Feasibility study on the DFP adoption of medical cyclotron decommissioning in the Republic of Korea Postprint

Authors: Rina Woo, Minchul Song, Daehyung Cho, Wantae Kim, Yongmin Kim

Date: 2023-06-18T00:00:00+00:00

Abstract

Since the development of positron emission tomography in 1937, the number of medical cyclotrons used in producing radioisotopes (RI) has risen sharply. In its operation, the structural materials of a medical cyclotron and the concrete shielding of its vault are activated by neutrons. In analyzing domestic and international decommissioning practices, the dismantling characteristics of medical cyclotrons result in a large amount of radioactive wastes, such as concrete, although their activity level is very low. In the United States, the dismantling plan must be established by the applicant. The decommissioning funding plan (DFP) is a financial assurance demonstration based on a site-specific cost estimate of decommissioning the facility. In 10 CFR 30.35, NRC requires the submission of DFP in the case of the possession and use of unsealed byproduct materials with a half-life of greater than 120 days and in quantities exceeding 105 times that of the applicable quantities. The dismantling of the Seoul National University Hospital (SNUH) cyclotron (TR-13) was performed in December 2012. Some of the risks resulting from this dismantling are related to radioactive wastes, as well as issues concerning dismantling costs. Hence, we propose introducing the DFP at the authorization stage. DFP will be helpful in preparing reliable decommissioning plans for safe decommissioning and unexpected early decommissioning in the future. DFP can also contribute in reducing radioactive waste and in decreasing the decommissioning cost by preventing excessive establishments. This study provided an overview of the decommissioning aspects of the SNUH cyclotron and the necessity of adopting the DFP for decommissioning medical cyclotrons.

Full Text

Preamble

ChinaXiv Cooperative Journal NUCLEAR SCIENCE AND TECHNIQUES 25, S010301 (2014)

Feasibility Study on DFP Adoption for Medical Cyclotron Decommissioning in the Republic of Korea

Rina Woo[1], Minchul Song[2], Daehyung Cho[2], Wantae Kim[2], and Yongmin Kim[1],†

[1]Department of Radiological Science, Catholic University of Daegu, Gyeongsangbuk-do, 712-702, Republic of Korea
[2]Korea Institute of Nuclear Safety, Daejeon, 305-338, Republic of Korea

(Received June 30, 2013; accepted in revised form October 15, 2014; published online November 25, 2014)

Since the development of positron emission tomography in 1937, the number of medical cyclotrons used for radioisotope (RI) production has risen sharply. During operation, the structural materials of a medical cyclotron and the concrete shielding of its vault become activated by neutrons. Analysis of domestic and international decommissioning practices reveals that dismantling medical cyclotrons generates large amounts of radioactive waste, particularly concrete, although the activity levels are very low. In the United States, the dismantling plan must be established by the applicant. The Decommissioning Funding Plan (DFP) is a financial assurance demonstration based on a site-specific cost estimate for decommissioning the facility. Under 10 CFR 30.35, the NRC requires submission of a DFP for possession and use of unsealed byproduct materials with half-lives greater than 120 days and in quantities exceeding 10^5 times the applicable limits. The dismantling of the Seoul National University Hospital (SNUH) cyclotron (TR-13) was performed in December 2012.

Some risks associated with this dismantling involve radioactive waste management and cost concerns. Hence, we propose introducing the DFP at the authorization stage. The DFP will facilitate preparation of reliable decommissioning plans for safe decommissioning and for unexpected early decommissioning scenarios. It can also contribute to reducing radioactive waste and decreasing decommissioning costs by preventing excessive facility establishment. This study provides an overview of the decommissioning aspects of the SNUH cyclotron and demonstrates the necessity of adopting the DFP for medical cyclotron decommissioning.

Keywords: Medical cyclotron, Decommissioning, Decommissioning funding plan (DFP)
DOI: 10.13538/j.1001-8042/nst.25.S010301

INTRODUCTION

II. ANALYSIS OF DECOMMISSIONING CYCLOTRON IN THE REPUBLIC OF KOREA

Cyclotrons have a mechanical lifespan of 30–40 years. However, examination of dismantling practices reveals that early decommissioning often occurs due to mission changes, facility relocation, and equipment upgrades rather than age-related defects. Since the development of positron emission tomography (PET) in 1937, the number of medical cyclotrons used for radioisotope (RI) production has increased dramatically. In a cyclotron, charged particles are injected into a vacuum chamber subjected to a magnetic field. During medical cyclotron operation, structural materials and the concrete vault shielding become activated by neutrons [1–4]. Most medical radionuclides are transient and quickly decay to acceptable levels. Nevertheless, analysis of domestic and international decommissioning practices shows that medical cyclotrons, typically housed in large, thick-walled concrete structures, experience activation of trace elements in these materials, producing large quantities of low-level radioactive waste [4–7] and consequently increasing decommissioning costs. Therefore, careful preparation and proper management of cyclotron dismantling procedures are essential to reduce decommissioning expenses.

This section provides an overview of the decommissioning aspects of the Seoul National University Hospital (SNUH) cyclotron and offers recommendations for improving the regulatory system to ensure safe dismantling of medical cyclotrons.

In December 2012, the medical cyclotron (13 MeV, TR-13) was decommissioned and relocated from SNUH to Sungkyunkwan University in the Republic of Korea (Fig. 1 [Figure 1: see original paper]). The SNUH cyclotron was constructed in 1994 and operated specifically for research and medical RI production for 17 years.

A. Process of SNUH Cyclotron Dismantling

Before dismantling, radiation and contamination surveys were conducted, and the activation of targetry and stoppers was assessed. The cyclotron was dismantled in the following sequence to minimize radiological hazards (Fig. 2 [Figure 2: see original paper]): (1) ion extractor, (2) targetry (2 units), (3) ion source, (4) power and manipulation cabinets (4 units), (5) shielding housing (6 units), (6) magnet (2 units), (7) rail removal, and (8) transport of all packages. The magnet and shield, weighing approximately 80 tons, were removed and size-reduced. Components of the vacuum electromagnetic system and Dee were protected from damage such as scratches. All project personnel, including eight dismantling workers, nine moving personnel, and a designated manager responsible for radiation safety, received training before work activities commenced. The health physics manager for the decommissioning project

recommended that project safety procedures and decontamination and decommissioning (D&D) activity criteria follow the as low as reasonably achievable (ALARA) principle.

B. Main Consequence of Decommissioning the SNUH Cyclotron

The maximum surface exposure level measured approximately 1.4 mSv/h at the stopper due to proton contamination with a few resilient radionuclides, as shown in Table 1 . The total collective dose from the decommissioning project was 0.48 person-mSv. Detailed radiation survey results indicated 0.3 mSv from dismantling and transport operations and 0.18 mSv from safety management operations. Table 2 shows the radioactive waste generated during cyclotron dismantling.

C. Legal System for Cyclotron Decommissioning

The SNUH principal communicated with the Korea Institute of Nuclear Safety and regulatory authorities in April 2012. The ACT Corporation determined the optimal approach for performing the decommissioning task. The D&D project required six months to complete (including preparation, dismantling, and transport operations, which took 60 days). All applicants for medical cyclotron use authorization must submit a license application, including a radiation safety report and safety management rules, to the Republic of Korea authorities. Thus, after facility shutdown or cyclotron decommissioning, the decommissioning plan is considered independently from installation approval. An initial decommissioning plan for the SNUH cyclotron shutdown was prepared and submitted by the applicants.

III. PROPOSAL FOR SAFE AND ECONOMIC CYCLOTRON DECOMMISSIONING

A. Analysis of SNUH Cyclotron Decommissioning Problem

Information and documentation regarding SNUH facility construction and dismantling techniques are lacking. The primary problem encountered was the enormous volume of radioactive waste generated during dismantling (Table 1), although the activity levels were very low. Since the dismantling was performed to relocate the cyclotron, the costs and labor incurred exceeded the original plan. The estimated total cost, including safety administrative expenses, was $270 000. Given this problem (high dismantling costs), commercial hospitals are reluctant to dismantle medical cyclotrons. The D&D costs of medical cyclotrons are expected to increase in the future depending on the amount of waste and disposal, such as con- crete.

Introduction of the decommissioning funding plan (DFP) In the United States, the DFP must be established by the applicant. The DFP is a financial assurance demonstration based on a site-specific cost estimate for the decommissioning of

the facility. In 10 CFR 30.35, NRC requires the submis- sion of a DFP in case of the possession and use of unsealed byproduct materials with a half life of greater than 120 days S010301-2 FEASIBILITY STUDY ON THE DFP . . .

Nucl. Sci. Tech. 25, S010301 (2014) ChinaXiv 合作期刊 Radioisotope* Maximum estimated radioactivity (MBq) Surface dose rate (mSv/h) Weights (kg) Table 1. Type of transport package and major properties Bin(Stopper, Targetry) 22Na, 54Mn, 56Co 58Co, 60Co, 65Zn Body(Magnet, Cover) 54Mn, 22Na, 56Co, 40K, 60Co, 65Zn Shielding Housing 54Mn, 40K, 60Co 20,000 9,230 Table 2. The volumes of radioactive waste generated from SNUH cyclotron Category Combustible paper Combustible plastic Combustible timber Non-combustlble concrete Weight(ton) Feature Decontamination facilities Byproduct & Workers wearing Byproduct Remove contaminated parts and in quantities exceeding 105 times the applicable quanti- ties. DFP should be prepared without delay, and the following information must be included in the DFP [8]: i. A detailed cost estimate for the decommissioning that reflects: (A) the cost of an independent contractor to perform all decommissioning activities; (B) the cost of meeting 10 CFR 20.1902 criteria for unrestricted use, provided that the applicant or licensee can demonstrate its ability to meet the provisions of 10 CFR 20.1403 (the cost estimate may be based on 10 CFR 20.1403 criteria); (C) the volume of onsite subsurface material containing residual radioactivity requiring remediation to meet the crite- ria for license termination; and (D) an adequate contingency factor.

Identification and justification for the use of the key assumptions contained in DCE. iii. A description of the method to assure funds for decom- missioning from paragraph (f) of this section, including the means of adjusting the cost estimates and associated funding levels periodically over the life of the facility. iv. A certification by the licensee that financial assurance for decommissioning has been provided in the amount of the cost estimate for the decommissioning. v. A signed original of the obtained financial instrument to satisfy the requirements of paragraph (f) of this section (un- less a previously submitted and accepted financial instrument continues to cover the cost estimate for the decommission- ing).

West Virginia University intended to install the ion beam application (IBA) PET trace self-shielded cyclotron for $150,000 of the DFP cost. This estimate was not feasible for safe decommissioning using current radiological data. The NRC required $ 356,263.68 for DFP cost in detail and also refused to authorize the submission of insufficient DFP [9].

IV. RESULTS AND DISCUSSION The problem with the statute is that the decommissioning plan should be submitted by the applicant before the instru- ment approval of the medical cyclotron, which is not the case how- ever in the Republic of Korea. Henceforth, the basis of decommissioning preplanning should be reviewed during the installation of the cyclotron itself to encourage each cyclotron user to take responsibility for safe de- commissioning actions.

Beyond the cause and effect that provided essential input to this study and addressed an appropriate solution of issues related to medical cyclotron decommissioning, we are con- sidering the introduction of DFP at the authorization stage.

Preparing reliable decommissioning plans for future safe de- commissioning and unexpected early decommissioning will be helpful. DFP can also contribute to the reduction of ra- dioactive wastes and decrease the decommissioning cost by preventing excessive establishments.

A. Expectation from the adoption of DFP The decommissioning of medical cyclotron is set to be- come an increasingly important issue in the Republic of Ko- rea in the future. According to the results of the DFP adop- tion [10–12], DFP offers a decommissioning plan overview, which covers the financial problem underlying the disposal of radioactive wastes and preparatory measures for appropriate dismantling strategies.

B. Future consideration for the adoption of DFP In the current domestic situation, additional research on the adoption of DFP is necessary. First, the standard data on decommissioning medical cyclotrons to estimate the DFP cost and the revision of the rules and regulations should be modernized. Second, if the cost of the entire decommission- ing process is not well planned, then the procedure should demonstrate the alternatives and legitimacy of all the various S010301-3 Rina Woo et al.

Nucl. Sci. Tech. 25, S010301 (2014) funding plans. The expiration date for relevant documents and records should be recent by the time of the operation of the cyclotron facilities and should be regularly comple- mented.

ChinaXiv 合作期刊 [1] IAEA, Decommissioning of Small Medical, Industrial and Re- search Facilities, IAEA technical report series No. 414, 2003. [2] IAEA, Decommissioning of Medical, Industrial and Research Facilities, IAEA safety standard series NO. WS-G-2.2. 1999. [3] IAEA, Decommissioning of Facilities Using Radioactive Ma- terial, IAEA Safety Requirements No WS-R-5, 2006. [4] Calandrino R, del Vecchio A, Savi A, et al. Health Phys. 2006, 90: 588–596. [5] Collins E L, Boyance J, Clark F R, et al. Decontamination and Decommissioing of the 60" cyclotron facility at Argonne Ba- tional Laboratory-East Project Final Report, ANL, 2011. [6] European Commission Nuclear Safety and the Environment, Evaluation of the Radiological and Economic Consequences of Decommissioning Particle Accelerators, REPORT EUR 19151, March 1999. [7] IAEA, Management of small quantities of radioactive waste, IAEA-TECDOC-1041, 1998. [8] U.S. NRC. Financial assurance and recordkeeping for decom- missioning (10 CFR 30.35), http://www.nrc.gov/reading-rm/doc-collections/cfr/part030/ /part030–0035.html [9] U.S. NRC, International Cyclotron, Inc. Notice of violation and proposed imposition of civil penalties - $7000—and order suspending licensed activities within 60 days.

Note: Figure translations are in progress. See original paper for figures.