INDUCED RADIOACTIVITY RESEARCH FOR SCRAPER*

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Abstract

The 200MeV electron linac of NSRL (National Synchrotron Radiation Laboratory) is one of the earliest high-energy electron linear accelerators in China. The electrons are accelerated to 200MeV by five accelerating tubes and collimated by the scraper followed each accelerating tube. The scraper aperture is smaller than the accelerating tube, so some electrons will hit on the structure materials when they pass through them. These lost electrons will cause induced radioactivity due to bremsstrahlung, cascade shower and photo-nuclear reaction. The experimental results showed that electrons were lost mainly at the scraper during the accelerating period. Meanwhile, the induced radionuclide types have been studied. Recently, the linac mentioned above has been retired because of upgrading. The equipments and materials removed are used to study induced radioactivity generated in different materials. The research will provide the theoretical basis for the similar accelerator decommissioning plan, and is also significant for accelerator structure design, material selection and radiation protection programs design.

Key words: High-energy Electron Linear Accelerator, Scraper, Induced Radioactivity, Decommissioning

INTRODUCTION

The Synchrotron Radiation Facility of National Synchrotron Radiation Laboratory is composed of 200MeV electron linear accelerator (NSRL Linac) and 800MeV electronic storage ring [1]. The 200MeV Electron Linac is one of the earliest high-energy electron linear accelerators in China. Its acceleration process is: lower-energy electrons emitted from the electron gun are progressively accelerated to about 200MeV in five accelerating tubes, and then injected into the electron storage ring. The electrons will be slowly accelerated to 800MeV in the ring.

NSRL Linac has been retired because of upgrading recently. Its decommission will produce many real problems. The particle accelerator, which energy is over 10MeV, will produce induced radioactivity more or less [2-3]. At present, there is no any decommissioning experience and related data for the high-energy electron linear accelerator at home. Therefore it is a good chance to carry out in-depth study of induced radioactivity. Detail study and evaluation can be completed.

The scraper fixed after each accelerating tube is used for beam collimation. Its length increases with the energy increasing. The aperture of scraper is smaller than the accelerating tube, so it is reasonable that particles mainly loss at the scraper. At the same time, the experimental results show that the induced radioactivity in the accelerating structure except scraper can be ignored. So only the experimental results about the induced radioactivity of the scraper are described here.

Figure 1: NSRL Linac.

BEAM LOSS EXPERIMENTAL MEASUREMENTS

Scraper

200MeV electron linear accelerator of NSRL consists of five acceleration tubes, and each tube is followed by a scraper. The scrapers' lengths are different. They increase slightly with the energy increasing. The electrons are accelerated up to the expected energy in each acceleration tube and collimated by the scraper followed. The scraper pore diameter is 1cm, while the pore diameter of the accelerating tube is 4.8cm. The scraper aperture is smaller than the accelerating tube's, some electrons will hit on the scraper due to energy dispersion. These lost electrons will cause induced radioactivity because of bremsstrahlung, cascade shower and photo-nuclear reaction. The experimental results have really confirmed that electrons were lost mainly at the scraper during the accelerating period.

Experimental Measurements

In order to study the beam loss in 200MeV electron linear accelerator of NSRL, the thermoluminescent dosemeters (TLDs) were placed before and after the scraper (as shown in Fig.2). TLDs were used to measure the cumulative doses for 5minuts, 10minuts, etc. Finally, the data results were plotted and shown in Fig.3.

*Work supported by NSFC(11175180 and 11175182)
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ISBN 978-3-95450-122-9

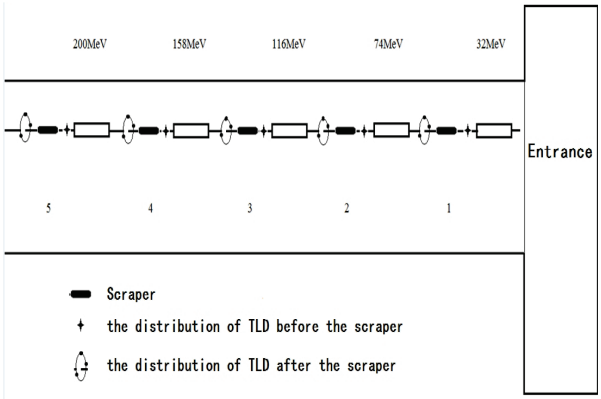


Figure 2: TLD Distribution Diagram.

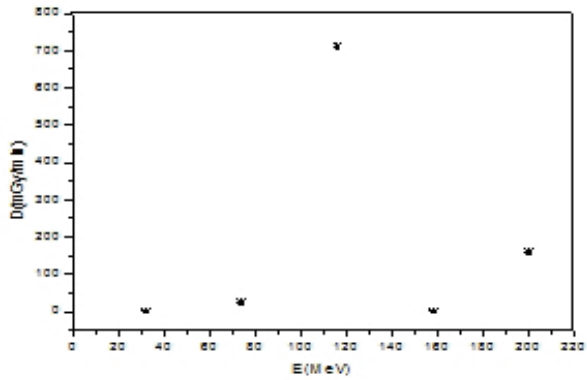


Figure 3: Beam Loss Measurement Results.

Discussion and Analysis of Experimental Results

The results shows that the beam loss at the third scraper (followed the accelerating tube with 116MeV) is greatest. The reason may be that the position deviation of the third scraper resulted from the uneven settlement of foundation during the latter operation period. The beam loss here is serious. Quantity of electrons hit on the scraper. This leads to a higher result at the third scraper.

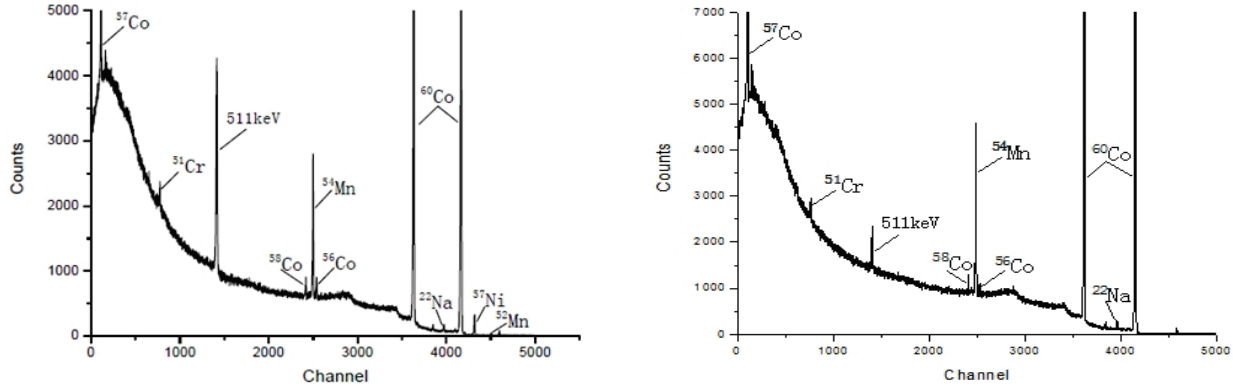
INDUCED RADIOACTIVITY OF THE SCRAPER

Radioactivity Prediction of the Scraper

The literatures show that radionuclides may be generated at the scraper were preliminarily determined, see table 1.

Table 1: Prediction Nuclides in the Structural Material of the Scraper

Parent Nucleus	Reaction Type	Radionuclide	$T_{1/2}$	Threshold (MeV)	Ray Type Emitted From Nuclide (keV)	Measured Or Not
Fe-57	(γ,p)	Mn-56	2.576h	10.57	5β, γ (846.7,1810.7,2113)	
Cu-63	(γ,2n)	Cu-61	3.32h	19.73	5e+, 3e, γ (511,282,656)	
Cu-63	(γ,sp)	Co-58m	9.2h	41.75	5e, γ (6.9)	
Cu-65	(γ,n)	Cu-64	12.80h	9.91	1β, 1e+, 2e, γ (511,1346)	
Ni-58	(γ,n)	Ni-57	36.0h	12.19	4e+, 4e, γ (511,1377,1919,127,6.9)	yes
Fe-54	(γ,np)	Mn-52	5.6d	20.89	1e+, 2e, γ (1434,935.5,744,511,5.4)	yes
Fe-54	(γ,sp)	Cr-51	27.72d	19.74	2e, γ (4.95,320.08)	yes
Fe-58	(n,γ)	Fe-59	45.6d	——	5β, γ (099,1291)	
Cu-63	(γ,sp)	Co-58	71.3d	41.75	1e+, 2e, γ (810.7,511)	yes
Fe-54	(γ,sp)	Sc-46	83.9d	37.41	2β, γ (1120.5,889)	
Fe-56	(γ,np)	Mn-54	303d	20.42	2e, γ (834.83,5.4)	yes
Fe-56	(γ,n)	Fe-55	2.60a	11.21	2e, γ (5.899)	
Cu-63	(γ,n2p)	Co-60	5.263a	18.86	1β, γ (1173,1332)	yes
Cu-65	(γ,np)	Ni-63	92a	17.11	1β	



(a) 1h After the Machine Shut Down (b) Half a Month After the Machine Shut Down

Figure 4: γ Spectrum of the Forth Scraper (158MeV) for the Different Downtime.

Induced Radioactivity Measurements

In order to study the induced radioactivity of the scraper, a portable HPGe γ spectrometer (GR3519) was used to measure γ spectrum of the forth scraper (158MeV) after the machine shut down for 1h and half a month.

Discussion and Analysis of the Radionuclides

The measured radionuclides are also listed in table 1, which are compared with the predicted nuclides. This can provide a certain direction for the latter part of the experimental work.

By observing Figure 4 and Table 1, one can see:

- The induced radionuclides generated at the scraper are mainly Ni-57, Mn-52, Cr-51, Co-58, Mn-54, Co-60, Na-22, Co-56, Co-57, etc. The first six nuclides are predicted.
- Through the comparison of (a) and (b) in Fig.4, we find that the short-life nuclides are markedly reduced, such as Ni-57, Mn-52.
- Meanwhile, we can find that the peak of 511keV are significantly decreased, indicating that some short-life nuclides which can produce positrons are markedly reduced, such as Ni-57, Mn-52.

CONCLUSION AND PROSPECT

In this work, TLD was used to measure cumulative dose at the scrapers followed the accelerating tubes with different energy. The results showed that electrons were lost mainly at the scraper during the accelerating period. In addition, the induced radioactivity at the forth scraper (158MeV) has been studied. Some conclusions have been described in the last section.

Recently, the linac mentioned above has been retired because of upgrading. The research about induced radioactivity is just beginning, so there are still many questions to ponder and further tasks to do:

- The radionuclide's types, content data and decay laws in copper need to improve by the long-term measurements.
- Whether or not the scraper with higher level of the induced radioactivity also need the long-term measurements, which may be used to explain that the scraper plays a very important role in protecting the accelerating tubes.
- At present, the copper of the scraper followed the accelerating tube with 158MeV has been sliced, the radionuclides in it are being measured. At the same time, in order to get the relationship between the photon energy and the produced nuclides, Monte Carlo program EGSnrc is being used in the simulation.
- In the future, the author will use FLUKA for simulating the induced radioactivity at the scraper and compared with the measured results. Meanwhile, in order to get the corresponding relationship between the electron energy and nuclide type, induced radioactivity at the scrapers followed the accelerating tubes with different energy will be measured.

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ISBN 978-3-95450-122-9