INDUSTRIAL TRAINING REPORT

MUHAMMAD FAHMI BIN MOHD ZAINAL

17163319/2

DEPARTMENT OF PHYSICS

FACULTY OF SCIENCE

UNIVERSITY OF MALAYA

SEPTEMBER 2022

DECLARATION

Name of student: MUHAMMAD FAHMI BIN MOHD ZAINAL

Matric number: 17163319/2

I sincerely declare that:

1. The details of training and experience contain in this report describe my involvement as a trainee.
2. All the information contains in this report is certain and correct to the knowledge of the author.

Student’s signature: 

Date: 2 September 2022

ABSTRACT

This report presented an overview of company, responsibility as an internship student, experience and skills gained for 12 weeks at Malaysian Nuclear Agency.

Agensi Nuklear Malaysia (Nuklear Malaysia), as a premier research and development (R&D) organisation in nuclear science and technology, continues to play an active role and contributes to the implementation and realisation of national science and technology (S&T) policies to ensure it remains a relevant public research institute for the country. With more than three decades operational, Nuklear Malaysia is mature and capable to face the challenges and manage the change efficiently. In line with the current needs and development, a strategic action plan and its implementation has developed to meet the set targets. Nuklear Malaysia has emphasis on building the human capital potential and also ensuring that all activities fit the mainstream S&T and national interest.

During this industrial training programme, I was responsible to handle project entitled Neutron Flux Profiling At The End-Of-Cycle (EOC) RTP Core Configuration supervised by Dr. Julia Binti Abdul Karim. RTP is stand for Reactor TRIGA PUSPATI. Neutron flux study and measurement plays an important role in maintaining the safe operation of RTP reactor. So, in this report ,there will be measurement that be done to contribute for the data collection for the continuity of the safe operation of the RTP reactor.

I also involved in annual semi-maintenance of reactor such as INTERLOCK system, SCRAMP test, DROP test and many more activities and study visit around the MNA area.

.

ACKNOWLEDGEMENTS

First and foremost ,thanks Allah ,The Almighty God, for giving me this once in a lifetime opportunity to do my internship at Nuclear Malaysia Agency ,Bangi as a research assistant .I am placed at Reactor TRIGA PUSPATI Unit ,Block 18, under supervision of Dr. Julia Binti Abdul Karim. My sincere appreciation to her as she has trained, guided me throughout the internship here. I also thank her for every comment that greatly improved this report and my skills as a whole.

I would like to thanks Mr. Na'im Syauqi Hamzah for his continuous efforts to help me with his knowledge on using Gamma vision software and taught me the way to do proper analysis during my part in methodology.

Thank you to Dr. Hasniyati for making visit to Sinagamma and Reactor TRIGA PUSPATI startup checklist possible.It was a great experience and had widen my perspective in just a couple of weeks. Thanks to Dr. Marks for sharing his pearls of wisdom with me on how to pursue my career as a successful research officer in the near future.

Last but not least, I must acknowledge as well ,friends, colleagues, students, teachers, and other librarians who assisted, advised, and supported my research and writing efforts over the internship period. Especially, I need to express my gratitude and deep appreciation to my supervisor again , Dr. Julia Binti Abdul Karim .She consistently helped me keep perspective on what is important in the research and how to deal with the problems.

Table of Contents

List Of Figures

List Of Tables

CHAPTER 1: INTRODUCTION

1.1 Introduction

In April 2022, I was searching for an internship at Malaysian Nuclear Agency (ANM) and I agreed to be part of the ANM as the industrial trainee soon after I got the offer letter.I am really enthusiastic to have the training here and planned to stay at my home near the Putrajaya-Kajang Boundary. The Malaysian Nuclear Agency (ANM) is located at Bangi ,43000 Kajang ,Selangor in which it does not cost me so much time to go there in the morning on every working days from home by a car or even a motorcycle.

Besides,the industrial training is compulsory for every student in the department of Physics ,University of Malaya as a condition for the award of the degree. This exercise is also intended to provide exposure and experience to the students about the real situation in the field of Nuclear Industry and as an early preparation for students before entering the working world. For my session, the training runs for 8 weeks, starting from 18 July until 11 September 2022 during the special semester.

I have sought and found a place to undergo industrial training in the Technical Support Division (BST) in Malaysian Nuclear Agency (ANM). In this position, I was placed in the Reactor Technology Center (PTR). During this training, I was given the opportunity to learn nuclear related knowledge from the experts here. For example, I have learned how a nuclear based agency function in Malaysia, how it works and how the daily routine here is so much important to maintain a healthy environment in Malaysian Nuclear Agency. I was given a project entitled “Neutron Flux Profiling at the End-of-Cycle (EOC) RTP Core Configuration” supervised by Dr. Julia Binti Abdul Karim ,Research Officer cum The Manager of Reactor Technology Center (PTR).

1.2 Significance of Industrial Programme

Industrial Training must be lived by all students in public higher education institutions or private as a prerequisite for qualifying students receive a certificate degree in majors taken. It is to create awareness about the situation in the working environment. With the industrial training many useful and valuable experience gained as supply before set foot in the sphere of employment. It also can build confidence with the experience and knowledge available. So quite easy and convenient to carry out the work which will be given later.

Industry training is important because such training can expose students to the real working environment. It also can add and expand technical knowledge and skills of the student, if the student has previously acquired knowledge is limited, but when students attend this training, students can find out more about things, and when something will work. In addition, students can learn about the latest technology or skills in industry.

In addition, this exercise also introduces the students themselves in terms of ability, willingness and attitude to the employer. This exercise can highlight the ability of students to work hard and to work with dedication and show a positive attitude to the employer.

1.3 Limitation of Industrial Programme

Short Period of Time

Due to only 8 weeks of Internship ,and sadly it is announced that at the 7th week ,the report should be submitted a week earlier than supposed, I supposed that it could be affecting my schedule thus by having this internship done early , probably there is a space that I'm missing that should be earned herein.

1.4 Conclusion

Through this exercise, students are able to handle a problem with wise through experience that has been through this before. The value of respect for those around him will arise within the student if the student's Industrial Training heartfelt and sincere. It is hoped that these properties will be sustained in the future.

The conclusion that can be defined on the importance of industrial training are:

a) To build and strengthen the students to be more confident to face any task and tribulations faced in the workplace.
b) Planting teamwork and good relations between workers and employees of an organization.
c) To expose students to the real working environment.
d) To make students do not face any difficulty or clumsy when start working soon.
e) Adopt and comply with safety regulations in the industry.
f) Linking theory to practice and so on.
g) Build confidence.
h) Fostering honesty and responsibility in performing tasks.
i) Provide an official report on completion of training.

CHAPTER 2: OVERVIEW OF ORGANIZATION

2.1 Introduction

The establishment of Agensi Nuklear Malaysia (Nuklear Malaysia) was mooted from idea of the then Malaysia's Deputy Prime Minister, Tun Dr. Ismail Dato' Abdul Rahman, that Malaysia should play a role in the development of nuclear science and technology for peaceful purposes. The Centre for Application of Nuclear Energy (CRANE) was the entity to mark the of Malaysia's nuclear programme, focussing on manpower development for a nuclear power programme to provide an option for energy source, following the worldwide oil crisis of the early 1970's. The Cabinet officially approved the establishment of the Tun Ismail Atomic Research Centre (PUSPATI), under the Ministry of Science, Technology and the environment on 19 September 1972. The era of nuclear research in Malaysia began with the historic event signified by the Reaktor TRIGA PUSPATI reaching its first criticality on 28 June 1982. When Puspati was placed under the auspices of the Prime Minister's Department, it assumed the name Nuclear Energy Unit (UTN). The Nuclear Energy Unit was later placed under the Minister of Science, Technology and the Environment. In line with the national development, the institute was name Malaysian Institute for Nuclear Technology Research (MINT) on 10 August 1994.

To reflect its vision, mission, objectives and activities in the challenging world, a new identity was established, and was officially named as Agensi Nuklear Malaysia (NUKLEAR MALAYSIA) on 28 September 2006. Agensi Nuklear Malaysia, is strategically located nearby the government administration, centre Putrajaya, and Cyberjaya. Malaysia's progressive programme on industrialisation and manufacturing was reflected in Agensi Nuklear Malaysia, through the establishment and development of the important laboratories and facilities. These include Non-Destructive Testing Laboratory, SINAGAMA Plant, Electron Beam Processing Service Centre, Gamma Irradiation of Rubber Latex Plant, Non-Ionising Radiation Laboratory, Secondary Standard Dosimetry Laboratory, Radioisotope Production Laboratory, Environmental Laboratory, Analytical Chemistry Laboratory, Radioactive Waste Management Centre, Flora Centre and Tissue Bank. Through these facilities, nuclear science and technology assume an important and significant role in the national development programme. It is hoped that this booklet would provide useful insight to the public on the facilities and activities at Agensi Nuklear Malaysia, a progressive national research institution.

The organisation has rename itself from Malaysian Institute for Nuclear Technology (MINT) to Agensi Nuklear Malaysia, and restructure the management to realign its functions and activities. Following this restructuring exercise, Nuklear Malaysia now has four programmes, namely; research and technology development, technical support, commercialisation and technology planning and management services. These programmes will provide means for Nuklear Malaysia to focus on its activities, including the readiness to be technical support organisation, if Malaysia decided to embark on nuclear power programme as an alternative option for future electricity generation.

For the Technology Planning and Development;,in realising the potential of S&T as an agent for new economic development for the nation, particularly in facing the global competitive market, Nuklear Malaysia has focused its R&D activities into six priority areas, namely advanced material, advanced manufacturing, biotechnology, ICT, advanced alternative energy and nanotechnology. With its multidisciplinary features, nuclear technology has the ability to offer technical solution to arising technical problems. The R&D projects are market driven to produce beneficial products to generate economic returns through downstream activities. The implementation of R&D projects are periodically monitored and analysed to ensure that the projects are on the right track and meet the set target within the time frame. To strengthen project implementation and optimising resources sharing, several related projects have been consolidated into a few main projects, which will produce more significant socioeconomic impact. In this respect, apart from conducting collaborative research internally through the matrix system, research is also conducted through collaboration with other research organisations. Research collaborations with industrial partners have been also enhanced to produce research products that can be directly beneficial to end users. Thus, efforts have been made to ensure that research products can be commercialised through technology transfer and licensing

For Commercialisation of Technology;in realising the potential of S&T as an agent for new economic development for the nation, particularly in facing the global competitive market, Nuklear Malaysia has focused its R&D activities into six priority areas, namely advanced material, advanced manufacturing, biotechnology, ICT, advanced alternative energy and nanotechnology. With its multidisciplinary features, nuclear technology has the ability to offer technical solution to arising technical problems. The R&D projects are market driven to produce beneficial products to generate economic returns through downstream activities. The implementation of R&D projects are periodically monitored and analysed to ensure that the projects are on the right track and meet the set target within the time frame. To strengthen project implementation and optimising resources sharing, several related projects have been consolidated into a few main projects, which will produce more significant socioeconomic impact. In this respect, apart from conducting collaborative research internally through the matrix system, research is also conducted through collaboration with other research organisations. Research collaborations with industrial partners have been also enhanced to produce research products that can be directly beneficial to end users. Thus, efforts have been made to ensure that research products can be commercialised through technology transfer and licensing (Agensi Nuklear Malaysia, 2022; Malaysian Nuclear Agency, 2017)

2.2 ANM Organizational Structure

Figure 2.1 : Organizational Chart of Malaysian Nuclear Agency (Agensi Nuklear Malaysia, 2022)

2.3 BST Organizational Structure

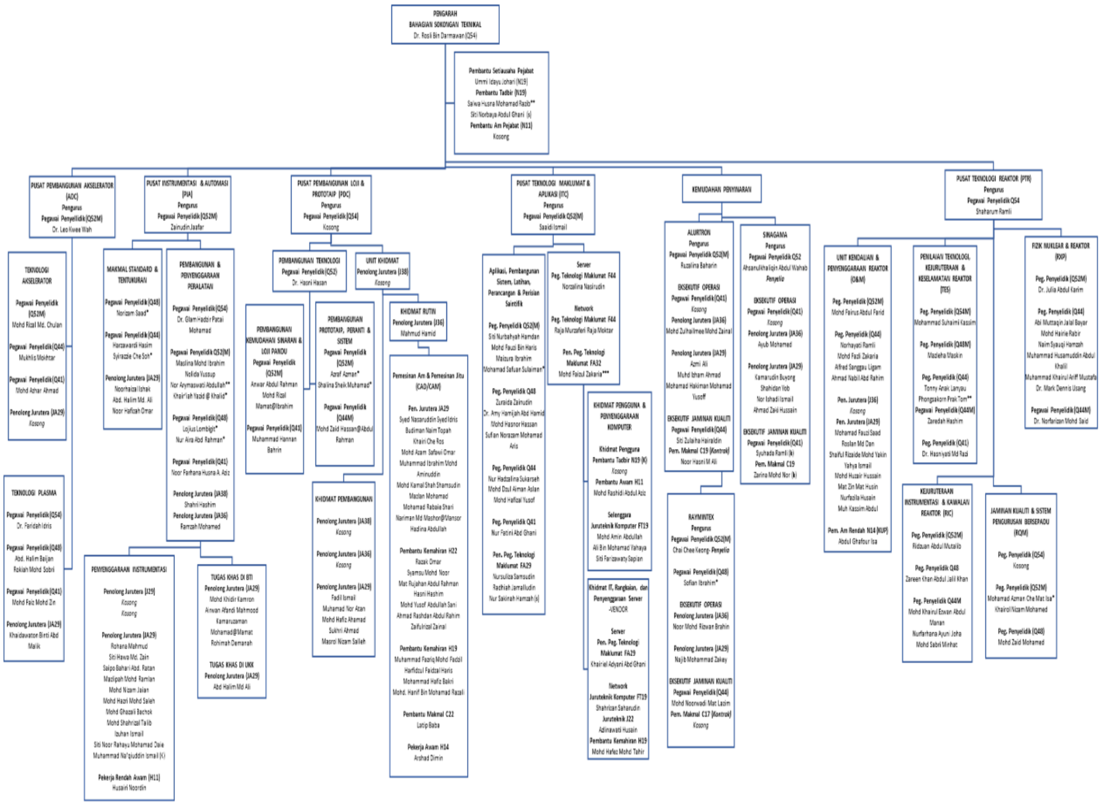


Figure 2.2 : Organizational Chart of Technical Support Division (BST) which consist Reactor Technology Center (PTR) and other different centers (Agensi Nuklear Malaysia, 2022)

2.4 PTR Organizational Structure

Figure 2.3 : Company overview above Bandar Kajang.(Photo taken from the board at the foyer of RTP Reactor)

2.5 ANM Organizational Function

ANM functions are to:

1. Conduct research and development (R&D), services and training in the field of nuclear technology for national development.
2. Encourage application, transfer and commercialization of nuclear technology.
3. Coordinate and manage the national and international nuclear affairs, and act as the liaison agency with International Atomic Energy Agency (IAEA) and Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO).

2.6 Mission And Vision

VISION

Nuclear science and technology for knowledge generation, wealth creation, and societal and national well-being

MISSION

Excellence in research and applications of nuclear technology for sustainable development

2.7 Objectives of the Organization

To generate new products and technologies through research and innovation based on the national development agenda

To achieve an income, at minimum 30% of the annual operating budget, through transfer and commercialisation of technology

To enhance organisational excellence through planning and quality management

2.8 Location and Company Overview

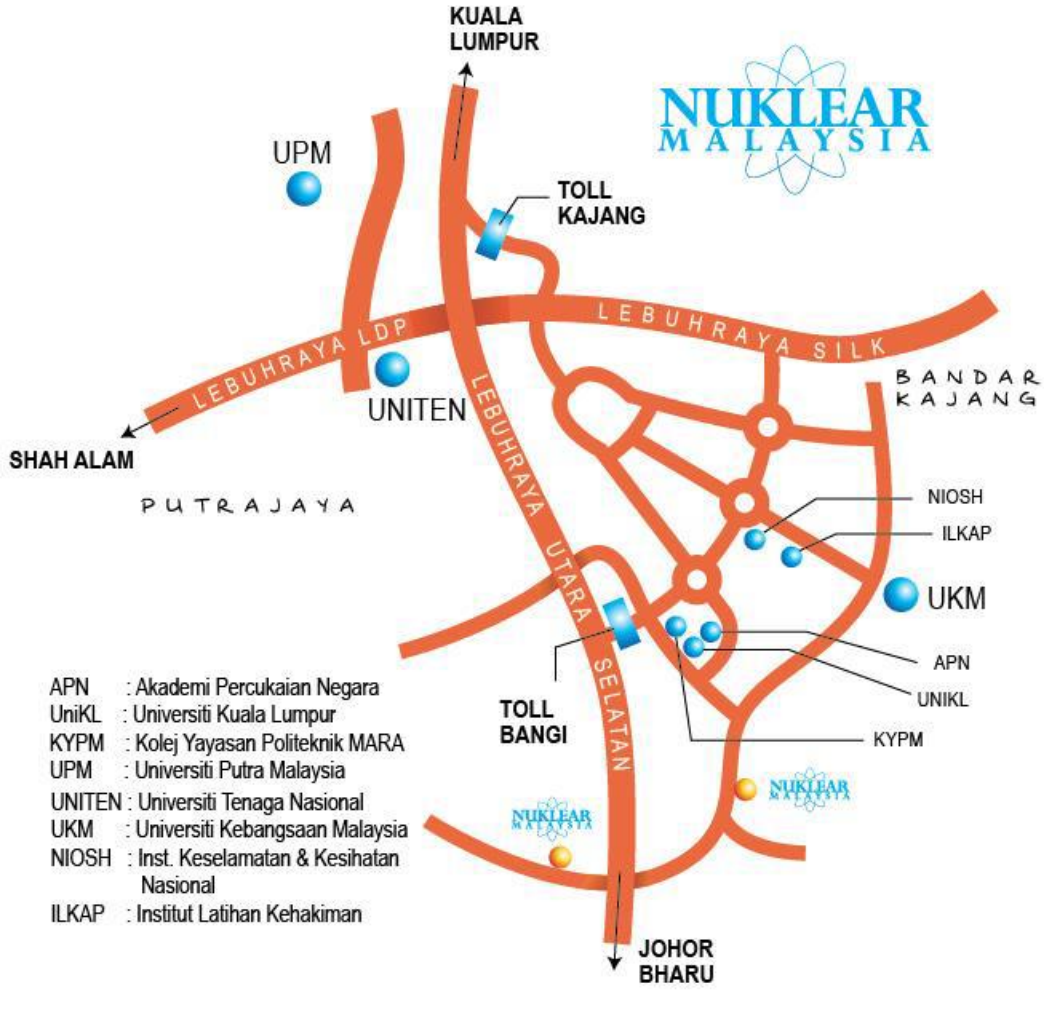


Figure 2.4 : Company overview above Bandar Kajang. (Agensi Nuklear Malaysia, 2022)

CHAPTER 3: WORK CULTURE

3.1 Occupational Health and Safety

All organization are required to ensure that employees and people engaged in work or employment remain safe all the times. Occupational health and safety is one of the crucial parts in any organizations to foster safe and healthy environment. Poor enforcement of laws or guidelines regarding safety in workplace will affect a workers' ability to effectively perform his job duties. Employees must be aware about the hazards and risks in laboratory and any activities regarding research work.In addition, it is very crucial for everyone in workplace to know how emergency situations should be handled.

Nuclear Malaysia Training Centre has been conducted the training on environmental safety and health issue for the last 10 years. Nuclear Malaysia Training Centre address the technological changes that have introduced new hazards in the workplace, proliferation of safety and health legislation and corresponding regulation, and realization by executives that workers in a safe and healthy workplace are typically more productive. As each person entitled to safe and healthy condition at the workplace, an amount of efforts have been concentrated to develop the program that can meet the need of workers in Malaysia who face the occupational safety and health hazards daily. The programs offered have sufficient awareness, information and communication between professionals and community especially employers and workers.

Focusing on research and technology transfer, Nuclear Malaysia through Nuclear Malaysia Training Centre with other government agencies always looking for the best medium to share the knowledge and technology to educate and help the publics. For the desirable development and increase in economy activities, many new program have been created to extensive technology that would result in increased productivity and enhanced economy.(Agensi Nuklear Malaysia, 2022; Malaysian Nuclear Agency, 2017)

3.2 Radiation Safety and Health

The use of radionuclides and radiation sources in industry, medicine, and education continues to create a need for persons trained in their safe use. There are a lot of demand for the competency of RPO and other safety personnel in an organization, in connection of that

Nuclear Malaysia Training Centre has played an important role in achieving the target through holistic approach in training, consultancy as well as research and development.

Radiation protection is an integral part of general health procedures, safety regulations and management systems at the workplace. The safe use and handling of radiation sources can be accomplished through familirisation with the associated technical topics. Safety can be assured when organization and radiation workers have enough information and practice the right working procedure.

All the courses will cover the basic science behind radiation safety and common applications of radiation safety principles. It also includes a description of common radiation sources, interaction of radiation with matter, biological effects, detection and measurement. The course will accompany by laboratory exercises that emphasize radiation detection and measurement techniques.(Agensi Nuklear Malaysia, 2022; Malaysian Nuclear Agency, 2017)

3.3 Laws and Regulation

The use of ionizing radiation is controlled by the National Law on the Atomic Licensing Act 1984 (Act 304). The aim of Act 304 is to provide the regulation and control of atomic energy; for the establishment of standards on liability for nuclear damage; and for matters connected therewith or related thereto. Subsidiary to the Act 304, there are few regulations which discussed in detailed provisions entrusted by the Act included the Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 (BSRP 2010) [P.U. (A) 46], which widely applied in our facility that related to ionizing radiation. BSRP 2010 is a replacement of the previous subsidiary legislation known as Radiation Protection (Basic Safety Standards) Regulations, 1988.

A. EXTRACTS FROM ACT 304

The contents of the Act 304 consist of 71 sections which are divided into ten parts. The following extracts from Act 304 are related to health and safety, and disposal of radioactive waste.

Part V: Health and Safety

Section 25

Deal with protection of the health and for the safety of workers and all other persons from ionizing radiation, including directives of matters pertaining to:

a) Conditions of exposure;

b) Dose limitation;

c) Occupational exposure;

d) Medical exposure;

e) Exposure of members of the public and persons other than workers, excluding medical exposure;

f) Accidental exposure;

g) Emergency exposure; and

h) Exposure other than any of those specified in (a) to (g).

Part VI: Disposal of Radioactive Waste

Section 26

No person shall dispose of or cause to be disposed any radioactive waste without prior authorization in writing of the appropriate authority.

Section 27

No person shall accumulate or cause to be accumulated any radioactive waste on any premises without prior authorization in writing of the appropriate authority.

Section 30

No person shall transport any radioactive waste without the prior authorization in writing of the appropriate authority.

Section 31

The appropriate authority may, if it fit to do so, consult the Director General of Environmental Quality appointed under subsection 3 (1) Environmental Quality Act 1974 on any matter.

B. EXTRACTS FROM BSRP 2010

BSRP 2010 was formed under the powers conferred by Section 25 (6) and Section 68 of the Act 304. The regulation shall be applied to all activities involving ionizing radiation. Based on this regulation, the registrant and licensees are required to foster and maintain safety culture. The regulations are categorized into 10 parts which in total includes 80 provisions. The following extracts are related to system of radiological protection, occupational, public and potential exposure, and intervention during emergency.

Part II: System of Radiological Protection

The provision of the regulations included the justification of practice (JOP); Optimization of protection and safety (OPS); Dose constraint (DS); and Dose limit (DL) for workers, members of public, apprentices and students, and special circumstances.

Part III: Occupational Exposure

The provision of the regulations encompassed the responsibilities of licensee and employer; employment of RPO and qualified expert; classification of working areas and administrative procedures; monitoring of work place, personnel monitoring and records; investigation of over exposure and notification and report accidental and emergency exposure; medical surveillance and responsibilities of worker.

Part V: Public Exposure

The provision of the regulations incorporated the protection of exposure to the public; control of visitor; control of radiation source in respect of public; control and monitoring of radioactive discharge; monitoring of public exposure; and release of radioactive material, nuclear material and prescribed substance.

Part VI: Potential Exposure and Safety of Radiation Sources

The provision of the regulations considered safety procedure for potential exposure; requirements for radiation source; prevention of accident; emergency plan; accountability for radiation source; security and protection of radiation source; and notification of theft, loss or sabotage.

Part VII: Intervention

The provision of the regulations explained the requirements for intervention; intervention in emergency situation; discontinuous protection action after accident; assessment and monitoring after accident; and protection for workers undertaking an intervention.(Agensi Nuklear Malaysia, 2022; Malaysian Nuclear Agency, 2017)

3.4 Responsibilities

In line with the enforcement of the Act 304, the radiation protection program [SHE/R/05] that has been established in Nuclear Malaysia since 1978 went through its first revision to cater the requirement of the regulations as well as requirements of safety according to IAEA safety series No.115, entitled International Basic Safety Standard for protection against ionizing Radiation and for the Safety of Radiation Sources.

The content of the radiation protection program is divided into eight parts including the organization structure; responsibilities; training program for workers; operational limit; maintenance, operation and keeping of records; operational procedures; abnormal operational procedures; and references. The following extracts of the document highlighting the responsibilities of Radiation Protection Officer (RPO), Radiation Protection Supervisor (RPS), Operator (Radiation Worker).

In order to control and regulate all practices involving nuclear and radiation activities compliances with Nuklear Malaysia internal procedure under the radiation protection program, a Safety, Health and Environmental (SHE) committee was established as the highest authority. Reactor Facility subcommittee (JKKR) has been formed with specific term of reference for supervising and improving safety of the RTP operation.

To ensure the safety, security and quality of the PUSPATI TRIGA Reactor operation, utilization and modification activities, an Integrated Management System (IMS) program has been established. The program is set in accordance to the general requirements of the IAEA Safety of Research Reactor [Safety Series No.NS-R-4 (2005)]. The following responsibilities and authorities are extracted from these internal programs.

A. Responsibilities of Radiation Protection Officer (RPO)

RPO is qualified personnel that have attended the Radiation Protection course which include topics on nuclear research reactors such as RTP and passed the Radiation Protection examination conducted by the Atomic Energy Licensing Board (AELB). The responsibilities of RPO are:

a) to prepare and update radiation protection programme whenever required or instructed by AELB.

b) to provide training and information on radiation protection for radiation workers.

c) to identify and analyse radiological hazards in workplace and their surrounding

d) to ensure the maintenance record, import/export and disposal of radioactive materials are kept and updated

e) to ensure the arrangement for medical surveillance of radiation workers.

f) to classify and label working areas in accordance with BSRP 2010.

g) to ensure that radiation protection devices are in good condition and are always being used by workers.

h) to ensure that engagement, termination and retirement of radiation workers follow procedures set by AELB.

B. Responsibilities of Radiation Protection Supervisor (RPS)

RPS enquired the same qualification as the RPO which is to sit the Radiation Protection course and passed the examination conducted by AELB. The responsibilities of RPS are:

a) to take over the tasks and responsibilities of the RPO in his absence and report all matters to him as soon as he returns.

b) to assist the RPO in implementing radiation protection activities in compliance with the Act 304 and subsidiary legislation made there under based on LEM/TEK/45 Sem. 1.

C. Responsibilities of Radiation Worker / Operator

The radiation workers are required to register themselves to AELB database and show up at the medical surveillance appointment arranged by the Health Physics Group. A reactor operator should be registered as a radiation worker with the minimum academic requirement is diploma in engineering discipline. In addition, all the reactor operators should undergo an intensive training in reactor operation, attending formal lectures including the plant walk around session and pass the written and practical examination conducted by AELB to be a licensed reactor operator. The responsibilities of the radiation workers and reactor operators are:

a) Follow all instructions, rules and procedures and refrain from careless practices that could result in unnecessary exposure.

b) Use, as instructed, all facilities, devices and PPE.

c) Use approved personnel monitoring devices.

d) Not interfere with, remove or alter any safety equipment.

e) Take all reasonable precautions to prevent damage to such equipment and immediate report any damage or malfunction of any equipment to his supervisor or RPO.

f) Immediately report all accidental exposures or any suspected exposures to his supervisor or RPO

g) Report pregnancy or suspected pregnancy to approved medical practitioner in the case of female worker

D. Responsibilities of Facility Users

The facility users are required to attend a comprehensive and dedicated safety briefing provided by the Health Physics Group prior to using the experimental facilities. The records of attendance should be informed to the RPS. The users are responsible for utilising the reactor in a safe manner to ensure safety to other users, environment and to the reactor itself (Malaysian Nuclear Agency, 2017).

CHAPTER 4: WORK EXPERIENCE

Since I am at the Bahagian Sokongan Teknikal (BST),under RTP division, so I got the golden opportunity to learn about Semi-Annual Maintenance of the reactor. The maintenance involved are Interlock system, Scramp Test and Drop test. All of this are for safety of the reactor and officers. The concept of interlock system are diversity and redundancy. Diversity mean the different thing but give the same function meanwhile redundancy mean in one thing have many functions that give the same result. For example, there are 3 pumps in primary cooling system but only one operate at a time. It is a redundancy concept. I also learned about Reactor Digital Instrument Control System (ReDICS). This system composed of RPS, OWS and DACS. The function of RPS is to protect and monitor, OWS is for operator work station (monitor) while DACS to control the system. All of them are important in safety system of the reactor. Next is the Scramp test. It is important to make sure the reactor is shutdown when the temperature increase higher than 45°C. Drop test is to determine the time taken for control rod to drop. The ideal time taken is less than 2 seconds.

Figure 4.1 : At Control room was doing SCRAM Test and DROP Test

I

NUKLEAR MALAYSIA

REAKTOR TRIGA PUSPATI

STARTUP CHECKLIST

RTP-F05
Revision: 03-2022 (Apr 2022)

NO.:	154/22	DATE:	1/7/2022	DAY:	THURSDAY	PREPARED BY:	Fahmi Zainal
NOTES:	okay.					CHECKED BY (SRO/RX MANAGER):	

GENERAL (✓ *Operating Conditions/Status*)

1. Console Power (RPS, DACS, OWS) ☐ON ☐OFF
2. CCTV Monitor ☐ON ☐OFF
3. Hand & Foot Monitor ☐ON ☐OFF
4. Survey / Contamination Meter ☐ON ☐OFF

CONTROL ROD POSITION (✓ *Current Reading*)

1. TRANSIENT 0 mm
2. SAFETY 0 mm
3. SHIM 0 mm
4. REGULATING 0 mm

SCRAM TEST (✓ *Operating Limits*)

1. Manual SCRAM (All Rods) ☑ All Rod Down
2. Linear Power RPS Ch. A (SF, SH) **(Limit 110%)** ☐ Rod Down; Lin. Power 110 %
3. Linear Power RPS Ch. B (REG, TR) **(Limit 110%)** ☐ Rod Down; Lin. Power 110 %
4. Short Period RPS A (SF) **(Limit 3sec)** 3 sec
5. Short Period RPS B (REG) **(Limit 3sec)** 3 sec
6. Fuel Temperature RPS A (SF) **(Limit 500°C)** 500 °C
7. Fuel Temperature RPS B (REG) **(Limit 500°C)** 600 °C
8. Water Level RPS A (SF) **(Limit - 30cm)** -30 cm
9. Water Level RPS B (REG) **(Limit - 30cm)** -30 cm

OWS PARAMETER (✓ *Current Reading*)

1. Fuel Temperature (upper) 27.4 °C; (lower) 35.6 °C
2. Bulk Water Temperature 26.3 °C
3. Inlet Water Temperature 27.7 °C
4. Outlet Water Temperature 26.5 °C
5. Reactor Hall Pressure -7.84 mmH₂O
6. TR Control Rod Pressure 550 kPa
7. DACS Status ☑ Normal ☐ Fail

RPS PARAMETER (✓ *Current Reading*)

1. Fuel Temperature RPS A 27 °C
2. Fuel Temperature RPS B 34 °C
3. Water Level RPS A -16.4 cm
4. Water Level RPS B -17.3 cm
5. Lamp Test RPS A ☑ Light ON
6. Lamp Test RPS B ☐ Light ON
7. Linear Power Ch. A 0.00 %; Ch. B 0.00 %; Ch. C 0.00 %

AREA RADIATION MONITOR (ARM) CONTROL ROOM (✓ *Current Reading*)

1. Reactor Top 0.64 µSv/hr
2. Pneumatic Room 0.29 µSv/hr
3. Control Room 0.14 µSv/hr
4. Plant Room 0.43 µSv/hr
5. Basement 3.35 µSv/hr
6. Spent Fuel Pool 0.29 µSv/hr

ACTIVE VENTILATION SYSTEM (✓ *Operating Conditions*)

1. Time **ON**: 9-10 am
2. Rx Hall Exhaust Fan ☑ Unit 1 ☐ Unit 2
3. AHU ☐ Unit 1 ☑ Unit 2
4. Argon Exhaust Fan ☐ Unit 1 ☑ Unit 2
5. Pneumatic Exhaust Fan ☐ Unit 1 ☑ Unit 2
6. Basement & Plant Room ☐ Unit 1 ☑ Unit 2
7. Emergency ☐ON ☑OFF
8. Energy Wheel ☑ON ☐OFF
9. AHU #3 ☑ON ☐OFF

STACK MONITOR (✓ *Operating Conditions*)

1. ☑ Background 3. ☑ Iodine
2. ☑ Particulate 4. ☑ Noble Gaseous

ELECTRICAL POWER SUPPLY (✓ *Operating Conditions*)

1. ☑ Normal
2. ☑ UPS
3. ☑ Essential

SEISMIC MONITOR (✓ *Operating Conditions*)

☑ ON ☐ OFF

CONTROL ROOM (✓ *Current Conditions*)

☑ In Order

Comment: ok

II

REACTOR TOP (✓ *Current Reading/Operations*)

1. Reactor Water Level (min 7.5 inch; max 6.0 inch) 6.9 inch
2. Transient Rod Air Pressure (nominal: 75 psi) ~~[illegible]~~ 80 psi
3. Rx Top ARM (Ch-A) 0.522 µSv/hr
4. Fuel location Notice Board ☑ In Order
5. Rotary Rack Motor ☐ ON ☑ OFF
6. Continuous Air Monitor (CAM) ☐ ON ☑ OFF
7. RR/Dry Tube Sniffer ☑ Checked
8. Surrounding Area ☑ Normal

PRIMARY COOLING SYSTEM (✓ *Operating Conditions*) 1

1. Main Switch ☑ON ☐ OFF
2. Operating Mode ☑ Remote ☐ Local
3. Primary Manual Valves:

PV3:	☑Open	☐Close	PV4	☑Open	☐Close
PV3A:	☑Open	☐Close	PV6	☑Open	☐Close
PV3B:	☑Open	☐Close	PV6A	☑Open	☐Close
PV3C:	☑Open	☐Close	PV6B	☑Open	☐Close

4. Pumps & Motorized Valves: 5. Heat Exchanger Valves:

PP#1:	☑ON	☐OFF	PV5A	☑Open	☑Close
PV4A:	☑Open	☐Close	PV5B	☑ Open	☒Close
PP#2:	☐ON	☑OFF			
PV4B:	☐Open	☑Close			
PP#3:	☐ON	☑OFF			
PV4C:	☐Open	☑Close			

6. Flow Rate 780 m³/hr
7. pH Reading (min 6.5; max 7.0) 5.57

FIRE FIGHTING SYSTEM (✓ *Operating Conditions*) 6

Valves Inspection:

1. After Tank ☑ Open ☐ Close
2. Before Pump 1 ☑ Open ☐ Close
3. Before Pump 2 ☑ Open ☐ Close
4. After Pump #1 ☑ Open ☐ Close
5. After Pump #2 ☑ Open ☐ Close
6. Pressure 65 lb/in²
7. Tank Level Indicator ☑ Normal
8. Surrounding Area ☑ Normal

BEAMPORT (✓ *Current Conditions*) tanpa tanggungan close

1. Beamport #1 : BP Shutter ☐Open ☑Close; ARM Reading 0.34 µSv/hr
2. Beamport #2 : BP Shutter ☐Open ☑Close; ARM Reading 0.76 µSv/hr
3. Beamport #3 : BP Shutter ☐Open ☑Close; ARM Reading 0.73 µSv/hr
4. Beamport #4 : BP Shutter ☐Open ☑Close; ARM Reading 0.47 µSv/hr

8

SECONDARY COOLING SYSTEM (✓ *Operating Conditions*) 2

1. Secondary Valves: SV1A: ☑ Open ☐ Close SV1B: ☑ Open ☐ Close
2. Heat Exchanger Valves: SV6A: ☐ Open ☑ Close SV6B: ☑ Open ☐ Close
3. Main Switch ☑ ON ☐ OFF
4. Cooling Tower Switch ☐ Auto ☐ 0 ☐ Man
5. Cooling Tower #1 ☑ Start ☐ Stop

*Make sure Motorized Valve Cooling Tower #1 is 'OPEN'!

6. Motorized Valve #1 ☑ Open ☒ Close
7. Motorized Valve #2 ☑ Open ☐ Close

*Make sure Motorized Valve #1 & #2 are 'OPEN'!

8. Secondary Pump #1 ☐ ON ☑ OFF
9. Secondary Pump #2 ☑ ON ☐ OFF
10. Volt & Current Meter A: 10 V: 415

*DO NOT 'ON' 2 pumps simultaneously!

11. Essential Power CT #2 ☑ ON ☑ OFF

*Make sure Motorized Valve Cooling Tower #2 is 'OPEN'!

12. Cooling Tower #2 ☐ Start ☑ Stop
13. Motorized Valve #3 ☐ Open ☑ Close

*Make sure Motorized Valve #3 is 'OPEN'!

14. Secondary Pump #3 ☐ ON ☑ OFF
15. Volt & Current A: 0 V: 415

REACTOR HALL (✓ *Current Conditions*) 7

1. Crane Location ☑ Northwest
2. Argon Piping ☑ Open ☐ Close
3. Rx Hall Surrounding ☑ In Order

PNEUMATIC ROOM (✓ *Current Conditions*) 7

1. Fume Cupboard Flow Rate 220 ft/min

* Make sure Pneumatic Exhaust Fan is 'ON'.

2. Pneumatic Transfer System Piping ☑ Checked

COMPRESSED AIR SYSTEM (✓ *Operating Conditions*) 4

1. Main Switch ☐ ON ☐ OFF; ☐ Unit #1 ☑ Unit #2
2. Valve CV 3 ☐ Close ☑ Open
3. Valve CV 5 ☐ Open ☑ Close
4. Valve CV 8 ☐ Close ☑ Open
5. Compressor ☒ON ☐ OFF ☑ON ☐ OFF
6. Air Dryer ☐ ON ☐ OFF ☑ON ☐ OFF
7. Air Storage Tank 110 psi
8. Operating Hour 2242 Hrs
9. Volt & Current Meter A: 28 V: 220

11

WATER PURIFICATION SYSTEM (✓ *Operating Conditions*) 3

1. Demineralizer Valves:

DV1:	☑Open	☐Close			
DV2A	☑Open	☒Close	DV3A:	☑Open	☐Close
DV2B:	☑Open	☐Close	DV3B:	☑Open	☐Close

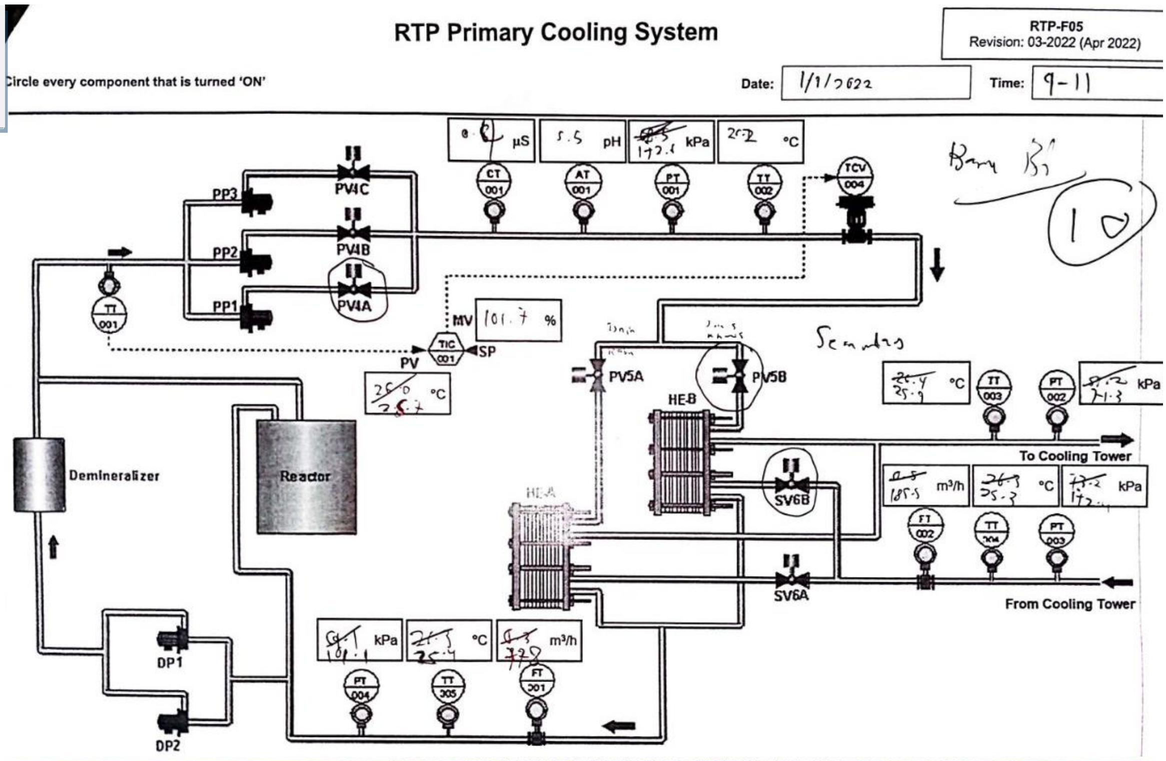
2. Demineralizer Pump ☐ #DP1 ☐ #DP2
3. Inlet Water Pressure 18 psi
4. Outlet Water Pressure 15 psi
5. Pressure Difference 3 psi
6. Inlet Water Conductivity 0.418 µS/cm
7. Outlet Water Conductivity (< 2µS) 0.155 µS/cm
8. Flow Rate (10 gpm) 10 gpm

BASEMENT (✓ *Current Conditions*) 5

1. Reactor Water Level Before 61 inch; After – inch

☐ In Order Comment: Ok

III



IV

PARAMETERS			
TIME: 11.14	REACTOR POWER AT: 750 kw		
LINEAR: 75	% OF 1 MW	LOG	
CONTROL ROD POSITION		WATER TEMPERATURE (°C)	
TRANSIENT	320	BULK	27.3
SAFETY	317	INLET	25.8
SHIM	317	OUTLET	31.1
REGULATING	318		
PERCENT POWER (%)		FUEL TEMPERATURE (°C)	
RPS A	74.4	CHANNEL 1	370
RPS B	75.0	CHANNEL 2	305
STACK MONITOR (Bq / m³)		ARM (µSv / hr)	
PARTICULATE	11.1 Bq/m3	REACTOR TOP	3331
GASEOUS	203540 Bq/m³	BASEMENT	7.08
COOLING TOWER (°C) - S		HEAT EXCHANGER (°C) - P	
TEMP. IN	25.4	TEMP. IN	70.3
TEMP. OUT	27.4	TEMP. OUT	26.3

Figure 4.2 (I) (II) (III) (IV) : Data Recorded of Startup Checklist for RTP reactor

Figure 4.3 : At the basement,was checking the valves for Primary cooling system

During this time , we (me at the most front from the reader’s point of view) were on the route of the startup checklist of the RTP reactor where we at last station which is at RTP Top. We were taking readings mentioned in Figure 4.4. We could see also the Cherenkov effect soon after the operation has begun. The Cherenkov effect occurs when a particle carrying an electric charge travels through a transparent medium like water or air. If the particle travels faster than light in this medium, its passage causes a brief flash of light, a Cherenkov light.(Radioactivity.eu, 2022)

Figure 4.3 : (I) At reactor top,was taking the reading of the reactor water level and transient rod air pressure , (II) Cherenkov effect photo taken from the reactor top.

Study tour to “Makmal Radiokimia dan Alam Sekitar”(RAS) Or Radiochemical and Environmental Laboratory ,Me and my colleagues ,Hanif, Aslam and Adam were briefed and taught by Mrs. Noradilah, about the gross alpha beta. Then, about the wipe test procedure , for example,every mineral water company must send their sample of water here at Nuclear Malaysia Agency as subjected by Ministry of Health (MOH) for safety and license.

Figure 4.4 : (I) Wipe Test’s samples at Radiochemical and Environmental Laboratory (II) The Series 5 LB5500 low background Alpha-Beta Counter

Here I have learned that Malaysian Nuclear Agency has the facility and started the projects on processing various products using gamma irradiation since January 1989.I learned that the facility is not just designed for Research and Development (R&D) purpose but also serves to the public and private enterprises for such services : namely

I. Sterilisation of medical products and packaging materials
II. Decontamination of food ,pharmaceuticals,herbs, and animal feeds
III. Disinfestation of insects in agricultural commodities ,including for quarantine purpose
IV. Samples of R&D purposes.

I learned from Mr. Cosmos, the gamma reactor operator, that for the medical stuff, usually the irradiation dose is more than 25kGy while for the food is below than 10kGy,1 lap of irradiation path inside the radiation room only eliminate 3kGy to the target material, therefore if we have to calculate on much ionizing radiation in (Gy) that we want to exert to the materials and period of time and laps of irradiation. The operation happens 24/7 so ,there must be certified operator , at a time , and some of them are even the radiation worker at the other block but offers to work part-time and over-time herein. Those who are in the RTP block as the RTP operator were really recommended to be working here , and their skills and experience were been channeled here for the sake of the peak performance of this gamma reactor.

Figure 4.5 (I) (II) (III) (IV) : A study visit to SinaGama,Malaysian Nuclear Agency ,Dengkil.

Then , as mentioned in the work culture herein, the staffs, Drs., radiation workers and all including me myself were trained to apply the knowledge of "S.T.D", shielding, time and distance which are as follows:

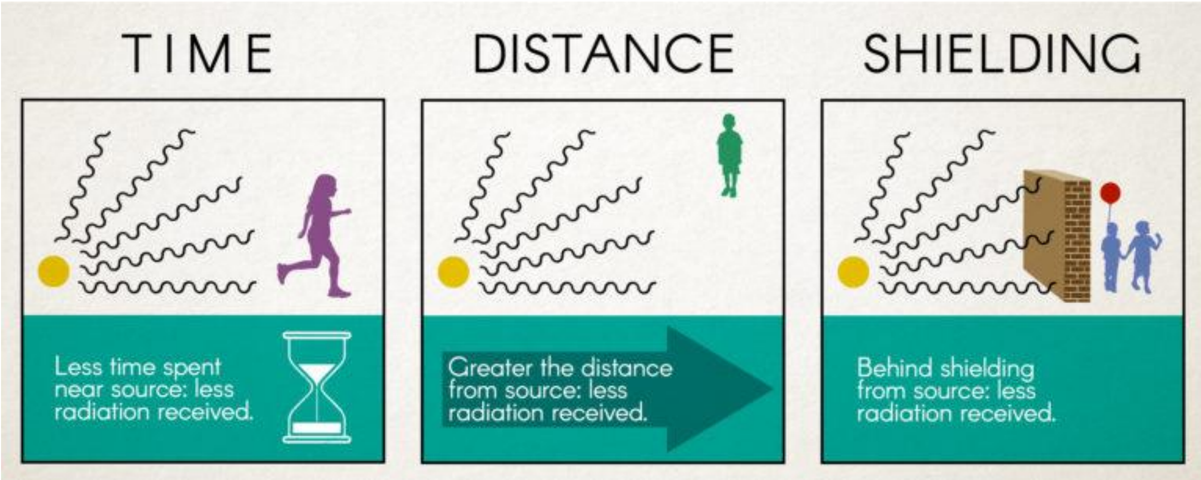


Figure 4.6 : Radiation safety precaution (Radiation Precaution, 2022)

Figure 4.7 : (I) Precautionary steps including wear gloves ,(II) wash hands after handling samples,(III) dry hands with tissue ,(IV) wear lab coat ,(V) wear dosimeter, (VI) use body radiation monitor after going out from RTP Hall, (VII) handle radioactive samples undersupervision of Radiation Protection Officer (RPO).

NUKLEAR MALAYSIA

Rekod Bacaan Dos

Nama MUHAMMAD FAHMI BIN MOHD ZAINAL

No KPT

Agensi/Institusi UNIVERSITI MALAYA ,KUALA LUMPUR

No Dosimeter RX 06

Tujuan LATIHAN INDUSTRI

Tarikh	Masa Awal	Bacaan Awal (A) (µSv)	Masa Akhir	Bacaan Akhir (B) (µSv)	Bacaan Kadar Dos (B – A)(µSv)
28/7/22	8.50 a.m	0	4.30 p.m	2	2
8/8/22	8.30 a.m	0	4.30 p.m	2	2
9/8/22	11.00 a.m	0	5.00 p.m	1	1
10/8/22	10.00 a.m	0	4.30 p.m	2	2
11/8/22	8.30 a.m	0	4.30 p.m	2	2
12/8/22	8.00 a.m	0	5.00 p.m	0	0
15/8/22	8.00 a.m	0	5.00 p.m	0	0
16/8/22	8.20 a.m	0	5.00 p.m	1	1
17/8/22	7:30 a.m	0	5.00 p.m	2	2
18/8/22	8.00 a.m	0	5.00 p.m	1	1
22/8/22	8.00 a.m	0	5.00 p.m	1	1
23/8/22	2.00 p.m	0	5.30 p.m	1	1
24/8/22	8.30 a.m	0	5.30 p.m	1	1

Figure 4.8 : The dose reading everytime before and after I been in the laboratory for certain period of time were recorded as above. (See Appendix Figure 12)

Other valuable experience and evidence of works were shown in the appendix part.

CHAPTER 5: NEUTRON FLUX PROFILING AT THE END-OF-CYCLE (EOC) RTP CORE CONFIGURATION

5.1 Introduction

Reactor TRIGA PUSPATI (RTP) has been operated to generate neutrons for various applications in nuclear study and research development. The first operational core started in 1982(namelyCore-01) in which it contains 86 fresh fuels and was successfully operated for years with the maximum power of 1MWth. The reactivity at that time around $7.00 and due to fuel burnup ,it has resulted into the depletion in core reactivity. Ever since then, the core configuration has been reshuffled for 15 times to maintain its safe operation and optimum condition to fulfil the neutron research demand in education and nuclear industry. Nuclear Malaysia Agency has introduced the fuel management strategy in order to encounter this problem and one of the strategy is to study the neutron flux profiling so that we can optimize the neutron flux distribution inside the core. To study the neutron flux measurement, I introduced three ways here in which by Dry Tube (DT) ,Pneumatic Transfer System (PTS) and Rotary Rack (RR). All these has different location inside the reactor and the closest to the core is Dry Tube (DT), followed by PTS and RR. The thermal and epithermal flux density is calculated by using the cadmium ratio with the aid of activation wire and radiation detection. With regards to this ,radiation detection using High-pure Germanium (HpGe) is used to find the net peak area inside the gamma spectroscopy depicted by the GammaVision Software. The net peak area produced by the samples namely Aurum is found by using activation energy of a stable isotope which has the activation energy of 411keV.Then,further analysis is taken into account where special activity, thermal and epithermal flux density is then calculated (Malaysian Nuclear Agency, 2017).

5.2 Objectives

The purpose of this project is to develop a comprehensive database of neutron flux.

1. To determine efficiency calibration curve for High-pure Germanium (HpGe) detector at Au-198 gamma energy photo peak and specific activity of activated samples prior to neutron flux measurement.
2. To determine the thermal and epithermal flux density in the reactor core using activated Aurum-Bare (Au-Bare) and Aurum-Cadmium (Au-Cd) wire samples.

3. To determine the neutron flux at the different position of the sample inside TRIGA tube.

5.3 Literature Review

5.3.1 Reactor TRIGA PUSPATI (RTP)

TRIGA PUSPATI Reactor known as RTP is the one and only nuclear research reactor in Malaysia by far. The reactor started its operation in 1982 and achieves its first criticality on 28 June 1982. TRIGA stands for Training, Research, Isotope Production and General Atomic. Its tiny core allows for a low critical mass and larger neutron fluxes while guaranteeing a high degree of safety.(Malaysian Nuclear Agency, 2017)

RTP is a pool type reactor, where the reactor core resides at the bottom of a 7-metre high aluminium tank surrounded by a biological shield composed of high density concrete. The reactor employs solid fuel components in which the zirconium-hydride moderator is homogeneously mixed with enriched uranium with 1MW thermal output. Demineralized water functions both as cooling and neutron moderator, while graphite acts as a reflector.

The reactor was developed to effectively implement the numerous domains of fundamental nuclear research and education. It incorporates facilities for advanced neutron and gamma radiation studies as well as for application, including Neutron Activation Analysis (NAA), Delayed Neutron Activation Analysis (DNA), radioisotope production for medical, industrial and agricultural purposes, Neutron Radiography and Small Angle Neutron Scattering (SANS) (SANS) (Malaysian Nuclear Agency, 2017).

5.3.2 In-core and out-core irradiation facilities

RTP has several irradiation facilities that are extensive and versatile. Irradiation tubes can easily be installed in the core region to provide additional facilities for high-level irradiation or in-core experiments. The in-core facilities in the present 15th core configuration consist of 5 in-core irradiation facilities includes of central thimble (CT), dry tube (DT), pneumatic transfer system (PTS), delayed neutron activation (DNA-Bare) and delayed neutron activation-cadmium (DNA-Cd) as shown in Figure 5.1. The out core consist of the rotary rack(RR) .3 facilities that were used herein were the DT,PTS and RR. (Malaysian Nuclear Agency, 2017)

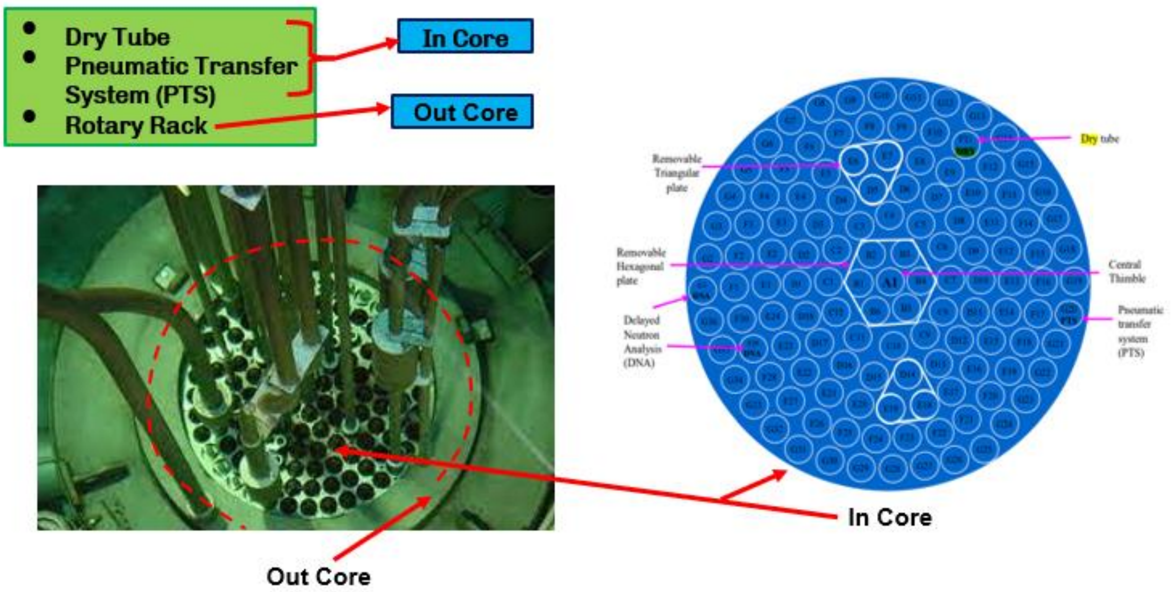


Figure 5.1 : RTP 15th core configuration and position of irradiation facility (Malaysian Nuclear Agency, 2017)

5.3.2.1 Dry Tube (DT)

As illustrated in Figure 5.1, DT is situated in position F-11 on the second layer outer ring of the core. This radiation facility consists of a vertical irradiation tube that is positioned in a rack outside the reflector (Koehl et al., 2015)

5.3.2.2 Pneumatic Transfer System (PTS)

PTS, also known as “rabbit system” has been used for neutron activation analysis especially for of short-lived radioisotope samples. PTS is located in outer ring of reactor core, in position G-20 as shown in Figure 5.1.This pneumatic system can rapidly move samples from pneumatic room to reactor core or vice versa in manual or automatic modes.(Malaysian Nuclear Agency, 2017)

5.3.2.3 Rotary Rack (RR)

RR also known as Lazy Suzan is assembled in annular well on the inside diameter of the graphite reflector as shown in Figure 5.1. The rotary specimen rack assembly consists of a ring-shape, seal-welded aluminium housing containing an aluminium rack mounted on special bearings. The rack supports 40 evenly spaced tubular aluminium containers that serve as receptacle for specimen containers. All receptacles can hold two specimen containers except receptacles number 1. Each irradiation positions are exposed to neutron fluxes of homogeneous intensity because of the rotary motion (Malaysian Nuclear Agency, 2017; Yavar et al., 2012).

5.3.3 Neutron flux

Neutron flux is defined as total path length covered by all neutrons in one cubic centimetre during one second (IAEA, 2022) .Mathematically, this is the equation 5.1 below:

$$\phi = nV \qquad (5.1)$$

where ϕt is the neutron flux ($n.cm^{-2}.s^{-2}$), n is the neutron density ($n.cm^{-3}$) and V is the neutron velocity ($cm.s^{-1}$). Neutron flux distribution in the reactor core relies on the fuel location and neutron energy. The neutron fluxes in research reactors normally vary from magnitude of 10^{11} to 10^{13} $n.cm^{-2}.s^{-1}$. Neutron flux may be utilised to identify the reactor states as its feeds the information to the reactor safety system and reactor power regulating (Mohd Ali et al., 2018, 2022; Munita et al., 2019).

5.3.3.1 Neutron activation analysis (NAA)

NAA is an analytical method based on the concept of neutron capture. It is a method that employs a source of neutrons to activate a given sample through neutron induced reactions and to analyse the radioactive decay gamma-rays released from the sample to identify its composition. Figure 5.2 illustrates the depiction of the process of neutron capture by a target nucleus.

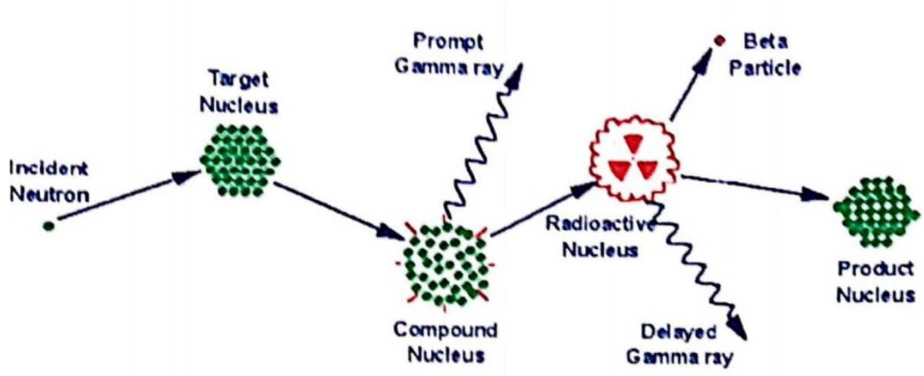


Figure 5.2 : Illustration of the process of neutron capture by a target (Malaysian Nuclear Agency, 2017)

A neutron and nucleus fused when the neutron collided with a stable element. When a free neutron collides with a target nucleus, the nucleus captures the neutron thus generating an excited state. The target nucleus quickly produces prompt gamma rays in order to return to the ground state. The nucleus remained unstable and continuing to release gamma rays and other kinds of ionising radiation via radioactive decay. Most of the time, another decay process will follow in order to become a more stable element. Neutron Activation Analysis (NAA) will characterise gamma energy created throughout the process in order to identify the elements that undergo the process. (Malaysian Nuclear Agency, 2017)

5.3.3.2 Neutron flux spectrum in nuclear reactor

The neutron flux in a nuclear reactor can be separated into three distinct regions based on its kinetic energy values. A typical spectrum illustrating the distribution of energies of neutrons in a reactor that consist of three main components which is fast, thermal and epithermal neutrons as shown in Figure 5.3 below.

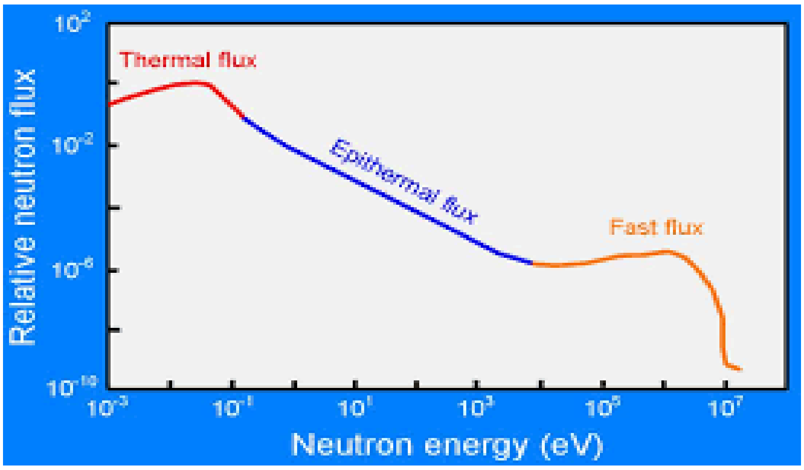


Figure 5.3 : A typical energy spectrum from a nuclear fission reactor (Nuclear-Power, 2022)

In the high energy region, neutrons still have their most of their original energy from fission which is fast neutrons energy. Fast neutrons produced in a rector are characterized by an energy distribution. Besides, the epithermal neutrons have been partially slowed down within the moderator and develop a distribution proportional to the inverse of neutrons in epithermal region approximates a 1/E slope. Meanwhile, the thermal neutrons approximately have the same velocity distribution as molecules and atoms of their surroundings. (Koehl et al., 2015; Nuclear-Power, 2022)

5.3.3.3 Neutron flux measurement using activation wire

Activation wire is one of the most extensively used detectors to measure neutron flux. Aurum is among the most often utilised materials as it has high thermal cross section of neutron capture,98.65 barn(1 barn=1.0 x10-24c$m^2$2) for nuclear reaction of 197Au (n,γ) 198Au (Steinhauser et al., 2012). Aurum has a short half-life property, typically around 2.7 days. Cadmium may be utilised to attenuate thermal neutrons, so activation wire sample covered with cadmium will only be activated by epithermal neutrons (Shalbi et al., 2018). By cadmium absorption, the thermal neutron is removed during the reactor activation (Aboudzadeh et al., 2015).

5.3.4 Radiation detection

Gamma spectrometry is one of the most extensively utilised detector technologies. The objective of gamma-ray spectroscopy in NAA is for detecting the energies and intensities of the photon released by the radionuclides. In this work, High-pure Germanium (HpGe) [Ortec GEM-10185] detector with gamma vision software as illustrated in Figure 5.4 was used to investigate the reaction rates of neutrons. HpGe detector can qualitatively identify radionuclides and quantitatively compute specific activities of radioactive material (Giuseppe et al., 2015; Naim Syauqi et al., 2019).

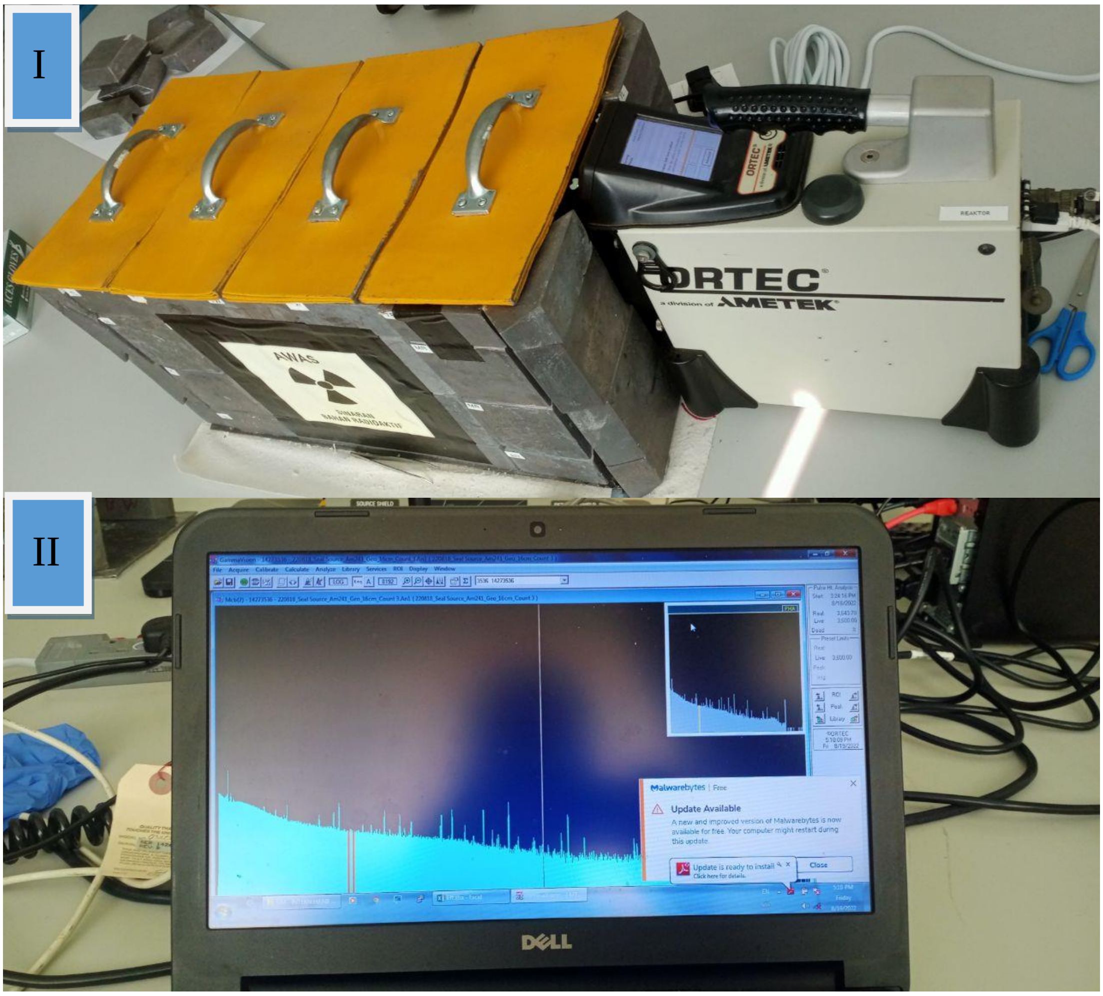


Figure 5.4 : (I) High-pure Germanium (HpGe) gamma detector at the Nuclear Physics Laboratory at Block 18, Reactor TRIGA PUSPATI Block , (II) Gamma Vision Software

5.3.4.1 HpGe detection principle

HpGe is one of the top radiation detection technologies which delivers outstanding and reasonably high efficiency in studying the gamma-ray spectroscopy of radioactive isotopes. A typical analogue HpGe detector-based gamma spectroscopy system comprises of HpGe detector, high voltage power supply, preamplifier, amplifier, analogue to digital converter (ADC),and multi-channel analyzer (MCA) . A gamma ray is released from the samples and enter the detector, where it passes through a series of interaction that finally results in the ionisation of the germanium atoms in the detector crystal (Alnour et al., 2015).

5.3.4.1 Detector efficiency

In accordance to (Hossain et al., 2012) ,detector efficiency is a measure of the percentage of radiation that given detector defects from the total yield that is released from the source into a solid angle of generally 4π in photo-peak. It's one of the most significant property of the detector in any radiation measurement. A comprehensive understanding of the detector spectrum performance is necessary in any radiation measurement The detector efficiency is reliant on the geometries of the source-detector, the detector and the gamma energy (Alnour et al., 2015). It may vary with the volume of the detector, shape of the detector, absorption cross-section of the material and attenuation layers in front of the detector (Akkurt et al., 2014) .

5.4 Methodology

5.4.1 Sample collection

The samples were collected as follows (see Figure 5.5); there were 32 samples :

4 set of samples

- Au :8 samples
- Au + Cd :8 samples
- Ni :8 samples
- Ni + Cd :8 samples

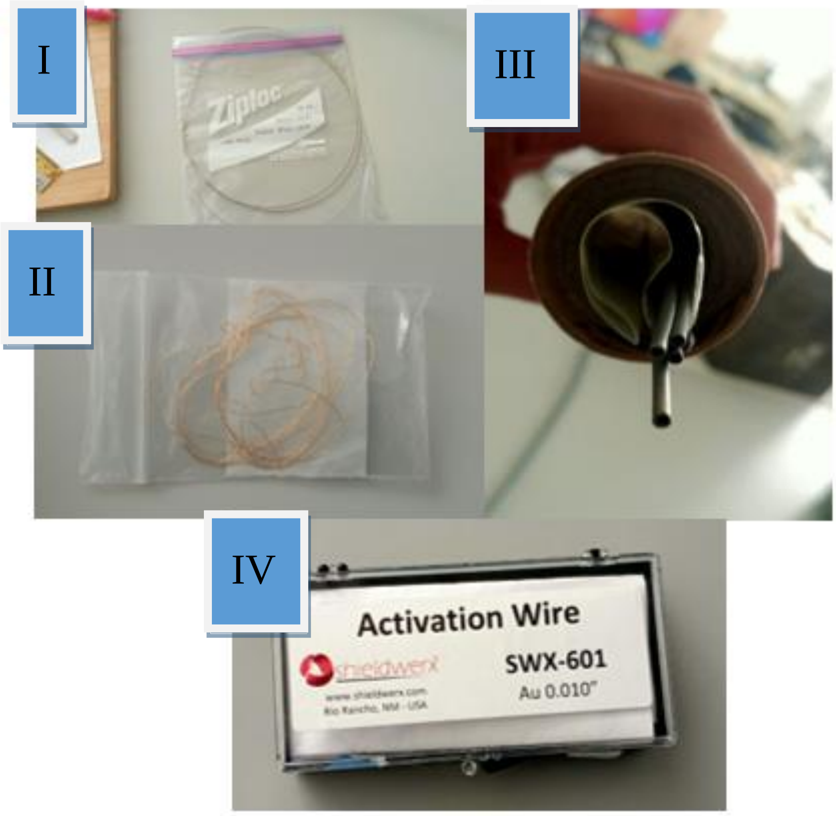


Figure 5.5 : (I) Nickel wire, (II) Gold wire, (III) ,Cadmium cover , (IV) The case of the Shieldwerx Activation gold wire.

5.4.2 Sample preparation

4 set of samples were prepared in form Aurum-Bare (Au-Bare) and Aurum covered with Cadmium tube (Au-Cd) ,Nickel-Bare (Ni-Bare) and Nickel covered with Cadmium tube (Ni-Cd) .Gold wires and Nickel wires been cut by 2mm length respectively. Cadmium wire cover been cut by 4mm.The mass of cut samples were measured using electronic weighing scale but before that ,the scale were calibrated before use by using a subject of known mass and the water leveler is ensured to be balanced before any reading is taken. Gold wires and Nickel wires were inserted inside the cadmium cover .The cadmium cover holes at each end were sealed by pliers. Each sets of wires been inserted inside a vials. The vials were closed with its lid. The lids were soldered so that its contents were not going out and get stuck inside the reactor when been irradiated and it is the safety procedure to abide with (see Figure 5.6). Then ,the vials that contained the sample are stacked inside the TRIGA tube (see Figure 5.7) , and were labelled and numbered from most bottom to highest top by 1,2,3 accordingly. DT and RR had 3 samples each and PTS had 2 samples each TRIGA TUBE. DT and RR had DT1,DT2,DT3,and DT4 same with RR;RR1,RR2,RR3 and RR4 .PTS had 2 samples in each TRIGA Tube also been stacked from most bottom to highest top by 1 and 2 accordingly and PTS had PTS1,PTS2,PTS3 and PTS4.The label number is as follows (see Table 5.1,5.2 and 5.3) ;

Example : DT1 , 1 refers to the set of sample 1

4 set of samples

- Au : Sample 1
- Au + Cd : Sample 2
- Ni :Sample 3
- Ni + Cd : Sample 4

Then , DT1(1) , (1) refers to the position of the samples inside the TRIGA Tube.

3 set of positions for DT and RR ,2 set of position for PTS.

Figure 5.6 : (I) 4 Samples in TRIGA TUBE ,(II) Labeled Vials containing sample been arranged before been soldered, (III) Electronic weighing scale , (IV) Empty Vial , (V) Labeled and Soldered vial , (VI) Lid of a vial been soldered , (VII) Process of calibrating the electronic weighing scale by using a load of a known mass (150g)

Table 5.1 : Labeling of sample irradiated at PTS(Pneumatic Transfer System)

Sample	Position	Label
Au-Bare	1	PTS1(1)

Au-Bare	2	PTS1(2)
Au-Cd	1	PTS2(1)
Au-Cd	2	PTS2(2)

Table 5.2 : Labeling of sample irradiated at RR(Rotary Rack)

Sample	**Position**	**Label**
Au-Bare	1	RR1(1)
Au-Bare	2	RR1(2)
Au-Bare	3	RR1(3)
Au-Cd	1	RR2(1)
Au-Cd	2	RR2(2)
Au-Cd	3	RR2(3)

Table 5.3 : Labeling of sample irradiated at DT(Dry Tube)

Sample	**Position**	**Label**
Au-Bare	1	DT1(1)
Au-Bare	2	DT1(2)
Au-Bare	3	DT1(3)
Au-Cd	1	DT2(1)
Au-Cd	2	DT2(2)

Au-Cd	3	DT2(3)

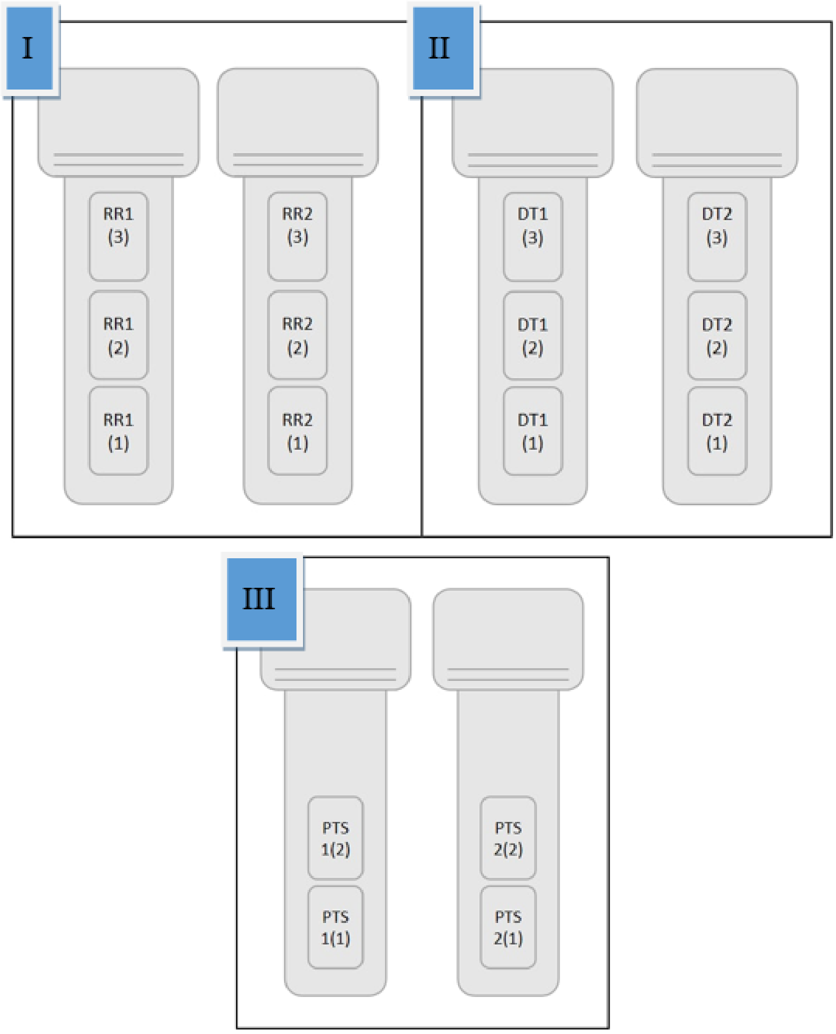


Figure 5.7 (I)(II)(III) : The arrangement of the sample inside the plastic vials inside the TRIGA tubes for Rotary Rack (RR), Dry Tube (DT), Pneumatic Transfer System (PTS) respectively.

Table 5.4 : Mass of the sample measured

Sample	**Mass (g)**
PTS1(1)	0.0042
PTS1(2)	0.0042
PTS2(1)	0.0033

PTS2(2)	0.0037
RR1(1)	0.0037
RR1(2)	0.0037
RR1(3)	0.0039
RR2(1)	0.0033
RR2(2)	0.0032
RR2(3)	0.0034
DT1(1)	0.005
DT1(2)	0.0042
DT1(3)	0.0043
DT2(1)	0.0038
DT2(2)	0.0033
DT2(3)	0.0046

5.4.3 Sample Irradiation

Before proceed for irradiation process, it is a must for those who want to irradiate to book for irradiation slot through website https://urtp.nuclearmalaysia.gov.my/login.php

The irradiation methods that were used are Pneumatic Transfer System(PTS) (refer Figure 5.7) , Rotary Rack (RR) , Dry Tube (DT) .PTS was conducted by me with the supervision of Radiation Protection Officer ,RPO ,Mr. Naim. Dosimeter , lab coat ,gloves was worn by me along the process for safety and protection. The irradiation process were planned well and the knowledge to execute the irradiation process been applied superbly, which are the time with irradiated sample, distance myself from it, and use appropriate shielding.

The samples were then irradiated according to the schedule provided and discussed. The irradiation time (refer Table 5.5) ,power used, were all recorded. All the samples were irradiated at power level of 750 kW for certain minutes ;RR and DT for 30 minutes while PTS for 2 minutes ,based on suitability of irradiation time and samples handling process.

Figure 5.7 (I) (II) : PTS Station

Table 5.5 : Time taken to irradiate the sample based on the reactor facility

Reactor facility	Time of Irradiation(Minutes)
DT	30
RR	30
PTS	2

5.4.4 Storing

After the samples been irradiated, the samples were then being stored for certain period of time according to the half-life of the samples. , the irradiated samples were left inside the reactor in the lead rack for approximately 3 days since the half life the Au-198 is around 2.7 days. Furthermore, the dose exposure rate was allowed to decrease until it reaches an acceptable level to be handled by reactor operator. The ionising radiation of samples were measured by using survey meter before storing. Geiger Muller survey meter were used to monitor the radiation level and the dose exposure rate was later recorded in the sample's irradiation form. All samples were kept inside a thick lead shielding storage until it reached optimum condition of analytical counting process (see Figure 5.8) . The safety precaution being introduced and applied here ,in which ,another extra care being taken where long stick with hands were used to hold the irradiated samples of Aurum where it is known to emit high amount of ionising radiation which when monitoring ,the reading is usually >300µS when using the DT and RR. When using PTS , the ionising radiation was >150µS which is considered high also and can damage the HpGe detector.

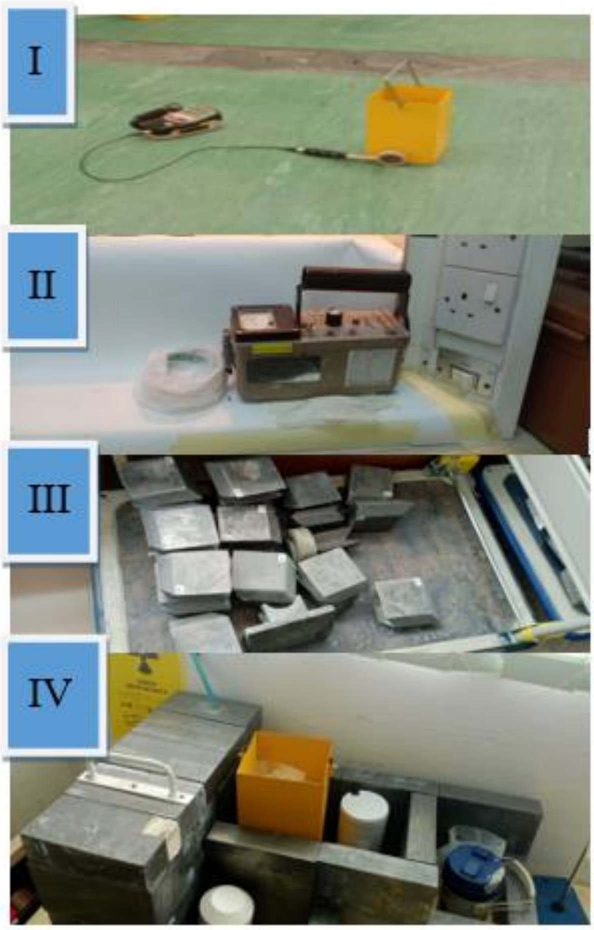


Figure 5.8 : (I) Geiger Muller survey meter (II) Survey meter (III) Lead blocks (IV) Lead storage

5.4.5 Counting

Then,for the counting process,it was carried using HpGe gamma spectrometry detector as shown in Figure 5.9. A 5 cm thick lead shield was used to reduce the effects of surrounding background radiation.

Figure 5.9 : ORTEC HpGe Detector with lead shielding

To obtain accurate results, it is essential to determine the efficiency of the detector prior to the analysis of the samples. The efficiency of detector was determined at geometry 20 cm (see Figure 5.11) by using Americium-241 (Am-241), Europium-152 (Eu-152) Barium-133 (Ba-133), Caesium-137 (Cs-137) as shown in Figure 5.10.

Figure 5.10 : Source of Americium-241 (Am-241), Europium-152 (Eu-152) Barium-133 (Ba-133), Caesium-137 (Cs-137) [see from left to right]

The counting time was set at 1 hour to obtain minimum photo-peak fitting errors. Once the detector efficiency is determined, Au-bare and Au-Cd samples were fixed horizontally facing the center of the detector as shown in Figure . The counting process was conducted for 15 minutes (900s) while the detector dead time was kept below 20%.

Figure 5.11 : Samples were fixed horizontally facing the center of the detector

5.5 Result and Discussion

5.5.1 Detector Efficiency

In this study, the efficiency of the detector was determined by using Americium- 241 (Am-241), Barium-133 (Ba-133), Caesium-137 (Cs-137) and Europium-152 (Eu-152) where Am-241 emit gamma at energy 59.67 keV, Ba-133 emit gamma ray at energy 81.02 keV, 303.19 keV and 356.36 keV, Cs-137 emit gamma ray at energy 661.66 keV and Eu- 152 emit gamma at energy 121.84 keV, 344.62 keV, 411.49 keV, 779.48 keV and 964.6 keV at 20 cm distance from detector. The detector efficiency was calculated using Equation 5.3 below:

$$Efficiency, \varepsilon = \frac{Net\ Area}{(Live\ Time)(Activity)(Yield)} \qquad (5.3)$$

The result of the efficiency calibration is shown in Table 5.6 below. From these results, the efficiency calibration curve was plotted as in Figure 5.12.

Table 5.6 : Efficiency calibration

Nuclides	**Energy (keV)**	**Efficiency, ε**
Am	59.67	1.99501E-03
Ba	81.02	3.25075E-03
Eu	121.84	3.99647E-03
Ba	303.19	2.65195E-03
Eu	344.62	2.36278E-03
Ba	356.36	2.32665E-03
Eu	411.49	2.05150E-03
Cs	661.66	1.34809E-03
Eu	779.48	1.20241E-03
Eu	964.6	1.01283E-03

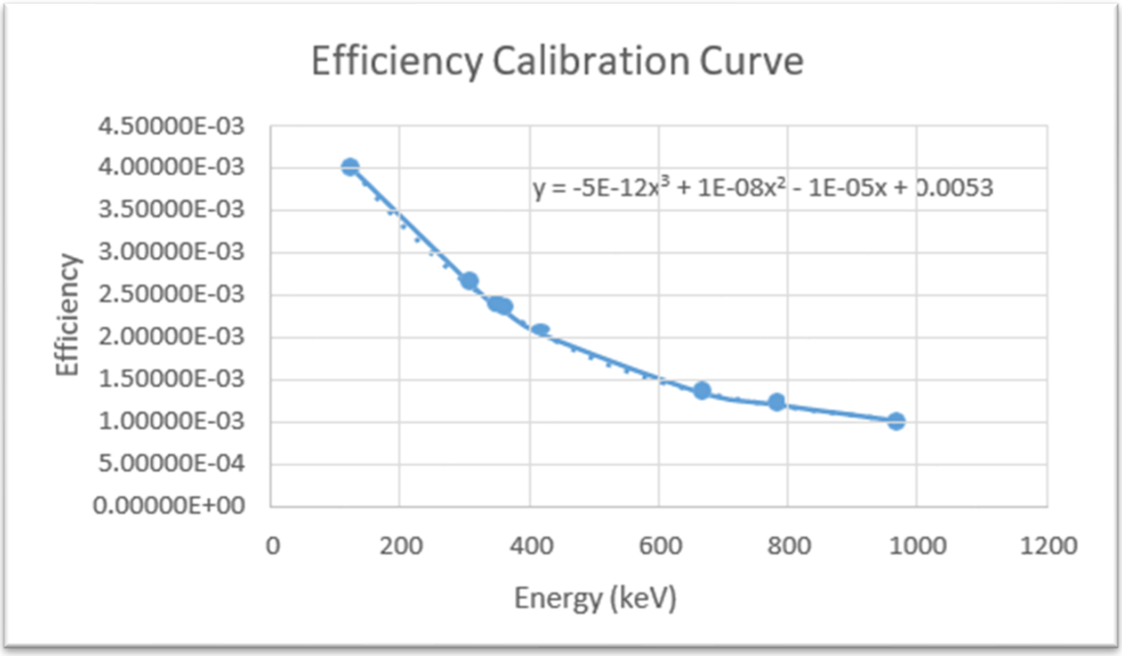


Figure 5.12 : Efficiency Calibration Curve

Using the equation obtain by the graph, for Aurum-198 with gamma energy 412 keV, the efficiency of detector, ε is 0.002528.

5.5.2 Specific Activity

After that, we need to calculate the specific activity in order to get neutron flux values. The activity of samples for irradiation process can be determined by using following equation 5.4:

$$Au_B, Au_{B+Cd} = \frac{\frac{net\,peak\,area}{mass} x\,\lambda}{\varepsilon\gamma\,(exp^{-\lambda t_{decay}})(1 - exp^{-\lambda t_{meas}})} \qquad (5.4)$$

where

λ is the decay constant of the nuclide,
ε is the efficiency of the detector
γ is the intensity of Au
t_{decay} is the time decay during cooling
$t_{measure}$ is the time decay during irradiation

Table 5.7, 5.8 and 5.9 below show the specific activity obtained for every sample.

Table 5.7 : Specific activity for sample irradiated by PTS

Sample	No. of counts	Mass (g)	Geometry (cm)	Net peak area	Specific activity,A (Bq mg-1)
	C1	0.0042	20	762954	177025513.8
PTS1(1)	C2	0.0042	20	757968	176874953.3
	C3	0.0042	20	753533	200908945.1
	C1	0.0042	20	767422	182885971.1
PTS1(2)	C2	0.0042	20	760364	208040671
	C3	0.0042	20	749472	208380398.9
	C1	0.0033	20	73051	27089281.43
PTS2(1)	C2	0.0033	20	72587	30910251.79
	C3	0.0033	20	71640	30688307.31
	C1	0.0037	20	53674	22890076.91
PTS2(2)	C2	0.0037	20	51757	26062406.01
	C3	0.0037	20	50137	22760890.1

Table 5.8 : Specific activity for sample irradiated by RR

Sample	No. of counts	Mass (g)	Geometry (cm)	Net peak area	Specific activity,A (Bq mg-1)
RR1(1)	1	0.0037	20	763862	13822.13536
	2	0.0037	20	757651	13815.93784
	3	0.0037	20	750865	13786.95341
RR1(2)	1	0.0037	20	703660	13199.70545
	2	0.0037	20	701633	13233.36703
	3	0.0037	20	691002	13235.73274
RR1(3)	1	0.0039	20	627295	11454.47942
	2	0.0039	20	624304	11446.0581
	3	0.0039	20	623052	11464.54366
RR2(1)	1	0.0033	20	80221	2158.141469
	2	0.0033	20	79150	2171.127878
	3	0.0033	20	79280	2183.103066
RR2(2)	1	0.0032	20	64275	1833.495594
	2	0.0032	20	64158	1837.639934
	3	0.0032	20	64012	1842.467208

RR2(3)	1	0.0034	20	65593	1785.386812
	2	0.0034	20	65205	1780.426444
	3	0.0034	20	65235	1787.702139

Table 5.9 : Specific activity for sample irradiated by DT

Sample	Count	Mass (g)	Geometry (cm)	Net peak area	Specific activity,A (Bq mg-1)
DT1(1)	1	0.005	20	744230	76.45103713
	2	0.005	20	741555	76.47194856
	3	0.005	20	737760	76.3227205
DT1(2)	1	0.0042	20	669860	82.80543157
	2	0.0042	20	666402	82.68936934
	3	0.0042	20	662777	82.52365509
DT1(3)	1	0.0043	20	675048	82.38731831
	2	0.0043	20	673101	82.41727073
	3	0.0043	20	670424	82.39022997
DT2(1)	1	0.0038	20	946904	12.38319611
	2	0.0038	20	942305	12.37199325
	3	0.0038	20	942457	12.4307184
	1	0.0033	20	1046598	15.96327579

DT2(2)	2	0.0033	20	1040162	15.98775805
	3	0.0033	20	1033676	15.94337623
DT2(3)	1	0.0046	20	789979	18.11987115
	2	0.0046	20	782597	18.13980988
	3	0.0046	20	777103	18.09111074

5.5.3 Neutron Flux Distribution

Once a specific activity has been identified, we can measure the neutron flux in both the thermal and epithermal regions. The relation to compute the measurement of neutron flux is shown in the following equation. The thermal, epithermal, and fast fluxes at in-core irradiation facility are calculated using Equation 5.5, 5.6 and 5.7 below.

$$\emptyset_{th} = \frac{A_{th}}{N_{\sigma}(1-e^{-\lambda t_{irr}})} \qquad (5.5)$$

$$\emptyset_{epi} = \frac{A_{cd}}{N_{\sigma}(1-e^{-\lambda t_{irr}})} \qquad (5.6)$$

$$\emptyset_{total} = \frac{A_{bare}}{N_{\sigma}(1-e^{-\lambda t_{irr}})} \qquad (5.7)$$

Where A_{th} is specific activity of Au-bare minus specific activity of Au-Cd, A_{cd} is specific activity of Cd, A_{bare} is specific activity of Au-bare, N is Avogadro's number, λ is decay constant, σ is the cross section of Au-197 and t_{irr} is irradiation time in second. The summary of neutron flux distribution for these three irradiation facilities at power level 750 kW are shown in Table below. (refer from Table 5.10 until Table 5.18)

PTS

Table 5.10 : Average Thermal Flux for PTS

Position	Average Thermal Flux (n/cm^2.s)	Std dev	Relative error(%)
1	1.44184E+12	1.21E+11	8.373434493
2	4.89964E+11	1.2935E+11	0

Table 5.11 : Average epithermal Flux for PTS

Position	Average Epithermal Flux(n/cm^2.s)	Std dev	Relative error(%)
1	2.74E+11	1.99E+10	7.255248738
2	2.21829E+11	17352794567	7.822616405

Table 5.12 : Average Total Flux for PTS

Position	Average total Flux(n/cm^2.s)	Std dev	Relative error(%)
1	1.71617E+12	1.36591E+11	7.959065429
2	1.85487E+12	1.28365E+11	6.920460915

RR

Table 5.13 : Average Thermal Flux for RR

Position	Average Thermal Flux(n/cm^2.s)	Std dev	Relative error(%)
1	7217631.434	1.91E+04	0.263988194
2	7061040.437	10157.36032	0.14385076
3	5997676.028	3559.95378	0.059355553

Table 5.14 : Average epithermal Flux for RR

Position	Average Epithermal Flux(n/cm^2.s)	Std dev	Relative error(%)
1	1.35E+06	7.74E+03	0.57509972
2	1139848.955	2784.791648	0.244312339
3	1106753.464	2305.362937	0.208299591

Table 5.15 : Average Total Flux for RR

Position	Average total Flux(n/cm^2.s)	Std dev	Relative error(%)
1	8563960.005	11647.79276	0.136009425
2	8200889.392	12498.42542	0.152403292
3	7104429.493	5739.932798	0.080793719

DT

Table 5.16 : Average Thermal Flux for DT

Position	Average Thermal Flux(n/cm^2.s)	Std dev	Relative error(%)
1	39705.28365	6.94E+01	0.174865524
2	41372.43751	81.28109593	0.196461946
3	39867.41038	10.04037552	0.025184419

Table 5.17 : Average epithermal Flux for DT

Position	Average Epithermal Flux(n/cm^2.s)	Std dev	Relative error(%)
1	7.69E+03	1.93E+01	0.251533116
2	9901.401296	13.78727973	0.139245742
3	11236.15469	15.18401612	0.135135342

Table 5.18 : Average Total Flux for DT

Position	Total Flux($n/cm^2.s$)	Std dev	Relative error(%)
1	47392.87381	50.11207017	0.105737564
2	51273.83881	87.83018019	0.171296283
3	51103.56507	10.24374943	0.020045078

According to the arrangement, where position 1 is the lowest level in the TRIGA tube and position 3 is the highest, the neutron flux for position 1 should be greater than for positions 2 and 3. This is due to the significantly greater neutron flux passing through the lowest location due to the closer distance to the radiation sources. With the exception of RR data analysis, some of the data acquired are less consistent. I suspected and considered that the experiment have the error due to the plastic vials weren't fastened in place.

5.6 Conclusion

By using Aurum-Bare and Aurum-Cadmium samples, thermal, epithermal, and fast neutron fluxes of Reactor TRIGA PUSPATI was successfully obtained.Fast neutron in this case, has not yet been analysed due to shortage of time as already planned with my internship supervisor here to do the analysis for Nickel during week 8. The detector efficiency was determined prior to the neutron flux measurement using Americium-241 (Am-241), Barium-133 (Ba-133), Caesium-137 (Cs-137) and Europium-152 (Eu-152) at geometry 20 cm. The detector efficiency was found to be 0.002528. The thermal flux, epithermal profile peaked at the center of the reactor core as expected and gradually decreased towards the end of the fuel.So,by using Au-Bare and Au-Cd samples,thermal and epithermal fluxes of RTP could be obtained thus contributing to the data that is needed to ensure safe operation of RTP and for next core configuration which is the 16th core configuration.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

6.1 Recommendation

6.1.1 To the Organization

Increase the number of Meeting and Visit, I see that it really gives a positive aura and good vibe when we meet each other here in MNA , I really love the vibe where I can recognise staffs and Dr. and every part of the community here in MNA as we can share ideas and I can ask and collect more and more pearl of wisdom from each and every members of the MNA. It is wonderful for me as deep in my heart , I really appreciate all of the knowledge and experience of the workers and officers here.

6.1.2 To the university

Increase the internship period, it would be good to have a longer period as some of the student are not able to finish their project within a short period of time.

Constant supervision of students, The intern recommends the university to carry out constant supervision and monitoring of students during the internship training so as to encourage them to perform the duties fully and also accurately. This will also put a close link between the academic supervisors and the field supervisors so as to foster appropriate assessment of what the interns are doing in the field.

Should continue with internship program, this is because it helps to prepare the students for their careers in future and also enable the students to practice the theoretical knowledge obtained during class be exercised practically. It also helps to develop students understanding of work ethics, employment demands, responsibilities and opportunities.

6.2 Conclusion

In conclusion the student benefited a lot in the field attachment in a way that the student managed to apply the theoretical knowledge from the university into practice through the many activities/tasks/assignments the intern was instructed to do.

The intern improved the skills like interpersonal, listening, presentation skills, acting freely around people, typing skills, recording, presentation, typing, conflict resolution, organizational skills to mention but a few. The student learnt many lessons which included; how to determine the neutron flux measurement , how the working environment runs, etc. The student got different ideas from the different people (employees) at the Organization and also through interacting with other interns from different course same university,University of Malaya,from the other university, UiTM University,UteM University and USM university and this has contributed a lot on the knowledge and experience.

Finally, internship was fun and therefore it is important to keep this opportunity to student for their academic requirement of internship from their organization.

REFERENCES

Aboudzadeh, M. R., Moassesi, M. E., Amiri, M., Shams, H., Alirezapour, B., Sadeghi, M., Sari, M. F., & Keyvani, M. (2015). Preparation and characterization of chitosan-capped radioactive gold nanoparticles: neutron irradiation impact on structural properties. *Journal of the Iranian Chemical Society 2015 13:2*, *13*(2), 339–345. https://doi.org/10.1007/S13738-015-0742-5

Agensi Nuklear Malaysia. (2022). *Portal Rasmi Agensi Nuklear Malaysia*. https://www.nuclearmalaysia.gov.my/

Akkurt, I., Gunoglu, K., & Arda, S. S. (2014). Detection efficiency of NaI(Tl) detector in 511-1332 keV energy range. *Science and Technology of Nuclear Installations*, *2014*. https://doi.org/10.1155/2014/186798

Alnour, I. A., Wagiran, H., Ibrahim, N., Hamzah, S., Siong, W. B., & Elias, M. S. (2015). New approach for calibration the efficiency of HpGe detectors. *AIP Conference Proceedings*, *1584*(1), 38. https://doi.org/10.1063/1.4866101

Giuseppe, V., Davide, C., Giancarlo, N., Luca, S., Francesco, N., Stefano, P., Simone, S., & Carlo, T. (2015). Nuclear fission as a tool to contrast the contraband of special nuclear material. *Pramana 2015 85:3*, *85*(3), 497–504. https://doi.org/10.1007/S12043-015-1061-1

Gopalakrishnan, V. (2021). Introduction. *Physics of Nuclear Reactors*, 1–86. https://doi.org/10.1016/B978-0-12-822441-0.00001-7

Hossain, I., Sharip, N., & Viswanathan, K. K. (2012). Efficiency and resolution of HPGe and NaI(Tl) detectors using gamma-ray spectroscopy. *Scientific Research and Essays*, *7*(1), 86–89. https://doi.org/10.5897/SRE11.1717

IAEA. (2022). *Physics and Kinetics Of TRIGA Reactors*. https://ansn.iaea.org/Common/documents/Training/TRIGA Reactors (Safety and Technology)/chapter2/physics11.htm

Koehl, M. A., Rundberg, R. S., & Braley, J. C. (2015). Measured neutron flux parameters in the USGS TRIGA MARK I reactor. *Journal of Radioanalytical and Nuclear Chemistry 2015 306:1*, *306*(1), 31–38. https://doi.org/10.1007/S10967-015-4058-9

Malaysian Nuclear Agency. (2017). *PUSPATI TRIGA Reactor Guidebook*.

https://urtp.nuclearmalaysia.gov.my/manual_public.php

Mohd Ali, N. S., Hamzah, K., Idris, F., Basri, N. A., Sarkawi, M. S., Sazali, M. A., Rabir, H., Minhat, M. S., & Zainal, J. (2022). Power peaking factor prediction using ANFIS method. *Nuclear Engineering and Technology*, *54*(2), 608–616. https://doi.org/10.1016/J.NET.2021.08.011

Mohd Ali, N. S., Hamzah, K., Idris, F. M., & Rabir, M. H. (2018). Thermal neutron flux measurement using self-powered neutron detector (SPND) at out-core locations of TRIGA PUSPATI Reactor (RTP). *IOP Conference Series: Materials Science and Engineering*, *298*(1), 012027. https://doi.org/10.1088/1757-899X/298/1/012027

Munita, Glascock, M. D., & Neff, H. (2019). Neutron activation analysis and provenance research in archaeology. *Measurement Science and Technology*, *14*(9), 1516–1526. https://doi.org/10.1088/0957-0233/14/9/304

Naim Syauqi, Khei Choong, K., Rodzi Ali, M., Talib, Y., Yen, N., Selina Abdul Hamid, S., Saedon, M., Kasbollah, A., Abdul Rahim, R., Hanaffi Mohamad Mokhtar, M., & Hamirul Bahrin Wan Kamal, W. (2019). Coolant Impurities and Radionuclides Production Rate Monitoring at Reactor TRIGA PUSPATI. *Research and Development Seminar Nuklear Malaysia*, 78–86. http://inis.iaea.org/Search/search.aspx?orig_q=RN:51073864

Nuclear-Power. (2022). *Neutron Energy | Classification of Neutrons | nuclear-power.com*. https://www.nuclear-power.com/nuclear-power/reactor-physics/atomic-nuclear-physics/fundamental-particles/neutron/neutron-energy/

Radiation Precaution. (2022). *time-distance-shielding_COLOR-768×307 | Discard Studies*. https://discardstudies.com/2016/05/09/illustrating-the-invisible-an-interview-with-yuko-on-the-radiation-monitoring-project-illustrations/time-distance-shielding_color-768x307/

Radioactivity.eu. (2022). *Radioactivity : Cherenkov Effect*. https://www.radioactivity.eu.com/site/pages/Cherenkov_Effect.htm

Shalbi, S., Wan Salleh, W. N., Idris, F. M., Ashraff Rosdi, M. A., Sarkawi, M. S., Jamsari, N. L., & Mohd Nasir, N. A. (2018). Neutron measurement at the thermal column of the Malaysian Triga Mark II reactor using gold foil activation method and TLD. *IOP Conference Series: Materials Science and Engineering*, *298*(1), 012031. https://doi.org/10.1088/1757-899X/298/1/012031

Steinhauser, G., Merz, S., Stadlbauer, F., Kregsamer, P., Streli, C., & Villa, M. (2012). Performance and comparison of gold-based neutron flux monitors. *Gold Bulletin*, *45*(1), 17–22. https://doi.org/10.1007/S13404-011-0039-0/FIGURES/4

Yavar, A. R., Khalafi, H., Kasesaz, Y., Sarmani, S., Yahaya, R., Wood, A. K., & Khoo, K. S. (2012). Verification of MCNP simulation of neutron flux parameters at TRIGA MK II reactor of Malaysia. *Applied Radiation and Isotopes,* *70*(10), 2488–2493. https://doi.org/10.1016/J.APRADISO.2012.06.015

APPENDIX

a) **Appendix A : Daily Records**

<u>INDUSTRIAL TRAINING LOGBOOK (2022)</u>

Name of Student: MUHAMMAD FAHMI BIN MOHD ZAINAL

Supervisor's Name: DR. JULIA BINTI ABDUL KARIM

Daily Records and Evidence of works.

<u>WEEK NO : 1 (DATE : 18/07/2022 – 22/07/2022)</u>

Week 1	**Duties Performed / Task setting**	**Role**
18/7	Internship registration :I gathered at seminar room with another 200 industrial trainees at Block 11 ,Nuclear Malaysia Agency sharp at 8:20 a.m Then,we were briefed by Pn. Azreen, administration officer , about the work ethics,responsibility as an industrial trainee, about workplace,rules and regulation and about the punch card thingy and safety. Then, we were been distributed a set of forms to be filled up as well as security screening form Me and two of my colleagues ,Hanif and Aslam had a meeting with our Internship supervisor ,Dr. Julia,at her room,block 18 to discuss on the topic of the project and daily works as an research officer herein. Brief on weekly schedule by Dr. Julia from Literature survey,project proposal presentation,preparation of sample, irradiation , storing to counting and analysis.	Intern
19/7	Meeting with the Dr at 8:30a.m and continue discussion on literature survey and presentation	Intern

	Literature Survey :Topic given :Neutron Flux Profiling at the End-Of-Cycle (EOC) RTP Core Configuration. Findings : Neutron Flux Profile Within a nuclear fission reactor, the neutron flux is the primary quantity measured to control the reaction inside. The flux shape is the term applied to the density or relative strength of the flux as it moves around the reactor. (Gopalakrishnan, 2021) Continue doing literature survey.	
20/7	Tour inside TRIGA PUSPATI Reactor,RTP, we were brought by the Dr. to the hall of knowledge where it is the transit before going inside to the RTP Hall. Herein , we were briefed by the Dr. on the diagram of the reactor, research made by herself and colleagues and by old previous researchers. Then, we were brought inside to see and learn about the location surrounding.There are control room ,office, pneumatic transfer system room, store room and reactor hall itself. Filled up and signed and sent the confirmation letter of my placement and attendance here to my University coordinator ,Dr. Imran through the email.	Intern
21/7	Literature survey.: Reading and learning more about the RTP. Guideline RTP : Neutrons are high-speed nuclear particles that have an exceptional ability to penetrate other materials. Free neutrons can be classified according to their kinetic energy. This energy is usually given in electron volts (eV). The term temperature can also describe this energy representing thermal equilibrium between a	Intern

	neutron and a medium with a certain temperature. (Malaysian Nuclear Agency, 2017) https://urtp.nuclearmalaysia.gov.my/files/TOC_PIC.pdf	
22/7	Literature survey Findings: Determination of neutron flux characteristics in irradiation facility is important to support various experiments that are performed in a research reactor. So far, measurements technique was used to determine neutron flux in irradiation facilities of the reactor core of Malaysian PUSPATI TRIGA (RTP). Rabir, M. H., Karim, J. A., & Zin, M. R. M. (2017). Neutron flux characterisation of irradiation facilities in RTP. *Jurnal Sains Nuklear Malaysia*, *29*(2), 33-43.	Intern

Name of industrial supervisor: Dr. Julia binti Abdul Karim

Signature:

JULIA BINTI ABDUL KARIM
Pegawai Penyelidik
Pusat Teknologi Reaktor
Bahagian Sokongan Teknikal (BST)
Agensi Nuklear Malaysia

WEEK NO : 2 (DATE : 25/07/2022 – 29/07/2022)

Week 2	**Duties Performed / Task setting**	**Role**
25/7	Literature survey Project proposal presentation:On this day, I presented my findings ,and survey to the Dr. ,Dr. commented on what to be focused more ,what to change and what to be removed from the literature survey that we did on the slides.	Intern
26/7	Literature survey:I changed and improved the findings on my slides according to what my supervisor had said before.	Intern
27/7	Literature survey.Search up for irradiation procedure for Pneumatic Transfer System (PTS),Rotary Rack (RR) and Dry Tube (DT) .I also asked Mr. Naim ,radiation protection officer to get more information about this.	Intern
28/7	*Gotong-royong* at the reactor hall,staffs,officers,trainees gathered up together , tidied up the RTP hall,removed the unwanted materials,and recycled things up. After this, I discussed with Mr. Naim , upon the set up for shielding used with the HPGe Detector. Me and my colleagues,we were brought to the store room to get the lead blocks to be transported to our laboratory. We planned and calculated the number of lead blocks to be sent to the lab by trolley,and the lead blocks is really heavy so we took extra care on that.	Intern

29/7	Meeting with Dr. Julia and discussed on the details of sample preparation. Here ,Dr. presented to us the sketch of what do we need to have and to find for the sample preparation. The samples were in the laboratory and been guided by my supervisor.The samples ;gold wire, cadmium wire cover , and nickel wire were collected.	Intern

Name of industrial supervisor: Dr. Julia binti Abdul Karim

Signature:

JULIA BINTI ABDUL KARIM
Pegawai Penyelidik
Pusat Teknologi Reaktor
Bahagian Sokongan Teknikal (BST)
Agensi Nuklear Malaysia

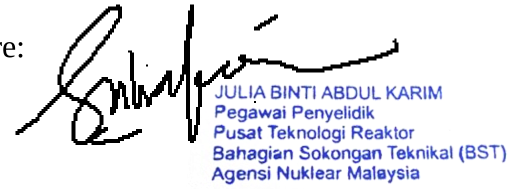
WEEK NO : 3 (DATE : 01/08/2022 – 05/08/2022)

Week 3	**Duties Performed / Task setting**	**Role**
1/8	Preparation of sample activation: There were 32 samples : 4 set of samples • Au :8 • Au + Cd :8 • Ni :8 • Ni + Cd :8 Meeting with Mr. Naim , discussed on the Irradiation time , when using the PTS .	Intern

2/8	Gold wires and Nickel wires been cutted by 2mm length. Cadmium wire cover been cutted by 4mm The mass of cutted samples were measured using electronic weighing scale but before that ,the scale were calibrated before use by using a subject of known mass and the water leveler is ensured to be balanced before any reading is taken. There was a visit from the Canberra company ,about new NaI detector , we were briefed by the personnel about how to use and calibrate it.We build the shielding for this detector using lead blocks	Intern
3/8	Meeting with Dr. Julia ,me and colleagues , we shared our progress and continue our works Gold wires and Nickel wires were inserted inside the cadmium cover . The cadmium cover holes at each end were sealed by pliers. Each sets of wires been inserted inside a vials.	Intern
4/8	The vials were closed with its lid The lids were soldered so that its contents were not going out and get stuck inside the reactor when irradiate and it is the safety procedure to abide with.	Intern
5/8	Discussion with Dr. more on specific details of irradiation part because it has to be done on next week. I filled up the obligatory form for irradiation through	Intern

	the website (Malaysian Nuclear Agency, 2017) https://urtp.nuclearmalaysia.gov.my/login.php	

Name of industrial supervisor: Dr. Julia binti Abdul Karim

Signature: 

WEEK NO : 4 (DATE : 08/08/2022 – 12/08/2022)

Week 4	**Duties Performed / Task setting**	**Role**
8/8	Irradiation of sample in RTP: The irradiation method that were used is Pneumatic Transfer System(PTS) , Rotary Rack (RR) , Dry Tube (DT) : PTS was conducted by me with the supervision of Radiation Protection Officer ,RPO ,Mr. Naim. I wore dosimeter ,labcoat ,gloves along the process for safety and protection. I also planned well and applied the knowledge to execute the irradiation process ,which are lessen the time with irradiated sample, distance ourselves from it, and use appropriate shielding. RR1 sample were irradiated.As planned ,for 1 day, 1 TRIGA Tube only which consist of three vials for rotary rack. Calibration of HPGe detector using controlled source ,Amerecium-241.There are 3 counts for each source to find average of detector efficiency.each count is 3600s or equivalent to 1 hour. I started my counting as early as 8.00 o'clock in the morning and finished at 1130a.m. Samples of PTS ,there are 4 sets ,PTS1,PTS2,PTS3 and PTS4 were irradiated , the ionising radiation of samples were measured by using survey meter before storing.	Intern

9/8	Study tour to “Makmal Radiokimia dan Alam Sekitar”(RAS) Or Radiochemical and Environmental Laboratory ,Me and my colleagues ,Hanif, Aslam and Adam were briefed and taught by Mrs. Noradilah, about the gross alpha beta. Then, about the wipe test procedure , for example,every mineral water company must send their sample of water here at Nuclear Malaysia Agency as subjected by Ministry of Health (MOH) for safety and license. Building the lead shielding to store the irradiated sample and detector. RR2 samples were irradiated at 1:20p.m. and stored well inside the lead box. Calibration of HPGe detector using controlled source Cesium-137. I started my counting as early as 8.00 o’clock in the morning and finished at 1130a.m.	Intern
10/8	Calibration of HPGe detector using another controlled source Barium-133. I started my counting at 8.20o’clock in the morning and finished at 12a.m. RR3 samples were irradiated and were stored. I measured the ionising radiation of samples PTS1-4 with the supervision of Mr. Naim whether it is suitable or not to be stored at Laboratory for counting. All of the reading taken were 30µS,18 µS,21µS and 20µS	Intern

11/8	RR4 samples were irradiated at 1:20p.m and were stored properly Calibration of HPGe detector using another controlled source, Europium-152 located at Nuclear Physics laboratory 1.	Intern
12/8	Continue calibration of HPGe detector, and write my daily reports. The crane at the RTP Hall been used for works and we were there to learn how it operates , helps dispose the old papers,unwanted documents from the office besides the reactor and from the control room. About the arrangement of site visit and presentation, I sent an email to Dr. Juan Carlos for the confirmation of the details.	Intern

Name of industrial supervisor: Dr. Julia binti Abdul Karim

Signature:

JULIA BINTI ABDUL KARIM
Pegawai Penyelidik
Pusat Teknologi Reaktor
Bahagian Sokongan Teknikal (BST)
Agensi Nuklear Malaysia

<u>WEEK NO : 5 (DATE : 15/08/2022 – 19/08/2022)</u>

Week 5	**Duties Performed / Task setting**	**Role**
15/8	Discussion with Dr. Julia on the samples irradiation and update the ongoing progress at 830a.m. and briefing about the neutron flux measurement. DT1 samples were irradiated at 1:20p.m Meeting with Dr. Hasni ,discussed further on the counting steps procedure. Meeting with Mr. Naim and been introduced and taught on the sample handling.For instance, how to handle the sample with care,so that we can avoid any accidents I measured the RR samples whether it is suitable for counting or not, if it below 20% deadtime , we can consider, it is safe for the detector. Gamma spectroscopy analysis:Counting the Sample of RR1	Intern
16/8	DT2 samples were irradiated at 1:30p.m and were then stored. Gamma spectroscopy analysis: Counting the Sample of RR2	Intern
17/8	DT3 samples were irradiated at 1:20p.m and were proceed for storing. Gamma spectroscopy analysis: Counting the Sample of RR3 I went with Mr.Naim to the RTP Hall , to check for	Intern

	the reading of ionizing radiation from the irradiated samples using survey meter whether it is suitable or not to bring them out from the reactor hall to my laboratory for counting purpose.	
18/8	DT4 samples were irradiated at 1:30p.m. Gamma spectroscopy analysis: Counting the Sample of RR4	Intern
19/8	Gamma spectroscopy analysis: Continue counting the samples Informal Meeting with Dr. Marks ,I discussed with him about how to further study for my next level education .He told me about the scholarship opportunities from IAEA, Erasmus,Kaist Korea ,Mext Japan and Biasiswa Agung Malaysia Next about the skillsets that I could explore is JAVA rules programming ,C++ ,Python-simulatio ,Fortrun,Gui Graphical. Tips from him: Try interact more with people,supervisors,officers to polish up the interpersonal skills,find some skill out there,do and see what interest me more.	Intern

Name of industrial supervisor: Dr. Julia binti Abdul Karim

Signature:

JULIA BINTI ABDUL KARIM
Pegawai Penyelidik
Pusat Teknologi Reaktor
Bahagian Sokongan Teknikal (BST)
Agensi Nuklear Malaysia

WEEK NO : 6 (DATE : 22/08/2022 – 26/08/2022)

Week 6	**Duties Performed / Task setting**	**Role**
22/8	I measured the DT samples whether it is suitable for counting or not, if it below 20% deadtime , we can consider, it is safe for the detector. Gamma spectroscopy analysis: Counting the Sample of DT1	Intern
23/8	Seminar with Director of Human Resource Department ,YM. Raja Jamal Abdul Nasser at Block 11 ,Nuclear Malaysia Agency , about "Why we choose Nuclear Malaysia" and "What do we want to gain from Industrial Training".The seminar started at 8:30 a.m. and finished at 11:30 a.m. Gamma spectroscopy analysis: Counting the Sample of DT2	Intern
24/8	Gamma spectroscopy analysis: Counting the Sample of DT3 Site visit and Presentation were conducted through online Google Meeting ,Wednesday ,24th August 2022, at 1:30pm https://meet.google.com/oeq-wkcc-oyc I presented in front of Dr. Juan and Dr. Julia about what have I been doing here throughout several weeks of internship ,my project, works experience,	Intern

	photos taken during works , methodology precautionary steps , and works as a research assistant here.We manage to start at 1:30p.m. and finished at 2:40p.m.	
25/8	Gamma spectroscopy analysis: Counting the Sample of DT4 Meeting with Dr. Hasni,research officer at RTP department taught us on the data analysis from the sample data obtained,Ex, net peak area (activation energy (Au) – 411keV ,count per energy, specific activity ,by then be used to count the neutron flux density.Meeting started at 3:30p.m. and finished at 5:30p.m.	Intern
26/8	Meeting with Dr. Julia at 8;30a.m ,updated my progress of counting. We discussed to have and to explore the experience for me about the checklist process of startup and shutdown of the reactor and a study tour to the control room simulator of Nuclear reactor. Gamma spectroscopy analysis: continue the counting.	Intern

Name of industrial supervisor: Dr. Julia binti Abdul Karim

Signature:

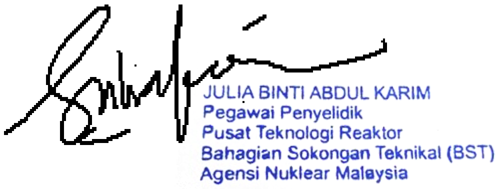
JULIA BINTI ABDUL KARIM
Pegawai Penyelidik
Pusat Teknologi Reaktor
Bahagian Sokongan Teknikal (BST)
Agensi Nuklear Malaysia

WEEK NO : 7 (DATE : 29/08/2022 – 2/09/2022)

Week 7	**Duties Performed / Task setting**	**Role**
29/8	Startup Cheklist for the RTP reactor Data Analysis for neutron flux measurement,I discussed with the Drs. on the progress,I managed myself to analyse the samples by using the GammaVision software to find peak in the spectrum that match the activation energy of the Gold wire. Then I transfered the data to the excel for analysis.Inside the excel , I managed to understand,make formula, manage large amount of data to be plugged in the nested formula,and managed to plot and analyse the data.	Intern
30/8	Startup Cheklist for the RTP reactor Continue with the analysis and University report writing progress	Intern
31/8	Malaysian National Day (Holiday)	Intern
1/9	Startup Cheklist for the RTP reactor Continue with the analysis and University report writing progress.	Intern
2/9	A study visit to the Sinagama,Malaysian Nuclear Agency with Dr. Hasniyati and my colleagues namely Hanif, Aslam and Adam. Finalised my University report writing.	Intern

Name of industrial supervisor: Dr. Julia binti Abdul Karim

Signature:



TO BE FILLED UP NEXT WEEK FOR ANY IMPROMPTU ACTIVITIES AND ET CETERA

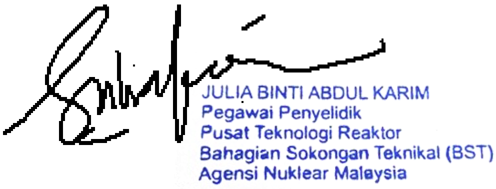
WEEK NO : 8 (DATE : 05/09/2022 – 09/09/2022)

Week 8	**Duties Performed / Task setting**	**Role**
5/9	According to the planning,is as follows: Shutdown checklist for RTP Reactor Continue Analysis for Nickel ,That is why I do not input the result in this discussion part yet. Nuclear Malaysia Final Report writing to be submitted to administration.	Intern
6/9	Continue Analysis for Nickel Shutdown checklist for RTP Reactor Nuclear Malaysia Final Report writing	Intern
7/9	Continue Analysis for Nickel Shutdown checklist for RTP Reactor Nuclear Malaysia Final Report wirting	Intern
8/9	Continue Analysis for Nickel Shutdown checklist for RTP Reactor Nuclear Malaysia Final Report writing .	Intern
9/9	Nuclear Malaysia Final Report Submission to the	Intern

	administration block,Human Resources Division,block 11 , to receive a certificate of internship. *Adios Amigos.Signing off.*	

Name of industrial supervisor: Dr. Julia binti Abdul Karim

Signature:



b) **Appendix B : Evidence of works**

Figure 1: Sample Collection including gold wire, nickel wire and cadmium cover

Figure 2: Sample Preparation before irradiation including labelling , weighing using electronic weighing scale and soldering.

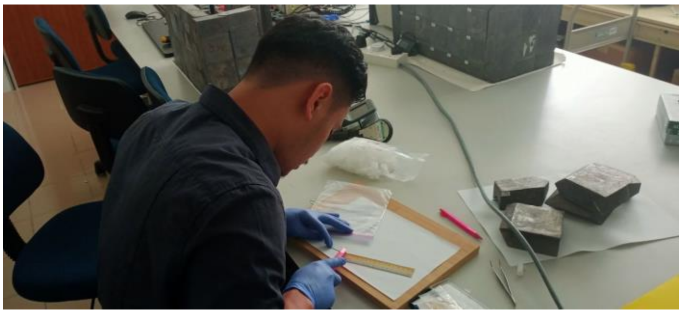


Figure 3: Cutting samples (wire)

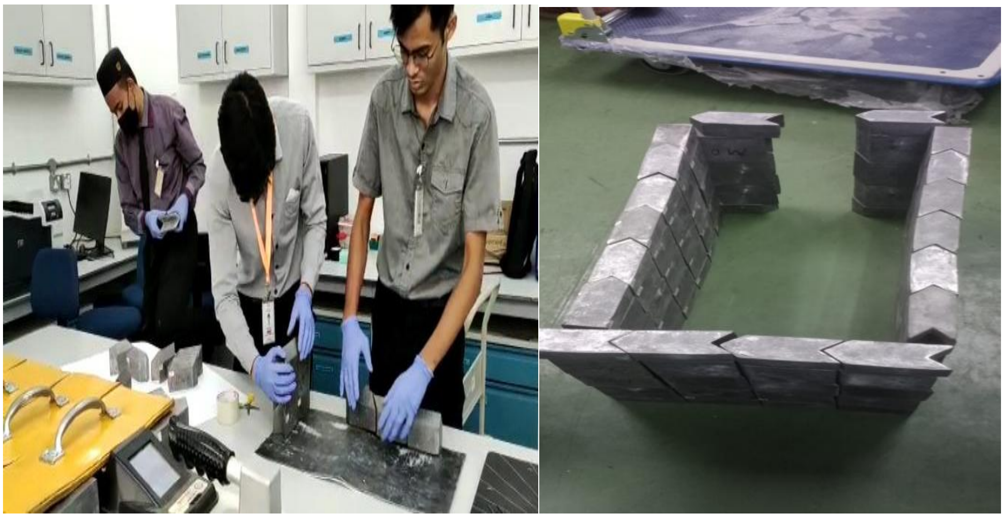


Figure 4: The shielding for detector was built using lead blocks

Figure 5 : PTS Station

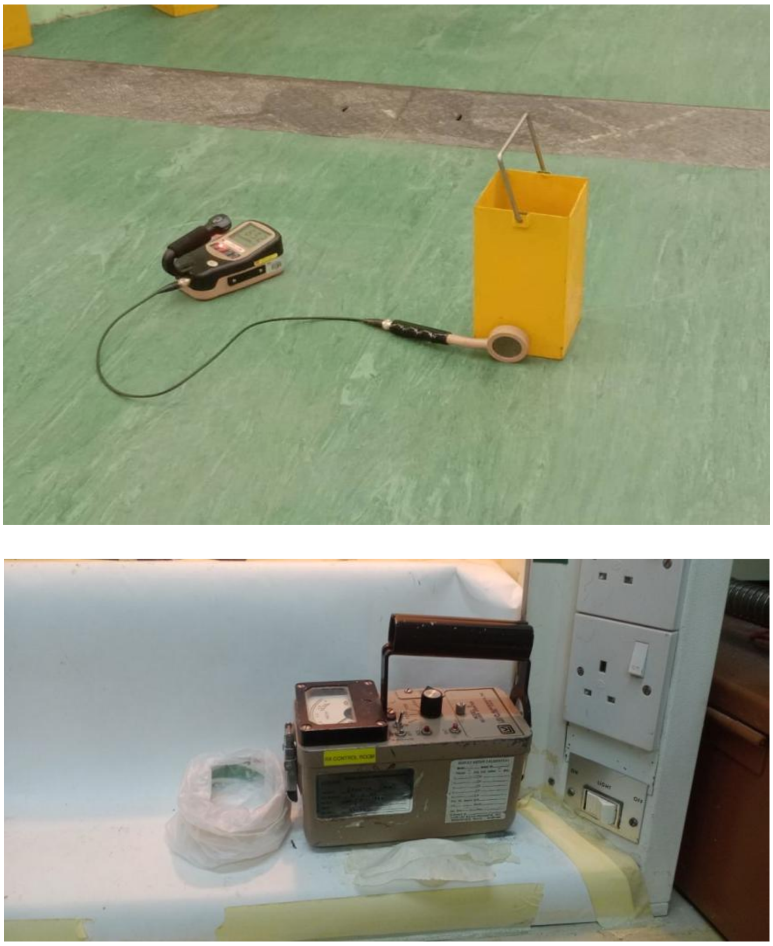


Figure 6 : Survey meter. It is used to count the radiation of the sample after irradiation

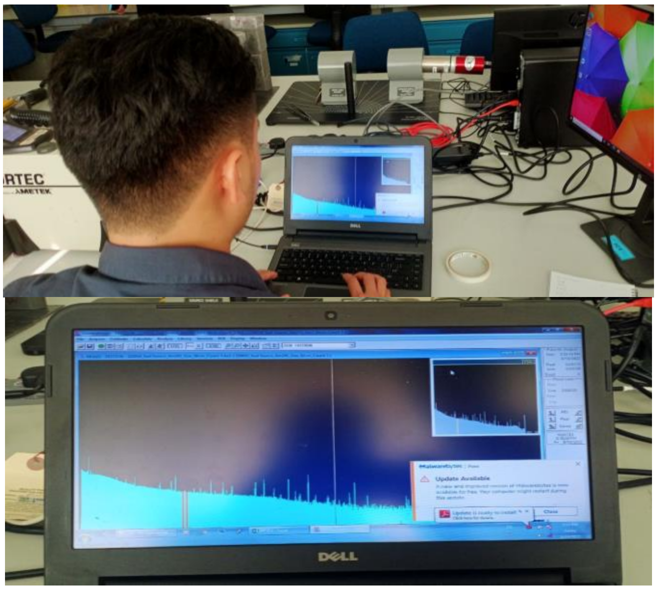


Figure 7 : Counting the radiation from the sample using HPGe detector

Figure 8 : Building storage place for irradiated samples using lead blocks at the Nuclear Physics Laboratory 1

Figure 9 : Precautionary Steps including wear gloves ,wash hands after handling samples,wear lab coat ,use body radiation monitor after going out from RTP Hall, wear dosimeter after handling the samples.

Figure 10 :A visit to radiochemical & environmental laboratories

Figure 11 : Briefing by the Canberra Personnel on the NaI detector and building the shielding for that detector.

Rekod Bacaan Dos

Nama	MUHAMMAD FAHMI BIN MOHD ZAINAL
No KPT	XXXXXX-XX-XXXX
Agensi/Institusi	UNIVERSITI MALAYA ,KUALA LUMPUR
No Dosimeter	RX 06
Tujuan	LATIHAN INDUSTRI

Tarikh	Masa Awal	Bacaan Awal (A) (μSv)	Masa Akhir	Bacaan Akhir (B) (μSv)	Bacaan Kadar Dos (B – A)(μSv)
28/7/22	8.50 a.m	0	4.30 p.m	2	2
8/8/22	8.30 a.m	0	4.30 p.m	2	2
9/8/22	11.00 a.m	0	5.00 p.m	1	1
10/8/22	10.00 a.m	0	4.30 p.m	2	2
11/8/22	8.30 a.m	0	4.30 p.m	2	2
12/8/22	8.00 a.m	0	5.00 p.m	0	0
15/8/22	8.00 a.m	0	5.00 p.m	0	0
16/8/22	8.20 a.m	0	5.00 p.m	1	1
17/8/22	7:30 a.m	0	5.00 p.m	2	2
18/8/22	8.00 a.m	0	5.00 p.m	1	1
22/8/22	8.00 a.m	0	5.00 p.m	1	1

23/8/22	2.00 p.m	0	5.30 p.m	1	1
24/8/22	8.30 a.m	0	5.30 p.m	1	1

Figure 12 : The record of dose reading everytime I was in the Nuclear Physics Laboratory or Inside the RTP hall.

Figure 13 : RTP Foyer of Hall of Fame study tour , we were being introduced by Dr. Julia ,Dr. Hasni and Mr. Naim about the brief of the RTP Reactor and highlighted research that has been done before this.