BATAN - IAEA Cooperation in the Program of Decontamination and Post Irradiation Examination (PIE) in Radiometallurgy Installation Hot Cell - BATAN

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Abstract

BATAN received expert assistance from the IAEA in cooperation of decontamination and post-irradiation examination program in Radiometallurgy Instalation hotcell - BATAN. Some of test equipments in the hotcell has undergone aging and therefore can not function anymore. For the test equipment that has been damaged and can not be repaired must be removed from the hot cells and will be replaced with new equipment. Hot cell decontamination activities has been carried out to remove the test equipment that has been damaged from the hot cells. BATAN staffs have conducted decontamination in concrete hot cells. Through the cooperation with the IAEA, in 2015 BATAN has held an interregional workshop on various techniques of decontamination in hot cell facilities. Cooperation between BATAN and IAEA continues with the arrival of experts to Indonesia in April 2017 through the IAEA Expert Mission on the decontamination of hot cells and PIE program in Indonesia. The activities carried out in the form of a workshop on decontamination and post-irradiation examination in April 2017. BATAN – IAEA cooperation activities in the decontamination and PIE facility preparation program in nuclear fuel technology center - BATAN will be described in the paper.

1. Introduction

BATAN is a non-ministerial government institution, one of its tasks is to conduct research, development and utilization of nuclear science and technology in Indonesia. Nuclear Fuel Technology Center is one of the centers in BATAN which is tasked to develop the technology of nuclear fuel fabrication and post irradiation test. To carry out its duties, the Center for Nuclear Fuel Technology is supported by Experimental Fuel Element Installation (EFEI) and Radio Metallurgy Installation (RMI) facilities. In Radiometalurgi Installation there is a hot cell facility to perform post-irradiation test. This hot cell facility has 12 hotcells consisting of 3 concrete cell and 9 steel cell. This hot cell was completed in 1991. This hot cell has been widely used to conduct post-irradiation tests, among them is to conduct post-irradiation test of U_3O_8-Al research reactor fuel and U_3Si_2-Al plate type, and unload Low Enriched Uranium (LEU) foil target. Because of the age factor so many test equipment and tools that exist in the hot cell began to aging, so many test equipment and tools that can not be operated again. In the concrete cells ZG 102 and ZG 103 there are NDT test kits and sample cutting tools, which are damaged and no longer functioning. These tools need to be removed and replaced with new tools. To remove these tools need to be decontaminated hot cell and test equipment. Therefore, in the year 2013 began to be made program activities of hot cell decontamination. Along with the decontamination program, the Center for Nuclear Fuel Technology (PTBBN – BATAN) is seeking a cooperation program with IAEA related to decontamination to support the decontamination program. In 2015, PTBBN BATAN obtained a program of cooperation with the IAEA through Technical Cooperation which is packaged in

the project number INT / 9/175 under the title Promoting safe and efficient cleanup of radioactively contaminated facilities and sites. The activities include the conducting Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities. The workshop was held in Serpong, Indonesia on 4 - 8 May 2015. The organizers are the International Atomic Energy Agency (IAEA) in collaboration with the Government of Indonesia through the Center for Nuclear Fuel Technology, BATAN.

2. Status of decontamination of hot cell facility

The Radio Metallurgy Installation at the Center for Nuclear Fuel Technology is equipped with hot cell to perform radio-metallurgy development, physicochemical analysis and post irradiation examination (PIE). Testing in hot cell can be conducted for nuclear fuel element of Material Test Reactor, Pressurized Heavy Water (PHWR) and Light Water Reactors (LWR). T he data generated from testing can be used for fuel element fabrication feedback and to determine the performance of the fuel and structural materials. The capacity of the hot cell was designed to be able to receive 6 fuel elements of MPR-30 type or one fuel rod of LWR / PWR type or one bundle fuel element of PHWR / CANDU type.

Hot Cell for testing activities of spent fuel or other post irradiated materials consists of 12 cells, i.e., 3 concrete cells (ZG 101, ZG 102 and ZG 103) and 9 steel cells (ZG 104 up to ZG 112).

Concrete Cell consists of 3 cells, namely:

- ZG 101, reception cell and temporary storage of nuclear fuel to be tested or other post irradiated materials.
- ZG 102, a place for visual testing, dismantling and cutting fuel elements for destructive test sampling.
- ZG 103, a place for non-destructive testing.

Steel Cell consists of 9 cells, namely:

- ZG 104 up to ZG 107 is used for the examination of macro and micro structure (metallographic test).
- ZG 108 and ZG 109 are used to physical chemistry analisys and wet chemistry.
- ZG 110 and ZG 111 are used to mechanical test and heat treatment.
- ZG 112 is used for the preparation of sample for SEM / TEM and testing samples with α, β autoradiography.

Utilization of the IRM hot cell for post-irradiation testing began in 1995. Hot cell was used to perform post-irradiation testing of the oxide fuel (U_3O_8-Al) and silicide fuel (U_3Si_2-Al). Both are research reactor fuel plate types. In addition, the hot cell was also frequently used for testing of LEU foil targets. Dismantling of fuels and LEU foil targets in concrete cell had been carried out resulting in very high contamination of radioactive materials in the concrete cell. Due to the high radiation exposure in the concrete cell, most of test equipment, electrical cables and many manipulator arms can no longer function.

In 2013 decontamination project was undertaken. Refurbishment for ZG-101 and ZG-14 has been done, and most of the concrete cell has been decontaminated by means of removal of waste and used manipulators; further decontamination is expected.

The refurbishment project requires sufficient knowledge and skills to ensure proper and safe decontamination procedures are followed. Competence of personnel working for

decontamination of hot cell is essential. Establishment of sufficient communication and networking in the expertise of decontamination of hot cell facilities with the international community and the appropriate assistance and support is deemed necessary to achieve the goals. In table 1 is explained Post irradiation examination performed at PTBBN-BATAN. While, in table 2 it is explained Decontamination of hot cell in 2013-2014.

Table 1. Post irradiation examination performed at PTBBN-BATAN

No	Activity	Customer	Type of sample	Description of activity	Contamination / Level of contamination
1	PIE of research reactor fuel plate types	Research reactor RSG-GAS	Oxide fuel U_3O_8-Al	Dismantling of fuel bundle Cutting fuel plate for sample preparation Post irradiation examination (Visual examination, burn up analysis, microstructure examination, hardness test)	N/A
2	PIE of research reactor fuel plate types	Research reactor RSG-GAS	Silicide fuel U_3Si_2-Al	Dismantling of fuel bundle Cutting fuel plate for sample preparation Post irradiation examination (Visual examination, burn up analysis, microstructure examination, hardness test)	N/A
3	Testing foil targets for Mo-99 production	Argonne National Laboratory	LEU foil target	Dismantling of LEU foil targets for Mo-99 production proses	N/A

Table 2. Decontamination of hot cell in 2013-2014

No	Cell	Description	Level of contamination
1	ZG-101	Removal of waste (contaminated PVC pipe, cotton/dust cloth waste, HEPA filter). Method:	α- surface contamination: 0.02 Bq/cm^2 β- surface

		• Green house preparation for safety protection during decontamination activities • Remote decontamination for floor, walls of the room and equipments • Direct decontamination by entering in the hot cell • Smear test and radiation exposure test	contamination: 0.675 Bq/cm^2 (11 June 2013)
2	ZG-102	Removal of used manipulator and slave arm manipulator Method: • Green house preparation for safety protection during decontamination activities • Remote decontamination for floor, walls of the room, used manipulator and slave arm manipulator • radiation exposure test	N/A
3	ZG-103	Removal of burnable solid waste and unburnable solid waste Method: • Green house preparation for safety protection during decontamination activities • Remote decontamination for floor, walls of the room • Radiation exposure test	N/A

3. Inter-regional workshop 2015

On 4 - 8 May 2015 in Serpong, Indonesia, the successful Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities was held. This workshop is aimed at providing training on the characterization and decontamination techniques for hot cell facilities as the part of nuclear decommissioning projects. Expected output from this workshop is participants should be familiar with various aspects relating to technologies and procedures for the characterization and decontamination of hot cell facilities, include planning, safety aspects as well as detailed practical considerations. The course take place over five days, providing lectures, national case studies illustrating good practice from implementation of relevant ongoing projects and the site visit. The participants of the workshop is 20 participants from 14 countries: Algeria, Bangladesh, Chile, Iraq, Latvia, Lithuania, Malaysia, Mexico, Morocco, Pakistan, Philippines, Poland, Russian Federation and Ukraine. Participants are technical staff from operating or sevice organizations, or technical advisors from engaged national bodies or regulators, who are personally involved in the planning and management of hot cell decontamination / decommissioning activities. Participants from Indonesia have 33 participants from various research centers in Batan and participants from the Nuclear Power Supervisory Agency. IAEA Experts present there are 4 experts, namely Mr. Vladimir Michal from IAEA-Department of Nuclear Energy-Division of Nuclear Fuel Cycle and Waste Technology-Waste Technology Section, Mr. Charly Mahe of France-Center d'etudes nucleaires (CEN) -CEA, Mr. Sergey Mikheykin from Russian Federation-Repository Project Management and Mr. Ed J. Butcher from United Kingdom-

British Nuclear Fuels Plc. (BNFL).
The materials provided by the experts include:

- Decommissioning Technical and Safety Guides & Decommissioning Planning [1]
- Characterization techniques – Introduction, Alpha and Gamma Imaging [2]
- Gamma spectrometry techniques and the use of calculation codes [3]
- Post-decontamination measurements [4]
- Decontamination methods and tools for hot cells [5]
- Chemical decontamination [6]
- Electrochemical techniques, Physical and mechanical method [7]
- Characterization and decontamination of hot cells – practice experience and lesson learned [8]
- Radiation protection, radioactive waste management and safety aspects [9]

The material given by the experts, the number is quite a lot so we get a lot of learning. Discussion from the participants was quite warm, many participants were proactive to ask questions. Some of the discussions or questions that arise include:

1. Chemicals/agents for decontamination of surface and under surface contaminants and their specific functions/purposes.
2. Equipments/devices for decontamination of hot cell
    a) Type, purpose (container, detector, frogman, tyveks suit, green house, etc)
    b) Category, quality (high exposure, high level waste, high efficiency, etc)
    c) Material (stainless steel, lead, rubber, etc)
    d) Form and dimension
    e) Handling
3. Procedure for decontamination of hot cell:
    a) Preparation, action, monitoring, evaluation, etc
    b) Different surface:
        i. Concrete
        ii. Stainless
        iii. Others (epoxy)
4. Techniques for reducing exposure level of radioactive waste.
5. Procedure for removing contaminated equipment/device from hot cell and replacing contaminated aging equipment/device with a new one (e.g. HEPA filters in hot cell)
6. Hazards or precautions before, during and after decontamination.
7. Preventive and mitigation measure against possible accident during decontamination.
8. Organizational and Personnel:
    b) Structure
    c) Qualification and competence
    d) Number
9. Legal and regulatory aspect.
10. Lesson learned from similar activities in other country
11. IAEA technical assistance and aid in future.
12. Research collaboration and technical cooperation with IAEA or other counties especially on Post Irradiation Experiment (Type of testings, advanced device and technique and grant possibility)

Meanwhile, all participants from various countries were also asked to present the National Presentation so that we know information related to hot cell activities from various countries that participated in this workshop.
In this workshop there is also a visit to hot cell facility in Nuclear Fuel Technology Center - BATAN so that all participants from various countries can see our hot cell directly.
This kind of workshop is very useful for us to understand each other activities of various

countries related to the activity of each hot cell. Such activities can also have opportunities for technical cooperation and non-technical cooperation, for example we want to visit other countries to study or study comparative, or we can also invite other countries to hold the next workshop with help and cooperation with IAEA.
So in general we want a follow-up of this workshop, among others are:

- Promote cooperation in the decontamination of hot cell and nuclear facilities
- Organize more meetings in the subject matteras necessary
- Develop related Coordinated Research Project (CRP) to allow sharing of hot cell facilities around the word

4. Expert Mission to BATAN 2017

Expert Mission (EM) to BATAN has a theme of Practical Aspects of Hot Cells Decontamination for further Dismantling or Revitalization [10]. The Expert Mission is focused on the remote decontamination of BATAN hot cells for further revitalization or dismantling and to advice on technical specification of equipment that will be later used for PIE (Post Irradiation Examination) starting from non-destructive testing to destructive testing. EM to BATAN has been conducted on 3 – 7 April 2017 with 3 IAEA experts from CEA, JAEA, Kurchatov Institute, and 1 expert from IAEA Technical Officer. EM to BATAN is follow-up of "Inter-Regional Workshop on Characterization and Decontamination Techniques for Hot Cell Facilities", BATAN, May 2015. Main focus on the practical aspects and advice, not on the 'academic' presentations and discussions. On that occasion also given some material from hot cell workshop in Beijing, 13 - 17 March 2017. EM to BATAN held for 5 days, Monday April 3, 2017: presentations of BATAN – overview of technical issues to be addressed, IAEA presentation and introductory presentations of IAEA experts on their national experience in hot cells decontamination and/or dismantling. Tuesday April 4, 2017 /Wednesday April 5, 2017: hot cells site visits and meetings/discussions with the BATAN staff. Thursday April 6, 2017: work on the EM report with recommendations. Friday April 7, 2017: presentation and discussion of recommendations.

Participants who attended the discussions and presentations in the EM to BATAN program came from BATAN researchers.
The material given by the experts includes about:

1. Decontamination of various surfaces using gels and foams for nuclear facilities
2. Waste management strategy
3. Technologies and processes of post irradiation examination in the reactor fuel examination facility
4. Decommissioning program of Research Hot Laboratories in JAEA
5. Concept of creation the PIE facility for studying of HTGR spent fuel
6. Experience in the decontamination and refurbishment of nuclear fuel cycle hot cells

Meanwhile, the form of cooperation that can be given by IAEA to us in the form of general activities, such as:

- Assisting in development of consistent policies and related strategies for decommissioning & support of planning and implementation of decommissioning projects;
- Conferences, workshops, training courses, seminars etc. to support sharing of good practices among involved specialists and organizations;
- Safety standards and guidance & technical publications;
- International Decommissioning Network and related projects;
- Technical Cooperation (TC) projects (national, regional, interregional);
- Coordinated Research Projects.

In this workshop, the CEA expert [11] gave a presentation entitled Decontamination of various surfaces using gels & foams for nuclear facilities to inspire us. Explained that, there are 2 categories of decontamination methods namely chemical and Physical & mechanical.

- For chemical, the types are:
  - Solution, with character
    - All surface types / Bath, wipes, spray
    - Large liquid waste volume
    - Long exposure time
  - Foam, with character
    - Difficult access : tanks, pipes
    - Small liquid waste volume
    - Short exposure time
  - Gel, with character
    - Simple shaped materials
    - Paintbrush / spray
    - Solid waste / Short exposure time
- For physical & mechanical, the types are:
  - Abrasion : sandblasting, grinding with character
    - Metal or concrete covered with paint
    - High efficiency / Damaged surfaces
    - Long exposure time
  - Dry ice blasting (cryogenic tech.)
    - Metal & concrete / dry ice spraying
    - Solid waste
    - Spread of contamination
  - Laser
    - Erosion depth : 30-40 mm/shot
    - Difficult implementation & nuclearization

For decontamination of hot cell whose condition of the Wall (large surface), Painted concrete, Labile & permanent contamination, Gel is more appropriately used as a material or method used to decontaminate. With Gel can also reducing operators' exposure time.
There are different types of Gel delivered by CEA experts, and the plan, BATAN will be given an example to try to use for decontamination in the hot cell.

Then, a presentation from JAEA, Japan entitled Decommissioning Program of Research Hot Laboratory in JAEA, Technical Review of Dismantling Works for the Lead Cells, describes his experience in conducting a decommissioning plan of Research Hot Laboratory (RHL)-JAEA, Japan [12]. RHL was constructed in1961, as the first Hot Laboratory in Japan. In RHL, various PIEs was performed for fuel rods and to the small samples. All the PIE operations in RHL had been completed. And the decommissioning works of RHL have been performed since 2003.The partial area of RHL has been utilized for the temporary storage of un-irradiated fuel materials used for our previous research. The lesson that can be taken is that nuclear facilities that have finished their functions and are not used anymore immediately decommissioning.

Decommissioning plan was made from 2003 to 2024. The work that has been done is the dismantlement of lead cells. 20 lead cells have been successfully dismantled, and 18 lead cells will be dismantled. Next is doing Decontamination of concrete cells and last will be done Decontamination of radiation control area. Described also in detail about the procedure of dismantling the lead cell, including also delivered a technique to perform a hard foundation dismantling and takes a long time when done by using jackhammer. The technique is to use chemical infusion materials. With this technique, dismantling can be quickly done.

The Japanese expert also presented his experience on Post Irradiation Examination done at

RFEF (Reactor Fuel Experiment Facility) JAERI [13]. The Japanese Expert also provides information related to the equipment used to support PIE activities in RFEF. Different types of test equipment available in the RFEF is EPMA (Electron Probe Micro Analyzer), X-ray diffractometer (XRD), optical microscope, melting-point apparatus, density meter, Thermal diffusivity measurement appliance, electric discharge machine and penetrometer. By knowing these tools we can consider the tools needed to support PIE activities in our hot cell.

Meanwhile, an expert from the Kurchatov Institute, presented his experience in decontaminating and decommissioning a pyrochemical hot cell facility [14]. Described hot cell description, history of hot cell facility operation, Russian Personal Protective Equipment (PPE) for working inside of contaminated hot cells, and Decontamination procedures are so detailed and can be used as our learning.

Moreover, the expert of the Kurchatov Institute also presented the Concept of creation the PIE facility for studying of HTGR spent fuel [15]. This topic we want because we have activities related to the development of kernel type fuels. Initially we wanted our hot cell, after the decontamination program was completed, we will also prepare test equipments for post-irradiation testing of ball type fuel. But after receiving a presentation from Kurchatov Institute Experts it turns out to do post-irradiation testing kernel fuel is very complex and requires a large hot cell space, so it is impossible to use an existing hot cell, must use another hot cell. Expert explained the Flowsheet of PIEs for fuel compacts (FC) is very detailed, ranging from cutting of capsules, Fuel Compact removal, gamma scanning testing, profilometric testing, density, metaolography, thermal conductivity, FC compression, tensile and bending tests, and others. Also described on PIE flow sheet of micro fuel elements with a lot of testing steps. Also explained about the List of Tasks for Designing of Facilities for PIEs are quite a lot and complex facilities, namely Facility for classification of micro fuel elements, Facility for disintegration of fuel compacts, Facility for simulation of emergency conditions with core overheating, Facility for determination of specific thermal capacity and thermal effects in FC, Investigation of dimension changes and surface of fuel compacts, “Leaching-burning-leaching” facility, Facility for gamma scanning of capsules and fuel compacts, Facility for metallographic investigations of micro fuel elements and fuel compact segments, Facilities for determination of FC density, Pulse facility for measurement of FC thermal conductivity, and Facility for measurement of coefficient of thermal expansion of irradiated fuel compacts. It is thus understood that for post-irradiation testing kernel type fuels are very complex and require other hot cell facilities to be manufactured.

5. The future plan

To continue the hot cell decontamination program at the nuclear fuel technology center - BATAN and undertake a test equipment purchase plan to support PIE activities. Cooperation with the IAEA and between countries needs to be improved so that it can support hot cell activities. Nuclear Fuel Technology Center - BATAN requests the IAEA to support decontamination and revitalization activities of hot cells so that hot cell activities to support PIE work can be optimized. Expected Nuclear Fuel Technology Center - BATAN can obtain IAEA TC program within 2018 - 2019 period to support decontamination program and hot cell decommissioning planning program.
As a follow up of EM to BATAN 2017 activities, the IAEA is currently sending gel samples from CEA-France to Indonesia to try to apply decontamination in hot cells using a gel.

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References

[1] Vladimir Michal, Decommissioning Technical and Safety Guides & Decommissioning Planning, NEFW, Waste Technology Section, Decommissioning and Environmental Remediation Team leader, IAEA, Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities, 4 – 8 Mei 2015, Serpong, Indonesia.

[2] Mahé Charly, Characterization techniques – Introduction, Alpha and Gamma Imaging, France-Centre d'etudes nucleaires (CEN)-CEA, Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities, 4 – 8 Mei 2015, Serpong, Indonesia.

[3] Mahé Charly, Gamma spectrometry techniques and the use of calculation codes, France-Centre d'etudes nucleaires (CEN)-CEA, Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities, 4 – 8 Mei 2015, Serpong, Indonesia.

[4] Mahé Charly, Post-Decontamination Measurements, France-Centre d'etudes nucleaires (CEN)-CEA, Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities, 4 – 8 Mei 2015, Serpong, Indonesia.

[5] Sergey Mikheykin, Decontamination methods and tools for hot cells, D-R PMU, Kozloduy NPP site svm958@yandex.ru, Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities, 4 – 8 Mei 2015, Serpong, Indonesia.

[6] Ed J. Butcher, Chemical decontamination, United Kingdom-British Nuclear Fuels Plc. (BNFL), Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities, 4 – 8 Mei 2015, Serpong, Indonesia.

[7] Sergey Mikheykin, Electrochemical techniques, Physical and mechanical method, D-R PMU, Kozloduy NPP site svm958@yandex.ru, Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities, 4 – 8 Mei 2015, Serpong, Indonesia.

[8] IAEA Experts, Characterization and decontamination of hot cells – practice experience and lesson learned, Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities, 4 – 8 Mei 2015, Serpong, Indonesia.

[9] IAEA Experts, Radiation protection, radioactive waste management and safety aspects, Inter-Regional Workshop / Training course on Characterization and Decontamination Techniques for Hot Cell Facilities, 4 – 8 Mei 2015, Serpong, Indonesia.

[10] Vladimir Michal, EM to BATAN on Practical Aspects of Hot Cells Decontamination for further Dismantling or Revitalization, Waste Technology Section, Nuclear Energy Department, EM to BATAN meeting, 3-7th April, 2017, Serpong, Indonesia.

[11] Célia Lepeytre, Decontamination of various surfaces using Gels & foams for nuclear facilities, CEA – Marcoule, Waste Treatment & Conditioning Research Department, Decontamination & Supercritical Processes Laboratory, EM to BATAN meeting, 3-7th April, 2017, Serpong, Indonesia.

[12] Hidenori Shiina, Decommissioning Program of Research Hot Laboratory in JAEA-*Technical review of dismantling works for the lead cells*-, TOKAI Research and Development Center, Japan Atomic Energy Agency, EM to BATAN meeting, 3-7th April, 2017, Serpong, Indonesia.

[13] Hidenori Shiina, Technologies and processes of post irradiation examination in the reactor fuel examination, TOKAI Research and Development Center, Japan Atomic Energy Agency, EM to BATAN meeting, 3-7th April, 2017, Serpong, Indonesia.

[14] Mikhail Kormilitsyn, Experience in the decontamination and refurbishment of nuclear fuel cycle hot cells, Based on Russian RIAR Institute, K-16 Hot Cell Experimental Facility operation experience, Design, capabilities, decontamination, refurbishment, NRC

"Kurchatov Institute, Moscow, Russia, EM to BATAN meeting, 3-7th April, 2017, Serpong, Indonesia.
[15] Mikhail Kormilitsyn, Concept of creation the PIE facility for studying of HTGR spent fuel, NRC "Kurchatov Institute, Moscow, Russia, EM to BATAN meeting, 3-7th April, 2017, Serpong, Indonesia.