

**STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES
OF THE IRT- RESEARCH REACTOR - SOFIA
/ INSTRUMENTATION AND CONTROL SYSTEM /
T. APOSTOLOV, D.DRENSKI, I.DIMITROV**



STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

1. Introduction

The research reactor IRT-Sofia will be reconstructed into a reactor of power 200 kW. The use of lowenriched uranium fuel, with uranium-235 enrichment below 20% (IRT-4M), is in accordance with the current norms on the security of transport and storage of nuclear and other radioactive materials which are vulnerable to theft by terrorists.



STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

The following experimental channels are planned:

- two vertical channels in the fuel assemblies to supply fast neutron flux $3 \cdot 10^{12}$ n/cm²s;
- two vertical channels in beryllium blocks to supply thermal neutron flux $8 \cdot 10^{12}$ n/cm²s;
- seven horizontal channels outside the aluminium vessel of the reactor core with fast neutron flux $1,6 \cdot 10^{12}$ n/cm²s, and thermal neutron flux $5 \cdot 10^{11}$ n/cm²s on the core vessel;
- six vertical channels outside the aluminium vessel of the reactor core with fast neutron flux $2 \cdot 10^{12}$ n/cm²s, and thermal neutron flux $7 \cdot 10^{10}$ n/cm²s on the core vessel;
- channel for BNCT with epithermal neutron flux $0,9 \cdot 10^9$ n/cm²s.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

For neutron flux and neutron spectrum measurements an assortment of neutron activation foils and threshold detectors (e.g., Au, In, Cd, Al) as well as counting devices such as gas flow proportional counters, NaI or HPGe detectors of the necessary class will be provided. For approach-to-critical experiments one or more neutron detection systems using BF₃, ¹⁰B, or a fission chamber, along with the necessary electronic equipment will be additionally provided.

Rooms (laboratories) for installation of measurement and automated systems, for radiation monitoring systems, and others according to the clients' needs are also planned. For express measurements of shortlived isotopes a pneumatic sample transfer system (rabbit system) is planned.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

2.General Modernization & Refurbishment Scope

The elaboration of the Technical Project [5] and the Detailed Design for the reactor reconstruction as well as of all of the documents needed for the Safety Analysis Report is done by the INTERATOM Consortium, which consists of:

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

The Technical Project, Safety Analysis Report – Revision 3 and General Plan for Partial Dismantling have been proposed for approval in Bulgarian Nuclear Regulatory Agency. The Detailed Design is in process of elaboration.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

All activities concerning fresh fuel conversion and spent nuclear fuel removal, financed by the US Department of Energy (DOE) in the frame of two programs: RERTR (Reduced Enrichment of Research and Test Reactors) and RRRFR (Russian Research Reactor Fuel Return), are in progress. The program RERTR is implemented for:

- return of highly enriched fresh fuel IRT-2M (HEU, 36% ^{235}U) to Russia. This was done in December 2003;
- joint studies at the Argonne National Laboratory [3,4] aiming at conversion from use of fuel, containing highly-enriched uranium IRT-2M to low-enriched uranium fuel IRT-4M (LEU, 20% ^{235}U), chosen for the reconstructed reactor IRT-200;
- delivery of fresh fuel IRT-4M from Russia, needed for the reactor start-up in 2008.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

Under the RRRFR program and the contract between the INRNE and the DOE, signed in April 2005, an intensive work has been carried out for the IRT spent nuclear fuel shipment to Russia. According to the work schedule, this fuel is expected to be shipped by the end of 2007.

The term of the spent fuel shipment is crucial and determining, as far as the first, preparatory stage of the reactor reconstruction is completing by it and the second one, the construction and assembling stage is beginning.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

The following other activities concerning reconstruction have been fulfilled:

- Signing of contract with "ANILS" company - Bulgaria for manufacturing, delivery and installation of Primary cooling loop, Secondary cooling loop, Water purification loops, reactor and NSF storage pool, Water make-up loop
- Signing of contract with "SKODA-JS" – Czech Republic for manufacturing, delivery and installation of reactor pool, fuel storage pool, experimental channels, reactor carrying box, reactor shroud, ejector and piping inside the reactor pool and Control rod drives
- Signing of contract under the EU PHARE program for delivery of equipment for "Radiation Monitoring System at the Nuclear Scientific and Experimental Centre with Research Reactor (IRT type) in Sofia, Bulgaria" with "SYNODYS GROUP". All the equipment was delivered in August 2006 on site, and now some of the laboratory and dosimetry equipment are in use.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

3. Modernization & Refurbishment Scope of Instrumentation and Control System.

The instrumentation and control system (I&C) of the IRT-2000 research reactor was developed in the 60's of the last century in the former Soviet Union. The system is constructed according to a relay-contact scheme. Relays and contactors of 110V and 48V direct current are used in these schemes. This equipment is physically and morally old, that's why this system will be entirely substitute by a new one, which will be according to the contemporary requirements for such system. The new system design corresponds to the requirements of the acting in Republic of Bulgaria regulatory documents, as well as of the applicable for this case foreign and international recommendations and standards. This system will provide reliable control and regulation of power level above the subcritical state, at different power levels and in dynamic regimes, as well as reliable reactor shutting down in normal and accidental conditions.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

The I&C system will have the following composition: complex of control and protection system equipment (CPSE complex) and information-computing system equipment (ICS equipment) [1].

3.1 CPSE complex.

The most important parameters in CPSE are the reliability and the fast response, determining the safety and failure-free operation of the reactor, so the CPSE will be built by “independent channels” principle and will satisfy the requirements for fast-execution (minimum delay) of control signal for emergency protection and of permissible probability of non-actuation of control signal for emergency protection by the requests for reactor shutdown. The system will ensure the control of emergency protection and displacement of actuators by means of duplicated channels for monitoring and protection by power, period and process parameters.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

The logic of CPSE operation is majority voting according to logic 2 out of 3 signals by each of the following parameters:

- reactor power;
- period;
- temperature of water at the core inlet;
- water heating in the core;
- level of water in the reactor pool;
- pressure drop in the reactor core;
- radioactivity of water in the primary circuit pipeline;
- radioactivity of gases at the above reactor space;
- seismic activity.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

The functions of the system will be:

- detection of neutron flux in all operating modes of the research reactor;
- detection of process parameters;
- generation of signals at reaching the threshold values by power and period for control of emergency protection and monitoring;
- generation of signals at reaching the threshold values by the process parameters (temperature of water at inlet to the reactor core, heating of water at the reactor core, level of water in the reactor pool, pressure drop at the core, radioactivity of water in the pipeline of primary circuit, radioactivity of gases in the above reactor space, seismic activity) for control of emergency protection and monitoring;
- generation of signals for control of actuators in the modes of reactor emergency shutdown and normal operation;
- monitoring of control rods position (detectors of the top, bottom and intermediate position of control rods are located in actuators);

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

- monitoring of reactivity;
- manual control of reactor power from the control panel;
- automatic power control;
- planned reactor shutdown;
- displaying and registration of information;
- determination of time of control rods insertion;
- automatic check of good condition for the equipment during operation process, including the check of good condition for communication lines, detection units of neutron flux and process parameters;
- archiving and documenting of information;
- fixation of initial cause for emergency situation occurrence;
- automated pre-start check for generation of emergency protection signals and preventive signalization;
- communication with information-computing system.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

3.2 Actuators of Control and Protection System – ACPS

The actuators are divided according to their function in two types [2]:

- compensative actuators for regulation of reactor power and for reactivity compensation
- safety actuators for shut-down of reactor in case of accident

The actuators will be multi-purpose. It means that one actuator can work either as compensative or as safety. Just switch-over in control room must enable to change function of single actuators. This solution simplifies working of the operating staff. In many cases won't be necessary to remove actuators on another position in reactor core.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

The main functions of the ACPS are to:

- Provide power level regulation during operation condition by absorber rod movement
- Provide reactor shutdown in case of accident by absorber rod free fall
- Provide reactivity compensation by absorber rod movement

The ACPS is composed from five following main parts:

- The drive mechanism
- The absorber rod channel
- The component of absorber rod
- The supporting part of ACPS
- The connection box

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

3.3 Information-computing system

Information-computing system will provide the execution of the following main functions:

- acquisition of data on state of the reactor, its technological systems and radiation monitoring systems;
- access to the archives;
- diagnostics of hardware and software means;
- support of the unified time and assignment of the time-mark during collection of data;
- protection from unauthorized access;

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

- presentation of information to external users.

ICS equipment should support functioning of the standard network interfaces RS-485, ETHERNET, and include:

- device for archiving, analysis of archived data, documenting;
- synchronizer (device for setting unified time);
- personal computers in industrial implementation;
- printers;

Software will satisfy the requirements of the *IEC 60880-1,2 – 2002* international standard.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

3.4 Control rooms

There will be build two new control rooms :

- *main control room* – there will be situated control panels; units for setting emergency protection threshold values by power of neutron flux monitoring equipment; unit for setting values by power and period of automated power controller; digital displays for displaying current power and period of neutron flux values; graphical displays; keyboards; workstations; printers; archiving, diagnostic and logging hardware; etc.
- *supplementary control room* will be situated in a separate place, distant from the basic control shield. It will be seismic-proof and fire-safe and will have local ventilation system and autonomous communications.

Choosing of a company for manufacturing, delivery and installation of I&C equipment is forthcoming.

STATUS OF MODERNIZATION AND REFURBISHMENT (M&R) ACTIVITIES OF THE IRT- RESEARCH REACTOR – SOFIA / INSTRUMENTATION AND CONTROL SYSTEM /

4.Reference

- [1] Reconstruction of the SOFIA IRT-2000 Research Reactor. Technical Specification of the Package № 3 (Instrumentation and Control System), Revision 2, Sofia, 2005.
- [2] Reconstruction of the SOFIA IRT-2000 Research Reactor. Technical Specification of the Package № 4 (Actuator of Control and Protection System) Revision 1, Sofia, 2004.
- [3] T.Apostolov, E.Anastasova, D.Drenski, V.Anastasov, A.Stoyanova, E.Moskov, S.Belousov, S.Kadalev. Progress of Activities Regard Reconstruction of the Research Reactor IRT - Sofia, 9th International Conference Research Reactor Fuel Management (RRFM'05), Budapest, Hungary, April 10-13,2005.
- [4] T. Apostolov, S. Belousov, P. Egorenkov, N. Hanan, J. Matos. Progress in Conversion from HEU to LEU Fuel At IRT-200, Sofia, RERTR2005, Boston, USA, November 2005.
- [5] Reconstruction of reactor IRT-2000, INRNE-BAS into reactor with small power. Process instrumentation and control system. Revision 1, Sofia, 2003.



Thank You for Your Attention!