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Transport of Dis-assembled Cyclotron

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ABSTRACT

Cyclotrons are usually operated to produce radioisotopes for medical researches and clinical diagnostic nuclear medicines in Korea. Until the end of 2012, 38 cyclotrons have been installed and some of them operated more than 15 years in Korea.

Seoul National University Hospital (SNUH) has operated a model Ebco TR-13 cyclotron for the same purpose since 1994. And following the operation of new cyclotron, they became to decommission it from June 2011 to autumn of 2012. According to 18 years operation, the cyclotron magnet, shieldings and other components had been activated. However, SNUH decided to donate the cyclotron to Sungkyunkwan University (SKKU) in Suwon, Gyeonggi-do, for research and education rather than disposal.

After decommissioning, they had to follow the transport regulations to carry all components from SNUH to SKKU. Because cyclotron magnet and other components were different shaped, weighed from 0.23 to 20 metric tons, showed various radiation levels, it was difficult for SNUH to select transport packaging. SNUH asked ‘approval of special arrangement’ to the Korea Institute of Nuclear Safety (KINS).

KINS reviewed SNUH’s decommissioning results and transport plans according to the provision of the Regulations of Technical Standards on Radiation Safety Controls etc. And Nuclear Safety and Security Committee issued approval for transport under special arrangements in December 2012. Every component was surveyed, wrapped with plastic film preparing for rain or snow, labeled, placarded and shipped with shipping documents. The dis-assembled components were transported by 5 vehicles from 21 to 22 December, 2012.

Nowadays some companies and hospitals that operate cyclotrons have plans to take out of service. The final step of cyclotron decommissioning process would be transport of dis-assembled activated components. According to this first experience, we will be able to make proper requirements and procedures for cyclotron decommissioning.

Introduction

In Korea, many cyclotron centers have been established for the purpose of academic research and medical use since 1985. Recently, as a part of the national policy to improve the health and welfare, cyclotrons required to radioactive medicine produce have been installed actively. These cyclotrons are used mainly to produce fluorine-18 necessary for Fluoro-deoxy-glucose (FDG) which is used in the positron emission tomography (PET) and PET-CT. There are 38 cyclotrons are in operation in 2012.

Cyclotrons installed in Korea during 1980s and 1990s were manufactured by foreign companies such as GE, CTI-Siemens, Ebco, IBA, Sumimoto, etc. and cyclotrons developed by Korea Institute of Radiological & Medical Science (KIRAMS) started to be installed from 2004.

Though it can differs from each maker or operator, the mechanical life of the cyclotron is known about 30~40 years in general. However, many cases reviewed by former study showed that the main cause of cyclotron facilities decommissioning was not life nor aging but transferring to other place or replacing with better one. In Korea, there had not been any cases of cyclotron decommissioning until 2011. The first case was in 2012, which was dis-assembling of the cyclotron installed at Seoul National University Hospital (SNUH) in 1994.

While in operation of a cyclotron, accelerated particles with high energy cause nuclear transform of target materials, and inevitably it can cause activation on shielding and mechanics of cyclotron, and even on building materials.

Because of such activation, packages contain some amount of radioactive materials, and we have to consider applications of transport regulations when carried dismantled components to other place.

In this article, I would like introduce the experience of cyclotron decommissioning at SNUH and transport to other university under the special arrangement.

Dismantling Cyclotron

Cyclotron is a type of ion accelerators, which applies the high-frequency voltage between two semi-circular accelerating electrodes installed between two circular magnets. Ions in a constant magnetic field have constant angular speed regardless of energy. Whenever they pass through the electrodes, ions are accelerated by high frequency electric field, the turning radius are increased. It makes ions draw spiral shaped trajectory and get high energy. In accordance with the principles, (p, n) reaction can take place at some components of the cyclotron, such as targetry, stopper, DEE and some parts of electromagnets. That leads activation on those components.

Cyclotron operated by SNUH

Figure 1. Ebco TR-13 Cyclotron

The first cyclotron decided to decommission was an Ebco TR-13 installed at SNUH in 1994. The main purpose of the cyclotron running was to generate Fluorine-18 used for Fluoro-deoxy-glucose (FDG) production.

Ebco TR-13 model was an iso-chronous cyclotron with compact magnet structure and an external ion source. There were four hills and four valleys with a narrow hill gap to give high flutter and strong focussing. The acceleration was done with two, in phase, 45° Dees in opposing valleys to give a large energy gain per turn and to reduce the acceleration time and minimize beam loss by stripping of the negative ions in the cyclotron. Acceleration energy was 13 mega electron-volts, and output current was 50 micro amperes with dual mode.

Following the new cyclotron in operation, SNUH made plan to quit the cyclotron TR-13 operation. Rather than disposal it, SNUH decided to donate the cyclotron to Sungkyunkwan University (SKKU) in Suwon, Gyeonggi-do for research and education.

Surface radiation dose rates of the targetry and the stopper measured before dismantling showed actual activation. The maximum surface dose rate was 1.2mSv/hr at the stopper, and 1.0mSv/hr at the targetry respectively. On the other hand, surface radiation levels on walls around the cyclotron were background levels.

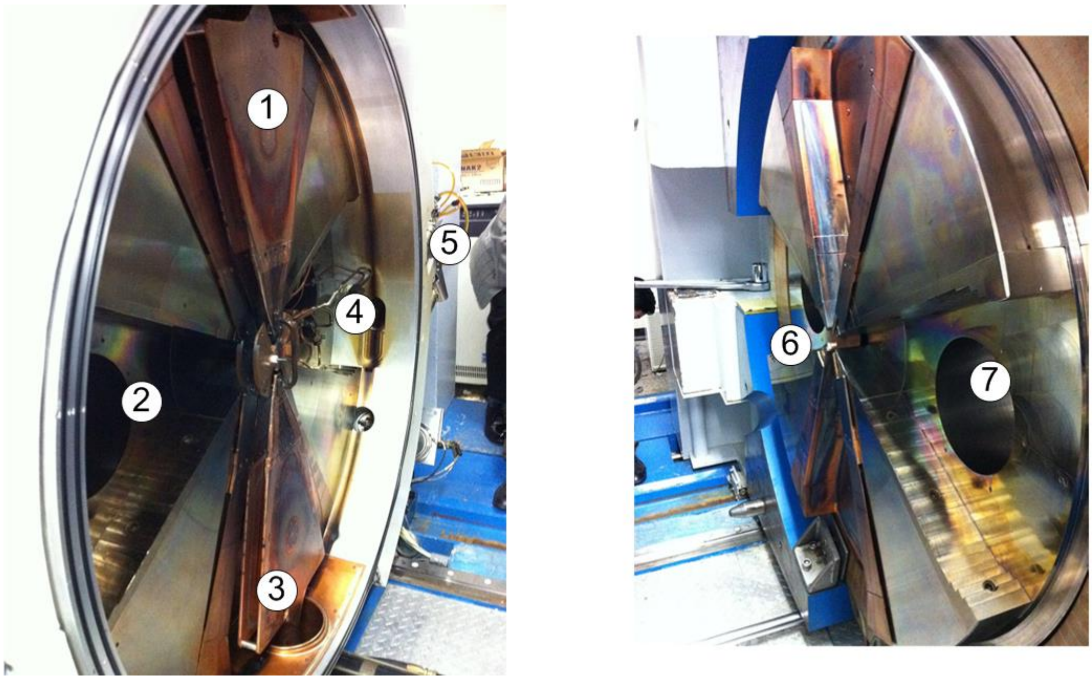

Figure 2. Survey points inside of the cyclotron [body side (left) and cover side (right)]

Table 1. Dose rate before and after dismantling some components

No.	Points	Dose rate before dismantling some components (μSv/hr)		Dose rate after dismantling some components (μSv/hr)	
		Surface	20cm	Surface	10cm
1	Dee	40	5	8.0	2.3
2	Magnet Valley	5	0.15	0.5	0.2
3	Dee	15	2.5	6.2	2.0
4	Stopper	1,200	92	4.0	1.5
5	Targetry	1,000	70	50	3.3
6	Cover side	5	-	3.5	0.4
7	Magnet Valley	2	-	3.5	0.4

Table 2. Dose rate of dismantled some components

Component	Dose rate (μSv/hr)		Component	Dose rate (μSv/hr)	
	Surface	10cm		Surface	10cm
Stopper	1,320	100	DEE(down)	25	2.5
Beam extraction	8.7	1.3	Shield plate(up)	98.9	7.0
Targetry	180	30	Shield plate(down)	60	6.0
Beam collimator	27	1.3	Target body	37.5	7.6
DEE(up)	18	2.3	Targetry side	7.2	1.2

Transport

Each component of the dismantled cyclotron showed different radiation level, and the higher surface radiation level were shown around the targetry. Some components were heavy and large for handling in complex and small space in the old building. Some shielding components, which contain large amount of steel sand (small iron balls mixed cooling water), weighted over 9 metric tons. Though the radiation level was not so high, steel sand was activated slightly over the exemption level. But partially it showed 1.3 mSv/hr of surface radiation level.

At first SNUH had plans to transport steel sand in shielding beforehand, and they transport it using drums for IP-1 package. But because steel sand was mixed with coolant water, it was difficult to pack a lot of drums. So, they changed the plan to transport shielding components with steel sand. Because the radiation levels were vary and there were some errors in estimation of specific activities, and it was hard to meet the transport regulations for preparing consignments, special arrangement was considered for the safe transportation.

Special arrangement

Korea adapted most provisions of the IAEA Regulations for Safe Transport of Radioactive Materials (TS-R-1). Provisions of ‘notification for transport’, ‘compliance with the relevant technical regulations’, ‘training and radiation dose monitoring of transport workers’, ‘emergency response’, ‘inspection’, ‘design approval of transport packages’, etc. are included in the AESA, the Enforcement Decree of AESA, the Enforcement Regulations of AESA, and the Regulations on Technical Standards for Radiation Safety Control, etc. (Radiation Regulations), and Notices of the Nuclear Safety and Security Committee (NSSC).

According to Article 94 of the Radiation Regulations, in case those actions necessary for safety were applied, radioactive materials which cannot be prepared in accordance with the provisions can be transported under the special arrangement.

The cyclotron transported was composed with vary shaped components with very diverse radioactivity distributions. The weight was large up to 20 metric tons. Average specific activity for shield was about 10Bq/g, but locally much higher specific activity was expected, at where radiation level was over 5μSv/h. Because of complex shapes and radioactivity distributions, applying transport packaging wasn’t appropriate, transport under special arrangement was considered.

Special conditions to transport the dismantled cyclotron were;

- to survey radiation revels and estimate activity of radioactive material by package,
- to determine surface contamination before transport radioactive material packages and, if necessary, to decontaminate,
- to apply the transport category ‘III-Yellow’
- to train workers on the transport safety and emergency plans before dismantlement,
- to give workers directly readable dosimeters for checking radiation dose,
- to make the areas where works such as preparation, carrying, loading on truck would be expected temporary controlled area,
- to wrap radioactive materials with plastic film to prevent contamination spread,
- to minimize impacts during transportation and consider how to protect the plastic wrap against damage during loading on vehicles,
- to check safety functions of vehicles,
- to avoid over loading,
- to control people not to touch packages on vehicles when they wait on the road,
- to check contamination on vehicles after transportation,

Figure 3. Transport of some part of steel sand and coolant

- to consider the used plastic wrap as radioactive waste after transportation,
- to follow the notified route and , if necessary, receive allowance from the regulatory inspector about changing the route,
- and not to transport in case of heavy rain, storm or snow which warned by the national weather service.

Transport to SKKU

Dis-assembled cyclotron components were transported to SKKU in Suwon, Gyeonggi-do, during 21 and 22 of December 2012. The cyclotron was divided with 16 main components. There were 3 shield boxes for small components with high radiation levels, main body, 11 shield housings, base plate and some electricity lines and pipes. The heaviest was main body which composed cyclotron magnets and other important parts, and it weighed about 20 metric tons. Shield housings were large steel cases with steel sand mixed with coolant, and weighed up to 9.23 metric tons. At first, they considered transport steel sand with another drums, but the shield housing were expected to have sufficient integrities, they decided to transport housings contained steel sand.

According to the results of surface radiation surveillance, radiation levels at 3 meters were lower than 10mSv/hr and that meant main body, shielding housings and base plate were able to be transported as LSA-I. But there were some mistakes in determining specific activities of the cyclotron components done beforehand, and detectable points were restricted before dismantlement.

The hardest thing was to carry heavy and large objects through the narrow and long hallway of the old building. Around the building where the cyclotron installed, some newer buildings had been constructed. The buildings were connected with long and narrow hallway. The components of the cyclotron should be carried out along the hallway. For dismantlement of cyclotron and carrying its components in the small space, special workers were invited. They had been trained about radiation safety and patched individual dosimeter. Because the place was very crowded hospital, carrying packages had to be done at night time to make easy control public.

The radiation level and the surface contamination of each component was surveyed after dismantlement and wrapped with plastic film to prevent spread contaminations and permeation of rain water.

5 vehicles which could load 5, 11 and 24 metric tons by each were used. Especially main body of the cyclotron weighed 20 metric tons was carried on a low bed trailer of which capacity was 24 metric tons.

Packages described in the shipping documents were like these;

- Radioactive material Special Arrangement, Class 7, UN2919, activated materials contains Zn-65 etc. 630.41 MBq, LSA-1, Category III - Yellow, TI 0.2

According to the article 75 of AESA SNUH requested regal inspection. Through the inspection main check points were;

- training for workers including special working group for dismantling and transporting through narrow hallway, and drivers of vehicles about radiation safety and some impotent conditions imposed by NSSC,
- wearing dosimeter for radiation dose and surveying radiation levels and contaminations of working places and packages,
- marking, labeling and placarding,
- appropriateness of vehicles with noticed ones,
- loading packages
- radiation level of the vehicles
- wrapping and measures to prevent contamination spread, and
- radiation dose received by workers.

Dismantling, checking for radiation levels and contaminations, wrapping, marking and labeling, documentation, carrying, loading, placarding and transferring were progressed slowly and safely. The transfer was started at 4:00 pm on 21 December and it continued until 6:00 am on 22 December. Every vehicle was accompanied by radiation safety controller (similar to RSO) who had radiation survey meters and some necessary toolkit. Though there was some snow on the road, all 5 vehicles item had been transported to SKKU safely.

Radiation dose

Dismantling, packing, carrying and transportation were done in very hard circumstance. Especially dismantling into components which weigh up to 9 metric tons in the small cyclotron vault and carrying through narrow and complex hallway could not help being done by special team. To monitor dose of individuals they monitor the working spaces and applied TLD as dosimeter. Fortunately there were no evidence those workers received radiation dose.

Figure 4. Dismantling by special working group and preparation for transportation

Conclusion

The cyclotron Ebco TR-13, operated over 18 years, had been activated on DEEs, Magnet Valley, Stopper, Targetry, Cover side and other shielding components. Highly activated components were Stopper, Targetry and DEEs. Most of components were activated to considerably low level. So, if those items had been prepared well, most of them could be transported as LSA-1 material. But there had been necessities of careful surveillances because of possibility of some hot points.

It was the first experience to dismantle cyclotron facilities. Through the dismantlement of Ebco TR-13 done by SNUH, one of lessons learned was the necessity to establish regulatory provisions for dismantlement of high energy accelerator facilities. We have plans to collect more experiences and make a basement for dismantlement of high energy accelerator facilities. It will include considerations about assessment of activation, transport and disposal of activated components on the decommissioning stage.

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