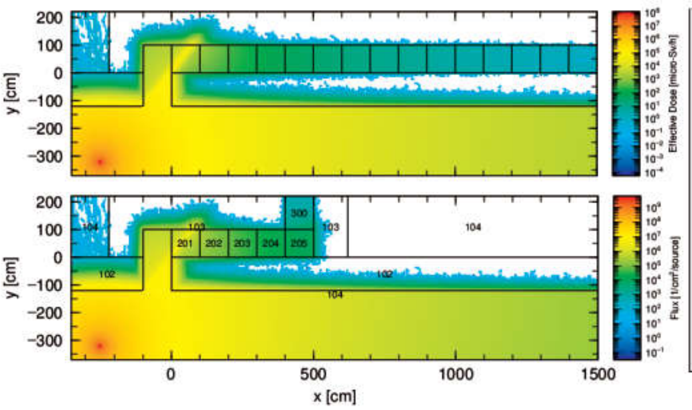
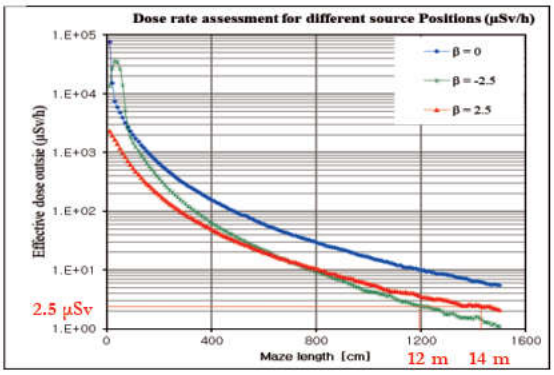
Korea Advanced Institute of Science and Technology

Korea Institute of Nuclear Safety

# Technical Rules for Radioactive Source Storage for NDT Companies in Cameroon based on PHITS Monte Carlo Simulations.

**Cebastien Joel GUEMBOU SHOUOP**




Academic year 2018-2019

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# Technical Rules for Radioactive Source Storage for NDT Companies in Cameroon based on PHITS Monte Carlo Simulations.

By **Cebastien Joel GUEMBOU SHOUOP**

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**ORIGINAL THESIS PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN SCIENCES**

December 2019

## ABSTRACT

Industrial radiography has been spreading world widely and its use as non-destructive testing method for different equipment, goods, and object of all sort has been proved to be an essential indispensable technique for objects' control. Depending on the type of sources used, attention must be paid differently on the protective measures to be taken around a facility. In this regard, protection measures around an X-ray generator are different from those necessary to protect people and environment around a radioisotope, which spontaneously emits radiation, alpha, beta, gamma, or neutron, until it decays to a stable isotope or element. As the great issues of protection highlighted along with justified activities is the measure to limit the dose to an acceptable limit, the present study was projected to solve the problem of shielding design around industrial radiographic facilities using gamma and neutron sources. Gamma sources of Co-60 under 100 Ci and Ir-192 under 50 Ci and a neutron source of Cf-252 with an activity of 100 Ci were considered as typical sources used in fixed industrial radiography. The PHITS Monte Carlo code was used to compute the appropriate concrete wall necessary to shield gamma radiation and the most effective material appropriate to shield neutron source. For the gamma radiation source, the shielding design took into consideration the double and single corner maze, while the in the neutron radiography testing room, only a reinforced shielded door was necessary without maze design.

The result of the calculation showed that the minimum concrete wall thicknesses necessary to shield the radiation were 70 cm, 120 cm, and 250 cm for the Ir-192, Co-60, and Cf-252 sources, respectively. All the presented values were obtained with acceptable statistic except the case of Cf-252 where the calculation involving neutron interaction was time consuming and computing resources demanding. In addition, different materials were subjected to investigation to find out the most appropriate for neutron shielding as the Cf-252 spontaneous fission produce fast neutrons. These fast neutrons undergo moderation in hydrogenous or light material prior to their absorption in borate material where they produce gamma ray shield using concrete of dense material. It was found that tungsten was efficient in shielding energetic neutron, but is expensive to be used in shielding design. Paraffin, graphite, polyethylene, plastic, and iron could be used for neutron slowing down process and the combination of some of these material is more effective. Water (light and heavy), the most effective neutron moderator of lithium cannot be used in radiographic test rooms as they posed a structure problem (easy leakage, difficult to use in wall form). Also, while using hydrogenous material, attention should be paid on the safety and security of the design, construction and operation of the facility as the fire likelihood increase.

Gamma ray shielding design showed that the most appropriate design to shield gamma from sources used in industrial radiography facilities in the double corner maze, compare to the single corner maze. The maze length necessary to shield gamma radiation up to 2.5 μSv/h in single corner maze design is almost the triple of the maze length needed in double corner maze design. This conclusion highlighted the importance of cost-benefit analysis in a plan stage prior its design, construction, commissioning, operation, and decommissioning. Three different positions of the source were evaluated and the outcome showed that the central position of the source in radiography testing facilities should never be allowed, unless there are special justifications as it is the case with highest exposure rate to the boundary areas enclosing the facility. The choice between the left and right position of the source in the facility merely depend on the length of the maze in the case the design is single corner maze. For example, in the case the source of cobalt-60 is used for neutron imaging, the left position of the source should be preferred when the maze length is less than 7 m and the right position if not. For iridium-192 source in industrial radiography facilities, the single maze design showed that at least 5 m maze length is needed to set the source position on the right side.

Neutron shielding is complex in industrial radiography using fast neutrons as those emitted by the spontaneous fission source of Cf-252 investigated in this research. Maze design is not appropriate for neutron shielding and the shielded enclosure in this case should be made of reinforced door including material for neutron slowing down, its absorption and the gamma-ray shielding. From the computation based Monte Carlo methods, the following material should be used in combination with iron for slowing the energetic neutron, boron or borate material for neutron absorption and concrete or lead and the end of the chain for gamma attenuation. The combination of three to five material could be enough when well-chosen and the shielded enclosures should be design and constructed based on a long term plan evaluation. Attention should be paid on materials used to avoid the critical problem of activation as the neutron interaction with an alloy is likely to produce new radioisotope with high risk of contamination.

To keep the effective dose rate as low as reasonably achievable (ALARA) in the areas adjacent to the radiographic facilities, the International Atomic Energy Agency (IAEA) has developed regulatory guidelines, safety reports series, and various number of technical documents to help governments, institutions, and individuals involved from near or far in the use of radioactive sources in the practice of radiography. These guidelines have been using worldwide to develop a safety culture and network with less risk of radiological accident from the industrial side. As the National Radiation Protection Agency of Cameroon is the regulatory authority in Cameroon for the practice of industrial radiography, there is a particular need of clear and precise regulation on the use of radioactive sources for non-destructive test. The regulatory authority has the opportunity to consider the Korean regulation (or USNRC one) and the IAEA case to develop appropriate laws and rules for safe acquisition, possession, planning, designing, construction, commissioning, operation, and decommissioning of a radiography testing facility. The licensees, radiographers, and any individual involved in the use of gamma or neutron sources for activities related to industrial radiography could then have a law as foundation and regulation for their practice without ambiguity.

**ACKNOWLEDGEMENT**

I am thankful to JEHOVAH, the creator of the universe and all in it, who gave us life and who made us in such a beautiful way we can feel home everywhere on the earth, even thousands km far away from the place we were born, while living. I owe him gratitude and submission as a simple subject of his immense creation.

How hard is it to thank all these unnumbered people that helped me and are still helping me during my life in Korea, individually. My try as written in the following paragraphs is just a try, because I don't know if there is another work greater than the word "THANK YOU".

THANK YOU to the Korean Government through both the Korean Institute of Nuclear Safety (KINS) with its International Nuclear Safety School (INSS) and the Korea Advanced Institute of Science and Technology (KAIST), Department of Nuclear and Quantum Engineering. It was a great privilege and experience to be part of the 10th batch of this international master program (KINS-KAIST International Nuclear and Radiation Safety Master Degree Program). I am thankful and I show my gratitude to the technical support first and the financial support through the period of the training.

I genuinely express my gratitude to my research supervisor, Dr. SANG-IN Bak from KINS department of industrial radiography. Through his constant technical advices, guidance, suggestions, and support during my research project despite his very busy schedule. It was a great combination of young individuals discussing about the PHITS code and sometime in my office, breaking the gap between the student and the adviser. I hope to keep this cooperation for longtime and for future projects.

The administration of the present thesis on KAIST side was gallantry conducted by my advisor, Professor SUNG-MIN Choi, the head the Nuclear and Quantum Engineering. Despite his busy schedule, the administration of my project was also his priority, shearing his wealth of knowledge in Nuclear and Radiation field. In addition, I would like to thank the entire faculty members of KAIST with its valorous professors, willing to share everything and assuring with up building commands.

THANK YOU to the program directors, coordinators, and administrators. Dr. RYU YONG-HO from KINS and Professor GYUSEONG CHO from KAIST were more than directors of the program as their proximity with me was remarkable. The coordinators Ms. Juyeong PARK, Ms. Hansol KIM from KAIST and Mr. MINJUNG Han from where not just administrators, but likely friends to whom I could ask everything, whenever, and get the appropriate answer.

I would like to thank particularly Professor YIM Man-Sung for his consideration for me. He showed wonderful and attractive qualities that moved me to another understanding of what social life is. As the coordinator of the NEREC program, he shared with me not only his scientific knowledge, but far beyond things happening in the laboratory: life experience, relationship, and even more about consideration. Thanks Professor YIM and professor CHOI SunGyeol.

I am grateful to the Government of Cameroon, through the Ministry of Scientific Research and Innovation (MINRESI) and the National Radiation Protection Agency (NRPA) of Cameroon. I'm thankful to the Director General, Dr. Augustin SIMO, for his support, and recommendations concerning the program on nuclear safety and radiation protection. The Littoral Division Head of NRPA, Professor

Maurice MOYO was more than a boss, but also as an advisor in every aspect of my professional life as a young researcher. I am thankful to the director of technical affairs, Dr. Felix BEYALA, to the responsible of research affair – Dr. Jean Faustin SABOUANG, and other colleagues for their support. Among them, I would like to namely thank Mr. SAMBA, Dr. Eric NGUELEM, Mr. Eric NJAKA MANYOL, Mr. NDZANA Thierry, Ms. Annie FOKOU. These seniors created good working conditions for junior scientific officers and researchers.

I'm thankful to Professor David STRIVAY from the "Spectroscopie Atomique et Nucleaire, Archeometrie" Laboratory of the University of Liege – Belgium. His support through my early stage life as a researcher was up building for genuine attitude of researchers. I would like to thank Professor Ousmanou MOTAPON, Professor Rene YAMAPI, Professor Jean-Pierre NGUENANG, and Professor Andre LENOUO as they inspired me and be references in different aspects I needed them. Thank you to Professor KIM Yonghee and the PHITS collaboration through TATSUHIKO SATO, from the Japanese Atomic Energy Agency (JAEA)

I built and am continuously building wonderful relationship with people from everywhere around the world. Among them, many support me emotionally during this program as LEE Jinki, Russel and Dorcas NJABA, LEE JunHoo, KIM YeongSeok, CHOI Kevin, CHO YongHoo, Jerwin VILLAMINE, and many other friend we share the same hope and faith. I would like to extend my thanks to Ms. Chelsea PICKETT, a friend who genuinely help in improving the quality of this report by volunteering to review the language.

THANK YOU to my friends and "family" members during the program, due to the proximity we shared. My roommate in KAIST, Mr. Peter SELATO was really encouraging with his high analytical capacity. Thanks to other with whom we share the lab space, breaks, and discussion – Julius Federico JECONG, Sajjad UR REHMAN, Shakirah Binti ABD SHUKOR, Hiba Yaseen MOHAMMAD AL-KHODIRE, Chantica CHINCHATCHAWAL, Erdenetsetseg ERDENE, Samya Yakoub Yousif FAIROUZ ISMAIL, and Rysken MUKHAMETZHAROVA.

Finally, I would love to appreciate my family including my mother, my brothers and sister, also my uncles, aunts, nephews, and cousins for their constant support and encouragements through hard time of this program. My deep appreciation is expressed to them with their love, inspiration, and understanding. I express my love and gratitude to all you who contributed closely or not to the achievement of the present project.

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