel storage
  - Dismantling of thermal column

CLASSIFICATION OF AREAS IN IRT-2000

The following working zones were formed in the Reactor hall with a view of the partial dismantling of IRT-2000 systems

- Zone I for dismantling of reactor pool equipment;
- Zone 2 for dismantling of I-st circulation loop equipment;
- Zone 3 for dismantling and other activities at the reactor site;
- Zone 4 for dismantling of the thermal column;
- Zone 5 for secondary processing and deactivation of the dismantled equipment site.

Two main zones were formed at the time of the reactor equipment partial dismantling:

- “clean” zone - there is no radioactive contamination and one is not expected;
- “dirty” zone - there is radioactive contamination of the equipment, the work appliances, the personnel, etc. or contamination is expected.

PARTIAL DISMANTLING
/execution/

According to DP dismantling activities of IRT-Sofia has been planned and implemented in the following zones:

Zone 1 - dismantling of reactor internal systems loop equipment


Zone 2 - dismantling of primary cooling


Zone 3 - dismantling at the reactor site


Zone 4 - dismantling of the thermal column



Zone 5 - secondary processing and decontamination of the dismantled equipment


Zone 6 - packaging and measurement of RAW



Partial Dismantling /execution/ cont.

All RAW from Partial Dismantling of IRT-Sofia research reactor were placed in special containers type СтБК on site next to the Reactor Equipment Storage.





All non RAW were placed in ISO containers on the reactor site.




A final radiological survey of the reactor pool and the premises after completion of dismantling activities has been performed to ensure that the realize criteria have been met.

The prepared Final Report gives opportunity for new equipment and systems mounting.

Execution of the Project

- Dismantling of First cooling loop

Before →

After ↗

Current state of the execution of the Project

- Reactor vessel equipment dismantling

Before

After

Current state and activities

Refurbishment of:

- Primary cooling system
- Secondary cooling system
- A part of radwaste system
- Ventilation system

Current state of the execution of the Project

- Dismantling of the support grid of spent fuel on the bottom of the spent fuel storage

Before →

After →

Decommissioning (execution, cont.)

Obtained collective doses during the Partial Dismantling activities:

- Dismantling of reactor internal systems – 2,47 man mSv
- Dismantling of primary cooling loop equipment – 123 man µSv
- Dismantling at the reactor site – 80 man µSv
- Dismantling of the thermal column – 2,41 man mSv
- On the site for secondary processing – 271 man µSv

Quantities of RAW as a result of the Partial Dismantling activities:

	Planned:	***Obtained:***
✓ Solid RAW, reactor pool, metal 2a and 2b category	1680 kg	1686 kg
✓ Solid RAW, reactor pool, non-metals 2a and 2b category	70 kg	70 kg
✓ Solid RAW, thermal column, metal 2a and 2b category	5040 kg	5040 kg
✓ Solid RAW, thermal column, non-metal 2a and 2b category	10000 kg	11035 kg
✓ Solid RAW, primary cooling loop, metal 1 and 2a category	5800 kg	2736 kg
✓ Liquid RAW, Reactor hall, tanks, coolant from reactor pool	60000 l	60000 l
✓ Liquid RAW, Reactor hall, tanks, decontamination solutions	6000 l	1000 l
✓ Liquid RAW, Reactor hall, RAW storage, ion-exchange resins	320 l	160 l

Current state of the execution of the Project

- Cooperation with ANL on conversion from HEU to LEU - Joint study: INRNE and RERTR Program at ANL, USA
- 2002/2003 – Initiated

NEUTRONICS

  - 2004 - IRT-4M FA Suitable for Conversion
  - 2005 - Initial LEU Core (in close collaboration with Russian RC "Kurchatov" Institute)
  - 2006 - Initial LEU Core Performance

NEUTRONICS, THERMAL- HYDRAULICS, ACCIDENT

  - 2007/2009 – **BNCT LEU Core**

SAR, OLC MODIFICATION

  - 2005/2010
  - **2011 New story** (NPP Fukusima, **stress tests**), National Report on Radiation and Nuclear Safety to the IAEA

Physical Protection :

- Engineering structures
- Central Alarm Station
- Access control system
- Access control point
- Intrusion alarm system
- Surveillance and situation assessment system
- Communication and warning system
- 24 – hour guard service.

Current state of the execution of the Project

- Returning of HEU fuel to country of origin Russia under RRRFR program per contracts between INRNE - DOE/NNSA and INRNE - Battelle Energy Alliance, LLC (INL)

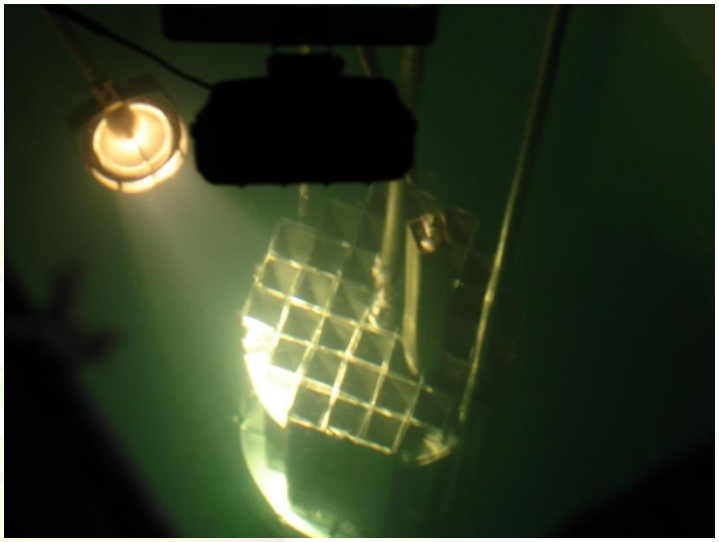
  Fresh Fuel – December 23, **2003**

  HEU: 16.91 kg, 28 type IRT-2M fuel assemblies (36% enrichment)

  Spent Fuel – July 5-17, **2008**

  HEU: 6.44 kg, 16 type C-36 fuel assemblies (36% enrichment)

  - LEU: 72.48 kg, 58 type EK-10 fuel assemblies (10% enrichment)
- Implemented Integrated Management System – ISO 9001:2008

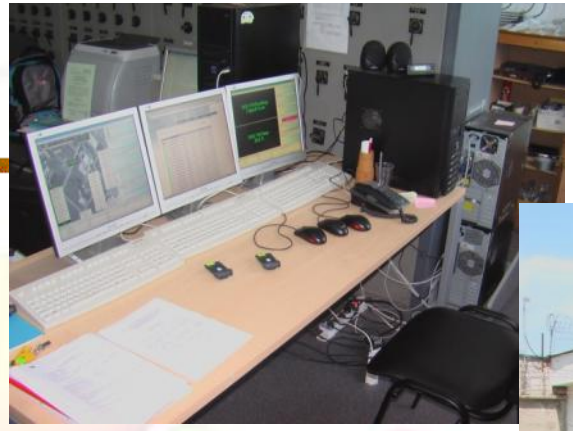


IRT-200 Project: Current state

Design, fabrication, procurement, installation and commissioning of :

Dosimetry Systems

- Radiometric Laboratory
- Radiation Monitoring System (External – RR site and Internal –RR laboratories)
- New crane (12.5 tons) and service support systems



Current state

- Dismantling of thermal column

Before

- Thermal power 200 kW
- LEU fuel IRT-4M
- (19.7±0.3)% U-235 enrichment:
- Six vertical experimental channels
- Seven horizontal experimental channels
- Maximal fast neutron flux : 3.10^{12} n/cm^{2}s
- Maximal thermal flux: 8.10^{12} n/cm^{2}s

→ **BNCT channel ?**

After

MANAGEMENT OF RAW

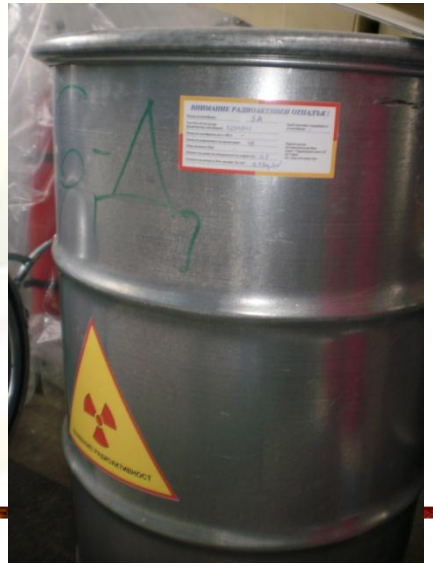
The quantities of RAW resulting from the partial dismantling of IRT-2000 equipment are as follows:

Solid RAW, metal 2a and 2b category	1686 kg	/1680 kg planned/
Solid RAW, non-metals 2a and 2b category	70 kg	/70 kg planned/
Solid RAW, metal 2a and 2b category	5040 kg	/5040 kg planned/
Solid RAW, non-metal 2a and 2b category	11035 kg	/10000 kg planned/
Solid RAW, metal 1 and 2a category	2736 kg	/5800 kg planned/
Liquid RAW, reactor pool	60000 l	/60000 l planned/
Liquid RAW, decontamination solutions	1000 l	/6000 l planned/
Liquid RAW, ion-exchange resins	160 l	/320 l planned/

Remark: All quantity of RAW that has been obtained from the dismantling was qualified as 1st and 2nd category according to Bulgarian Legislation.

INDIVIDUAL PROTECTION

MANAGEMENT OF RAW



MANAGEMENT OF RAW








Total weight of RAW in the containers : 9850 kg

Total activity of RAW: 4.00661367555.109 Bq=4.01 GBq

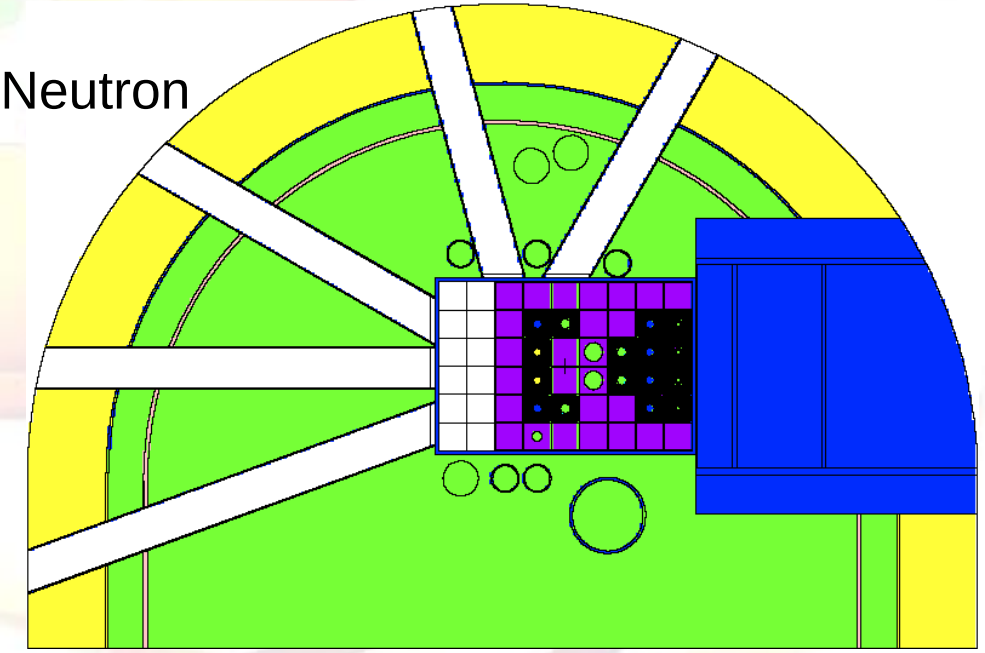
Total weight of RAW(incl. Shutter of TC : 20200 kg

BNCT activities

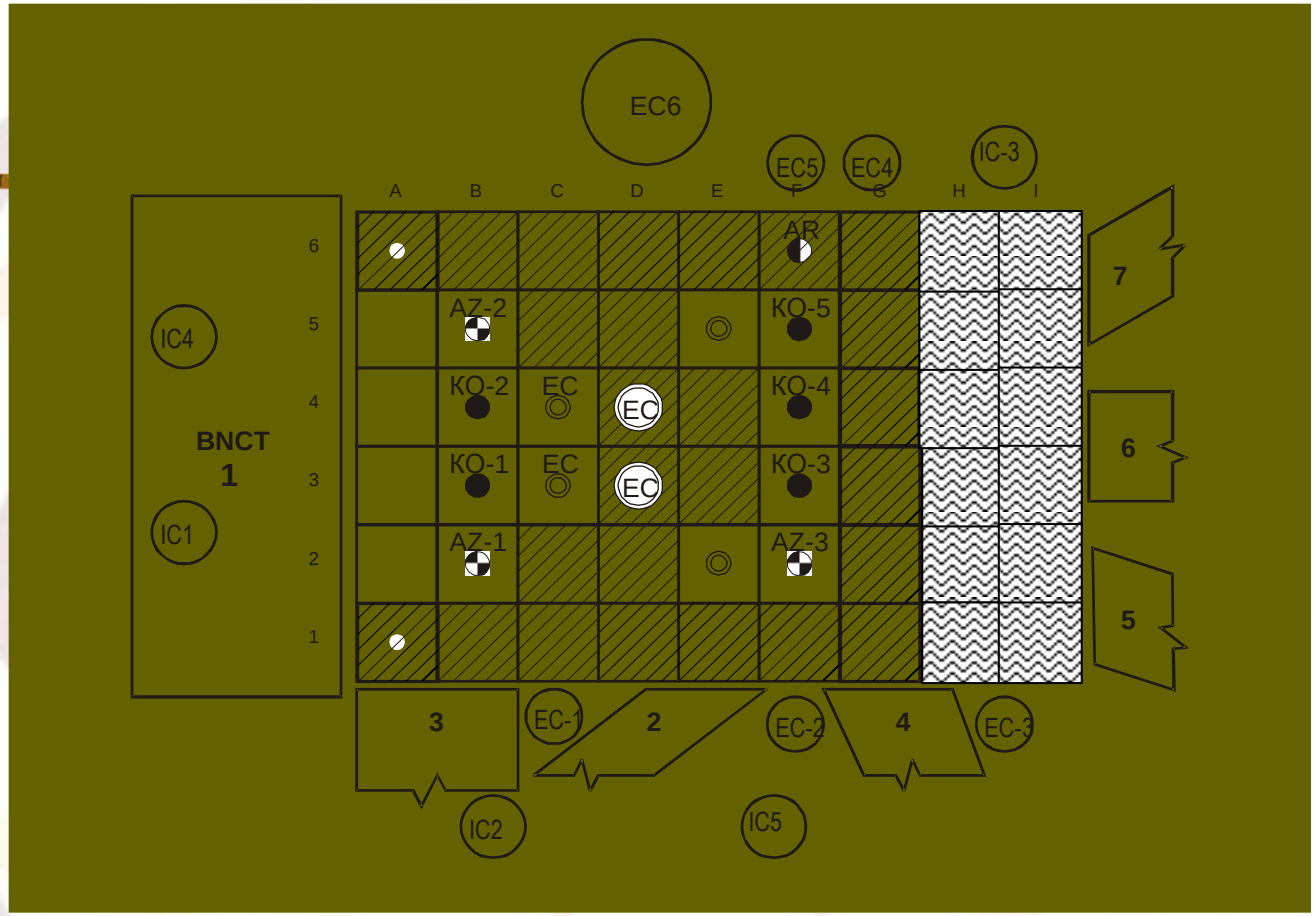
- **Boron Neutron Capture Therapy Irradiation**
  - **Tube Modeling**
  - **SAR consequences**

collaboration project with the Massachusetts Institute of Technology Reactor (MITR), USA

MCNP: Criticality and NCT Neutron Source Calculation



Initial Core Configuration (SAR)



8-tube FA: A2-A5;
EC – vertical beam tube;
IC – ionizing chamber' channel;

KO – shim CRs;
AZ – safety CRs;
AR – auto regulating CR

Current State of the Execution of the Project (Cont'd)

- Environment Impact Assessment Report - under Basic Ordering Agreement with ANL, DOE/NNSA;
- EIAR has been developed by EkoGeoConsult Co.
  - **Public Hearings** have been conducted on December 14, 2009
  - On **February 02, 2010** Bulgarian Ministry of Environment and Waters issued a resolution *1-1/2010* that approves the investment proposal of INRNE for "Reconstruction and transformation of the research reactor IRT-2000 into a civil type reactor with low power (200kW) "
  - In **2010** to the SAR was added "and additional application in medicine – BNCT"
  - EIAR was contested by National Association "Ekoglasnost" (Green party and others civil ecological movements)
  - Official decision in favour of MEW and INRNE - **15th June 2011**
- Establishment of contact with different organizations and companies and signing of appropriate contracts;
- Work on refurbishment documentation (SAR, Standard Operation Procedures, etc).

Required Work for Completion of the Project

- **Completion of Refurbishment of Radwaste System**
  - Refurbishment of Radwaste System Special Sewage

- **BNCT Channel**
  - Cooperation with Massachusetts Institute of Technology (MIT) , USA on design and calculations of the channel *(contract with MIT)* ;
  - Cooperation with many Bulgarian institutions and "Atomenergoproekt" on the design and construction of equipment and infrastructure supporting the BNCT application

Required Work for Completion of the Project

Safety Analysis Report, ed. 3 revision:

Neutronics
Thermal Hydraulics
Accident Analyses
Assessment of radioactive effluents during normal reactor operation

Operating Limits and Conditions (OLC)

The updated sections of the SAR including OLC revised edition resubmitted to the BNRA, 12/2010 in English and Bulgarian.

Some additional points raised after the Fukushima Daichi-1 NPP incident in March.

Design, fabrication, delivery, installation and commissioning of:

- Water purification system *(contract with "ANILS" co.)* ;
- Distiller system *(contract with "ANILS" co.)* ;
- Reactor Instrumentation and Control Systems *(contract with JSC"SNIIP-SYSTEMATOM", Russia)* ;
- Reactor Vessel *(contract with "SKODA JS" a.s.)* ;
- Spent fuel storage *(contract with "SKODA JS" a.s.)* ;
- Reactor Core *(contract with "SKODA JS" a.s.)* ;
- Control and Protection System Actuators *(contract with "SKODA JS" a.s.)* ;

Required Work for Completion of the Project (Cont'd)

- **Civil Construction Work (new control room, constructions in reactor hall, BNCT patient room, etc.);**
- **Delivery of LEU fuel –**under contract among TVEL and INRNE and DOE/NNSA - expected to be delivered up to the end of 2011;
- **Delivery of Be reflector** – negotiations stage ;
- **Development and completion of appropriate documentation required for licensing process;**
- **Training of the reactor operators and operational personnel;**
- **Commissioning of the reactor.**

IRT-200 Utilization

E-learning (Universities in Sofia, Plovdiv, Blagoevgrad; Technical University)

- EDUCATION AND TRAINING
  - Nuclear Energy
  - Radiation protection and radiology
  - Physics and biology
  - Public education
- APPLICATIONS
  - Neutron activation analysis
  - Radioisotope production
  - Radio-pharmacy (kits)
  - Materials irradiation (electronics)
  - Neutron radiography
  - Metrology
  - Boron Neutron Capture Therapy

IAEA Project RER/4/032 Experts' Mission, 28 – 30 March 2011 Sofia, Bulgaria,

IRT-Sofia

THANK YOU
for your attention