# IMPLEMENTATION OF THE PARTIAL DISMANTLING OF RESEARCH REACTOR IRT-SOFIA PRIOR TO ITS REFURBISHMENT

by

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**In 2001, the Bulgarian Government decided to refurbish and convert the research reactor in Sofia into a low-power reactor. Due to this, a partial dismantling of IRT-Sofia's old systems and equipment was carried out with the intention of reusing the concrete bioshield in the construction of the new low-power research reactor. For a more efficient use of available resources, an engineering project known as "The plan for the partial dismantling of IRT-Sofia equipment as a part of its refurbishment into a low-power research reactor" was drawn up and has since been successfully implemented.**

*Key words: research reactor, partial dismantling, radioactive waste, decontamination, safety assessment, radiation protection*

## INTRODUCTION

The first criticality of the IRT-Sofia research reactor was reached in September 1961. The reactor had been started up 4189 times and ran 24623 hours altogether, at different power levels (by 2 MW) agreed upon with the users at regular weekly meetings. The reactor was shut down in 1999 for refurbishment and conversion.

The reactor is of the pool type, cooled and moderated with light water. The core contains up to 48 fuel and graphite assemblies. There are 14, 15, or 16 fuel rods per assembly. The fuel rods are of the EK-10 (10% enrichment) and C-36 (36% enrichment) type. The reflector includes 13 graphite blocks. The safety and control system includes 7 in core rods – 2 safety rods, 4 regulating rods (made from boron carbide in aluminum cladding), and 1 automatic regulating rod (stainless steel in aluminum cladding). The cooling system includes 3 pumps, a special ejector pipe, maximum flow rate of 540 $m^3$, 2 heat exchangers, 4 ion exchangers, and 2 mechanical filters. The maximum capacity of the storage pool is 108 fuel assemblies. It has connections to the reactor pool and hot cell laboratories. The experimental channels are 11 horizontal and 12 vertical, maximum neutron flux at 2 MW thermal power is $2\ 10^{13}$ $cm^{-2}s^{-1}$.

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In 2001, the Bulgarian Government decided to refurbish and convert the research reactor IRT-Sofia into a low-power reactor. In order to realize this project, it was necessary to develop and carry out a Plan for the Partial Dismantling (PPD) [1] of research reactor IRT-Sofia, in keeping with national legislation [2, 3] and the IAEA Safety Guide [4].

The PPD was compiled with the aim of describing in detail the succession of procedures related to the dismantling of the IRT-Sofia equipment and was not meant to be used for the purpose of its reconstruction into a low-power reactor and the ensuing operations for the reduction of radioactive waste (RAW) volume, decontamination, sorting, packaging, temporary storage or transportation and delivery to the "Radioactive waste" state company. The main purpose of the PPD was to ensure the safety of the personnel and population on the whole and the protection of the environment.

## THE PURPOSE OF PARTIAL DISMANTLING

Partial dismantling (PD) activities are a part of a wider process of the reconstruction of the research reactor IRT-Sofia. Each and every one of these activities is meant to safeguard the health and safety standards of the personnel, as well as the protection of the environment. The final stage of the refurbishment, after the

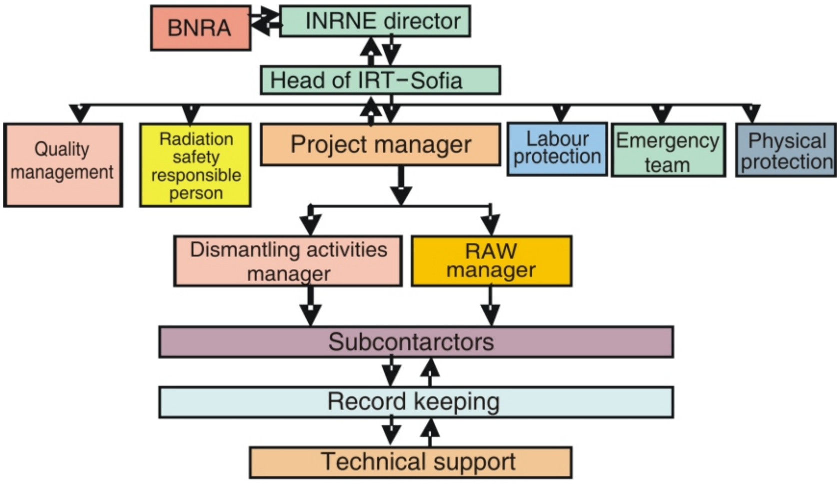


**Figure 1. Organizational structure for management of the PD procedure**

partial dismantling, is to be the initial stage of mounting new reactor systems and equipment. The criteria to be taken into account should be those that ensure utmost technological advantages for the mounting of new systems and equipment and guarantee that surface contamination levels and effective dose rates (EFD) are below values permitted by Bulgarian normative requirements.

The IRT-Sofia equipment has been dismantled in the following sequence:

– removal of the primary cooling loop systems,
– removal of internal reactor systems,
– removal of the bottom rack from the spent fuel storage, and
– removal of the thermal column.

The old bioshield and aluminum cover of the reactor pool have been preserved with the purpose of utilizing them for the new low-power reactor. The new stainless steel reactor vessel was to be mounted onto the old aluminum vessel with an appropriate material in between. The reactor building was also preserved for future use.

What the PDP offers is the advantage of the secondary use of reactor facilities and the utilization of experience previously gained by the personnel during the operation of IRT-Sofia.

## PRECONDITIONS FOR THE IMPLEMENTATION OF PARTIAL DISMANTLING ACTIVITIES

The first precondition was the transportation of the spent nuclear fuel to Russia under the international RRRFR project, financed and supported by the US-DOE. This was successfully carried out in the summer of 2008.

An organizational structure for the management of the PD procedure was set up, with clearly defined activities and responsibilities (fig. 1).

A *characterization* of the IRT-Sofia equipment for dismantling has been carried out by measuring methods, samples and smears (fig. 2), and through calculation methods.

The most significant radionuclides that have been determined in the metal samples taken are $^{63}$Ni, $^{152}$Eu, $^{137}$Cs, $^{55}$Fe, and $^{60}$Co. In addition, graphite blocks were taken out from the thermal column within.

The blocks were there throughout the operation of IRT-2000. A sample was taken from the graphite blocks for analysis with a high resolution X-ray spectrometer and a high resolution gamma spectrometer. The results from the analyses show the presence of $^{152}$Eu, $^{60}$Co, $^{14}$C, and a small quantity of $^{3}$H.

*Preparatory activities* prior to the dismantling were carried out. A sanitary check-point consisting of restrictive barriers and a portal monitor of the RADOS-RTM-860TS type was installed. For protection from radioactive discharges during the dismantling, a tent with temporary ventilation based on HEPA filters was set up (fig. 3).

Checks were also made of the condition of the 12.5 tons bridge crane and the operability of the per-

**Figure 2. Smear and sample-taking**

**Figure 3. Temporary tent and ventilation**

manent ventilation system, special sewage, power supply, radiation control systems, *etc*.

A site for secondary processing and decontamination of the dismantled equipment was set up. Special containers for the RAW (made of concrete and steel) were provided. The reactor's main hall was cleared of redundant equipment, shielding blocks, experimental devices *etc*., which could obstruct the PD procedure. After the preliminary pre-dismantling decontamination of the internal reactor equipment, a necessary quantity of water was drained from the reactor's tank. The equipment intended for dismantling was disconnected from the power supply. The draining of the primary circuit pipes, heat exchangers, and pumps was performed. Prior to the commencement of the dismantling, radiation conditions were checked.

## IMPLEMENTATION

During the implementation of the PD, following work zones were defined:

- *zone 1* – dismantling of reactor pool equipment (figs. 4 and 5),
- *zone 2* – dismantling of primary cooling loop equipment (figs. 6 and 7),
- *zone 3* – dismantling of equipment at the reactor site on the level of 8 m (I&C system drivers; vertical channels; drivers for stationary and mobile ionization chambers, *etc*.),
- *zone 4* – dismantling of the thermal column (figs. 8-10), and
- *zone 5* – secondary processing and deactivation of the dismantled equipment.

## SAFETY ASSESSMENT

The safety assessment of the PDP of IRT-Sofia identified hazards that could possibly accompany the procedure. They are to be mainly associated with radioactive materials obtained during the dismantling of the inner body devices, thermal column and primary circulation loop, the body of the reactor core, ejector, pipelines, pumps, heat exchangers, graphite, concrete from the biological shield, *etc*.

In addition, conventional (industrial) hazards are also to be taken into account when the operation of machines at high altitudes and risks caused by external

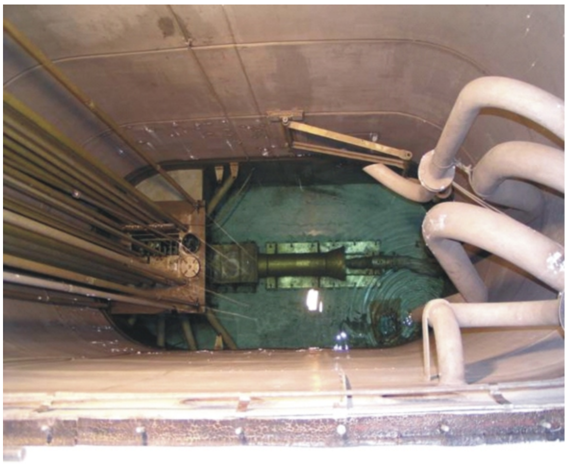

**Figure 4. Reactor pool prior to the dismantling**

**Figure 5. Reactor pool after the dismantling**


**Figure 6. Cooling loop prior to the dismantling**

**Figure 7. Cooling loop after the dismantling**

**Figure 8. Thermal column prior to the dismantling**

**Figure 9. Graphite from the removal of the thermal column**

factors such as fire, earthquake, and floods have to be taken into consideration, as well.

Based on the results of normal and accidental scenario analysis and comparison with safety criteria,

**Figure 10. Thermal column after the dismantling**

safety measures for radiation protection were defined, including measures such as the use of protective clothing, underwear, shoes, masks, and respirators against radionuclide inhalation. Also included into the system were: safety engineering protection measures (barriers, tents, ventilation, *etc*.), portable ventilation systems, materials for providing protection (lead blocks, PVC sheets, *etc*.)

The minimization of dose exposure of the personnel according to the ALARA principle was realized by optimizing the number of persons irradiated, in compliance with dose limits determined by the said regulation and the lowest attainable levels possible.

Rules and instructions concerning the conduct of the personnel during the dismantling were set up. At each of the zones, the person on duty determined the time allowed for dosimetry measurements, depending on the equivalent dose rate and accepted limits of permissible irradiation.

## RADIATION DOSES

Collective doses obtained during the partial dismantling are:

- in the reactor pool – 2.47 man mSv,
- during the external dismantling of the thermal column (reactor hall) – 2.41 man mSv,
- on the reactor site itself – 80 man μSv,
- on the site for the secondary treatment and decontamination of the dismantled equipment – 271 man μSv, and
- on the premises of the 1 CL (premises 103) – 123 man μSv.

*Waste management* involves all activities, including decommissioning, connected with the manipulation, preliminary treatment, processing, conditioning, storage and disposal of RAW, except for their transportation outside the perimeter of the reactor site.

RAW management stages are shown in the scheme on fig. 11.

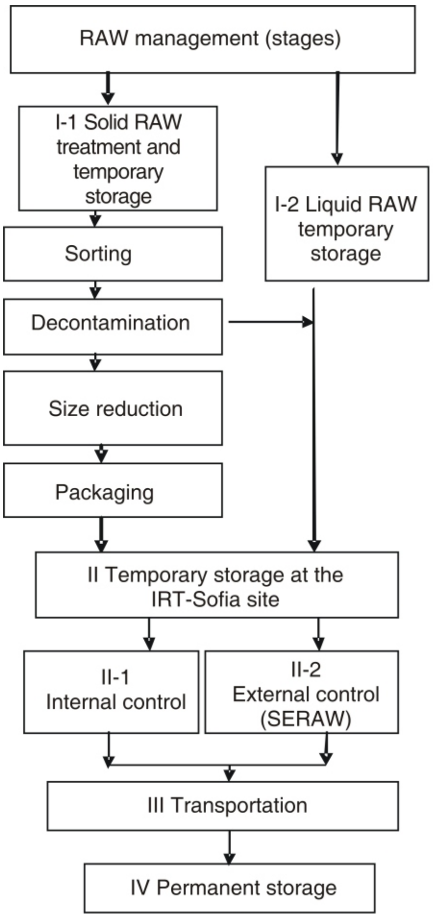


**Figure 11. RAW management stages**

All the radioactive materials and waste generated during the PD of IRT-Sofia are described in log-books, especially those concerning PD activities. The generated RAW was collected separately, according to kind (solid or liquid) and categorization. Radionuclide content monitoring was done with portable radiometric appliances, at a location where the radiation background in the restricted zone is sufficiently low, so as to give a qualitative analysis of the isotope content.

Following RAW categories were determined according to [5], article 5 and [6].

*Solid RAW of the first category (1)*: Transitional RAW which can be released from regulatory control after proper treatment and/or temporary storage.

*Solid RAW of the second category (2)*: Low- and medium activity wastes. Additionally, this category is categorized as *category 2a* – short-lived, low- and medium- activity wastes and as *category 2b* – long life-time, low- and medium activity wastes.

*Solid RAW of the third category (3):* High activity wastes.

Table 1 shows the quantities of RAW resulting from the partial dismantling of IRT-Sofia equipment.

The RAW obtained from the partial dismantling of IRT-Sofia equipment was collected, decontaminated, packed and temporarily stored on the reactor site (fig. 12). After packing, it was placed in licensed transport containers, to be delivered for storage to the state enterprise "RAW".

Liquid RAW from the IRT was delivered to the state enterprise for recycling and storage.

**Table 1. Quantities of RAW**

| RAW streams description | Planned | Obtained |
|---|---|---|
| Solid RAW, reactor pool, partial dismantling, RAW storage, metal of 2a and 2b category | 1680 kg | 1686 kg |
| Solid RAW, reactor pool, partial dismantling, RAW storage, non-metals of 2a and 2b category | 70 kg | 70 kg |
| Solid RAW, thermal column, partial dismantling, RAW storage, metal of 2a and 2b category | 5040 kg | 5040 kg |
| Solid RAW, thermal column, partial dismantling, RAW storage, non-metal of 2a and 2b category | 10000 kg | 11035 kg |
| Solid RAW, I CL, partial dismantling, RAW storage, metal of the 1st, and 2a category | 5800 kg | 2736 kg |
| Liquid RAW, reactor hall, partial dismantling, tanks, coolant from reactor pool | 60000 L | 60000 L |
| Liquid RAW, reactor hall, partial dismantling, tanks, decontamination solutions | 6000 L | 1000 L |
| Liquid RAW, reactor hall, partial dismantling, RAW storage, ion-exchange resins | 320 L | 160 L |

**Figure 12. Site for temporary disposal of containers with RAW**

## CONCLUSION

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

An inspection of radiation protection measures applied at the IRT-Sofia site was then performed by

BNRA inspectors. The conclusions of this inspection were as follows:

> "Adequate measures of radiation protection were applied during the partial dismantling procedure. Data coming from the monitoring of the IRT-Sofia site for radiation prove that the dismantling procedure did not have a significant impact on the reading."
>
> "The management of RAW obtained from the partial dismantling of IRT-Sofia has been carried out according to internal working documents and in keeping with radiation protection measures."
>
> "The commission advised IRT leaders to prepare and build a site for the temporary disposal of containers containing RAW."

As recommended, a site for the temporary disposal of RAW was built prior to its delivery and storage at the "RAW" state enterprise [7] and [8].

The final report and conclusions call for novel equipment and systems in dealing with the said issue.

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## ДЕЛИМИЧНО УКЛАЊАЊЕ ИСТРАЖИВАЧКОГ РЕАКТОРА ИРТ-СОФИЈА ПРЕ ЊЕГОВЕ ОБНОВЕ

Бугарска влада одлучила је 2001. године да истраживачки реактор у Софији обнови и преобрати у реактор мале снаге. У ту сврху спроведено је делимично растављање старих система и опреме ИРТ-Софија, са намером да се у конструкцији новог истраживачког реактора мале снаге поново употреби биолошки штит од бетона. Ради делотворнијег коришћења расположивих средстава, начињен је инжењерски пројекат познат под именом "План за делимично уклањање опреме ИРТ-Софија као део превођења у истраживачки реактор мале снаге", који се од тада успешно примењује.

*Кључне речи: истраживачки реактор, делимично уклањање, радиоактивни отпад, деконтаминација, процена сигурности, заштита од зрачења*