Analysis of Residual Nuclide in a ACM and ACCT of 100-MeV proton beamline By measurement X-ray Spectrum

Jeong-Min Park*, Sang-Pil Yun, Han-Sung Kim, Hyeok-Jung Kwon, Yong-Sub Cho
KOMAC, Korea Atomic Energy Research Institute
**corresponding Author: jmpark027@kaeri.re.kr*

1. Introduction

Korea multi-purpose accelerator complex (KOMAC) has been operating with 20 MeV and 100 MeV beam lines since 2013. The proton beam is provides to users as various energy range from 20 MeV to 100 MeV.

After protons generated from the ion source are accelerated to 100 MeV and irradiated to target through bending magnet and AC magnet. At this time, relatively high dose X-ray is emitted due to collision of proton and components of beamline. The generated X-ray is remaining after the accelerator is turned off and analyzing residual nuclides through the measurement of X-ray spectrum. Then identify the components that are the primary cause of residual nuclides are detected form the AC magnet(ACM) and associated components (ACCT).

2. Experiment and Results

Generated X-ray form the ACM and relevant part(ACCT) is measured by HPGe detector and the spectrum obtained. Using a ^{60}Co source, energy calibration was performed before the measurement of the HPGe detector. Distance between the detector and ACM, ACCT is set based on the detector dead time of less than 10% and each measured X-ray placed in the 16.5 cm(ACM), 5 cm(ACCT) from the detector during 300 sec(live time). Fig.1 shows the experimental set equipment. ACCT was measured the past nine month nine month after the separated from the ACM.

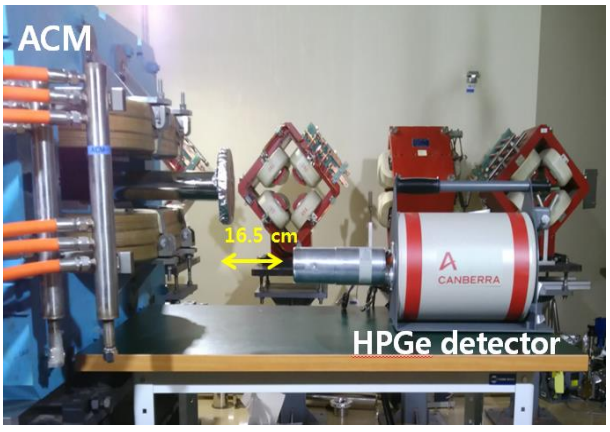

Fig. 1. Set of HPGe detector and AC magnet(ACM) of 100 MeV beamline

ACM materials are consist of Fe(YOKE) and Cu(coil), beam pipe(stainless steel) is located in the center of ACM. ACCT body material is stainless steel(STS) and ceramic Al_2O_3 is contained in the current gap and residual nuclides are emitted by the collision of proton beam with these materials.

Figure 2. and Figure 3. shows the energy spectrum of ACM and ACCT obtained by the HPGe detector(Geine2000).

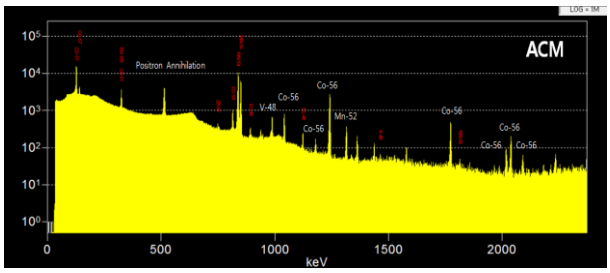

Figure 2. X-ray spectrum of AC manget(ACM)

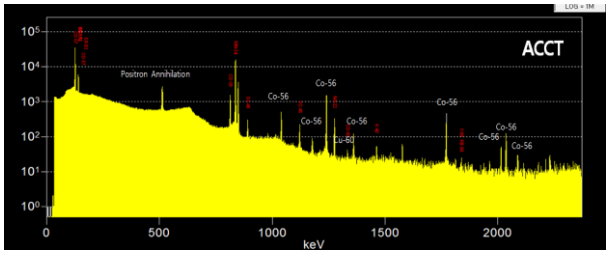

Figure 3. X-ray spectrum of ACCT

Using the mcnp simulation to identified the emitted residual nuclides in accordance with materials of ACM and ACCT and several nuclides are not contained in the default nuclear list of Genie2000(HPGe detector) then compared to nuclides detected by HPGe detector. As a result of the analysis, ^{46}Sc, ^{48}V, ^{51}Cr, ^{56}Co, ^{57}Co, ^{58}Co, ^{52}Mn, ^{54}Mn, ^{56}Mn were identified from ACM and these nuclides were emitted stainless steel(STS) mainly. In the ACCT, ^{46}Sc, ^{56}Co, ^{57}Co, ^{58}Co, ^{56}Mn, ^{60}Cu, ^{22}Na were identified. ^{22}Na was emitted from the Aluminum Oxide(Al_2O_3) contained in the wall current gap of ACCT and other residual nuclides were mainly emitted from stainless steel(STS). A peak at around 511 keV is considered as positron annihilation peak and a peak at 1461 keV is ^{40}K, which is a natural radioactive isotope.

Table1. shows search peak list and nuclides corresponding to the energy.

Table 1. residual nuclides list

No.	X-ray Peak (KeV)		Residual Nuclildes			Half-life	Remark
	ACCT	ACM	HPGe	MCNP	etc.		
1	121.92	121.09	^{57}Co	^{57}Co		270 d	
2	136.35	135.57	^{57}Co	^{57}Co		270 d	
4		319.39	^{51}Cr	^{51}Cr		28 d	
6	510.98	510.61					positron annihilation peak
7		744.15			^{52}Mn	5.6 d	
8	810.88	810.79	^{58}Co	^{58}Co		70.86d	
9	834.95	834.84	^{54}Mn	^{54}Mn		312d	
10	846.99	846.77	^{56}Mn	^{56}Mn ^{56}Co		2.5h / 77d	
11	889.38	889.31	^{46}Sc			83.8 d	
12		935.72			^{52}Mn	5.6 d	
13		944.22		^{48}V		16 d	
14	977.43	978		^{56}Co		77d	
15		983.71		V-48		16 d	
16	1038.01	1038.11		^{56}Co		77d	
17	1120.78	1120.76	Sc-46			83.8 d	
19	1174.65	1175.18		^{56}Co		77 d	
20		1238.3		^{56}Co		77 d	
22	1274.38		^{22}Na	^{22}Na		2.6 y	Aluminum oxide(Al_2O_3)
23		1312.24		V-48		16 d	
24	1332.53		^{60}Cu			23.7 m	
25	1359.99	1360.38		^{56}Co		77 d	
26		1434.23			^{52}Mn	5.6 d	
27		1443.84					unknown
28	1460.9	1461.03	^{40}K			1.25E+9 y	natural radioactive isotope
29	1576.22	1576.98					unknown
30	1771.43	1772.02		^{56}Co		77 d	
31		1811.16	^{56}Mn	^{56}Mn ^{56}Co		77 d	
33	1836.43						unknown
34	1963.97			^{56}Co		77 d	
35	2015.27	2016.04		^{56}Co		77 d	
36	2034.98	2035.78		^{56}Co		77 d	

3. Conclusion

Analysis of the X-ray spectrum generated form the AC magnet(ACM) and AC current transformer(ACCT) of 100 MeV beamline according to the proton beam irradiation, most of the residual nuclides are identified it can be seen that emission in the stainless steel by beam loss.

Acknowledgements

This work was supported by Ministry of Science, ICT & Future Planning of the Korean Government.

REFERENCES

[1] Radiation Detection and Measurement, 2nd, Glenn F. Knoll, Professor of Nuclear Engineering The University of Michigan Ann Arbor, Michigan
[2] Gamma Ray Spectrometry, Nafaa Reguihui, 2006
[3] National Nuclear Data Center (www.nndc.bnl.gov)