RESIDUAL RADIOACTIVITY IN THE 160 CM CYCLOTRON AND ITS SURROUNDING FACILITIES

I.Kohno,M.Miyagawa,Y.Matsuzawa,S.Kagaya,H.Kato and T.Katou

RIKEN(The Institute of Physical and Chemical Research)
Wako-shi,Saitama,351-01 Japan

Abstract

Residual γ-ray-emitting radio-nuclides in components of the RIKEN 160 cm cyclotron and its surrounding facilities have been measured with HPGe detector. These measurements were made before decommissioning of the cyclotron and its surrounding facilities at about one year after the shutdown of the machine.

Introduction

The RIKEN 160 cm cyclotron was shut down at the end of April 1990 after 23 years operation.During 23 years the cyclotron was typically in use for 4000 to 5000 hours/year and produced beams of p,d,^{3}He,^{4}He or lighter heavy ions(^{12}C,^{14}N,^{16}O and ^{20}Ne).Cyclotron characteristics and operation record during 23 years

Table 1 γ-ray dose measured around the cyclotron. Alphabets indicate detection points.(see Fig.1)

Detection point	NaI scintillation survey meter (Sv/h)	Ionization chamber survey meter (Sv/h)
A		1.4
B	2.9	1.5
C	8.0	8.0
D	1.0	0.8
E	9.5	7.0
F	5.5	4.0
G	4.0	2.4

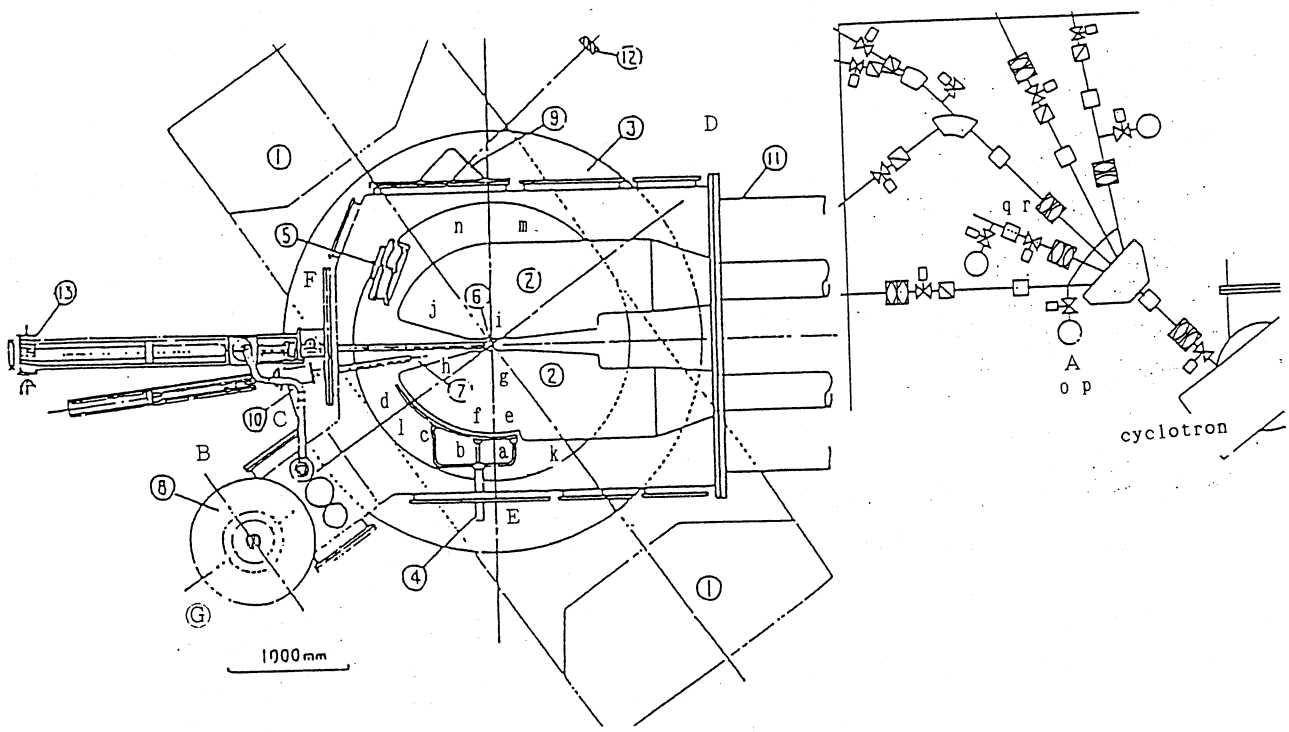

Fig.1. Schematic view of the accelerating chamber arranement and beam transport system
1,Side yoke;2,Dees;3,Coiltank;4,RF-deflector;5,Beam focusing magnetic channel;6,Ion source;7,Beam probe;8,32"oil diffusion pump;9,Beam exit flange;10,Exhaust pipe for ion source;11,Oscillator tank;12,Gate drop probe;13,Winch
A,B,C,D,E,F and G indicate points measuring γ-ray. G point is outside the bottom part of diffusion pump.
Alphabets of small letter indicate points smeared.
a,b,c,d;deflector electrode,e,f:septum electrode,g,h,i,j:Dees
k,l,m,n:earth plate,o,p,q,r:inside the slit box.

were reported in the other literature[1]. Accelerated beam energies ranged from 5 to 16 MeV at p, 8 to 25 MeV at d, 18 to 45 MeV at ^{3}He and 16 to 50 MeV at ^{4}He, and the internal currents of these beams were 10 to 50 μA. Heavy ions were accelerated at the energy from 60 to 150 MeV, and the average internal currents were about 1eμA. At these energies and currents measurable levels of radioactivity were produced in the cyclotron and its surrounding facilities. For purpose of discussing possible decommissioning of these facilities, it was necessary that there be available quantitative information on the degree of radioactivation. Some related studies of induced radioactivity in cyclotron laboratories have appeared in the literature[2)3)], but there is sufficient variation from one laboratory to another to require independent measurements for the 160 cm cyclotron before items can be released for disposal.

Measurements were made with three methods. At 1st radiation dose rate of several points outside the cyclotron and the slit box in the beam transport system were measured, and then γ-ray spectrum were measured with HPGe detector at the same points. Radioactivities in several materials inside the vacuum chamber were studied by measurement of smeared samples.

Measurement

Measurement of radiation dose rate

γ-ray dose rate were measured at various points (A~G) outside the cyclotron in the same height as beam line and the slit box as shown in Fig.1 with an ionization chamber survey meter and NaI scintillation survey meter. Table 1 summarizes dose rates measured.

Measurement of γ-ray spectrum

γ-ray spectrum were measured with HPGe detector at various points (A~G) to assign the radio-nuclides. Fig.2 shows a γ-ray spectrum measured at point F. The peak energies of the spectrum observed in Fig.2 and the assigned nuclides are listed in Table 2. Table 3 shows assigned nuvlides at all points measured (A~G).

Radioactive nuclides inside the vacuum chamber

γ-ray spectra of small samples smeared from several materials inside the vacuum chamber were measured. The γ-ray spectrum of sample a is shown in Fig.3 and the assigned nuclides are listed in Table 4. The Table 5 shows assigned nuclides in all smeared saples.

Table 2 Assigned radio-nuclides in the γ-ray spectrum measured at point F.

Peak no.	Peak energy (KeV)	Nuclide	$T_{1/2}$
1.	511		
2.	834	^{54}Mn	312d
3.	1037	^{56}Co	77d
4.	1115	^{65}Zn	244d
5.	1173	^{60}Co	5.27y
6.	1238	^{56}Co	
7.	1272	^{22}Na	2.6y
8.	1330	^{60}Co	

Table 3 Assigned radio-nuclides in the γ-ray spectrum measured at detection points

Detection point	Nuclide
A	^{22}Na, ^{54}Mn, ^{56}Co, ^{60}Co, ^{65}Zn
B	^{60}Co
C	^{56}Co, ^{60}Co, ^{65}Zn
D	^{22}Na, ^{54}Mn, ^{56}Co, ^{60}Co, ^{65}Zn
E	^{56}Co, ^{60}Co, ^{65}Zn
F	^{22}Na, ^{54}Mn, ^{56}Co, ^{60}Co, ^{65}Zn
G	^{22}Na, ^{60}Co, ^{65}Zn

Discussion and conclusion

The cyclotron and its surrounding facilities are made of iron(Fe), copper(Cu) and stainless steel(Fe, Ni, Cr). Radioactive nuclides assigned are ^{22}Na, ^{54}Mn, ^{56}Co, ^{60}Co, and ^{65}Zn. ^{65}Zn and ^{56}Co are supposed to be produced by the charged particle induced reactions ^{65}Cu(p,n), ^{65}Cu(d,2n) and ^{56}Fe(p,n), ^{56}Fe(d,2n), respectively. On the other hand ^{54}Mn and ^{60}Co are supposed to be produced by the neutron induced reactions ^{54}Fe(n,p), and ^{63}Cu(n,α), ^{60}Ni(n,p), ^{59}Co(n,γ), respectively. ^{65}Zn is supposed to be produced at the surface of copper

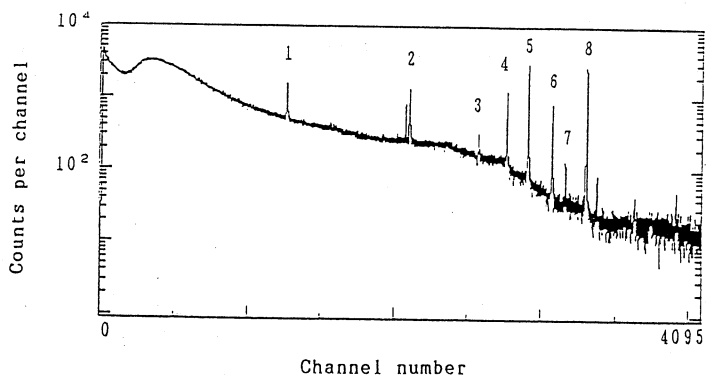

Fig.2 γ-ray spectrum measured at point F.

electrods and therefore,most of radioactive nuclides of smeared samples were ^{65}Zn.

The front part of the septum electrode was made of tungsten metal strip of 45 mm x 900 mm x 0.5 mm and the gap distance between the electrode and the deflector electrode was set to about 10 mm. Therefore, some samples smeared out from the deflector and the septum had radioactive nuclides ^{182}Ta, ^{183}Re, ^{184m}Re and ^{185}Os which were produced from tungsten by nuclear reactions.

Dose rates around the cyclotron and the constituent nuclides were found before decommissioning of the 160 cm cyclotron and its surrounding facilities at about one year after the shutdown of the machine. As was expected, we found only long lived nuclides, because the cooling time was so long to ensure the safety of the workmen who would be engage in the decomposition.

Though γ-ray dose rates around the cyclotron are not appreciable, quantity of the radioactivities found inside the cyclotron, most of which were ^{65}Zn and ^{60}Co are not so low level. We decided not to decompose the cyclotron, but to decompose its surrounding facilities.

References

1) The 160 cm Cyclotron(1966-1990).:RIKEN Accelerator Prog. Rep. Supplement (1990)
2) Y.Uemura et al..:Bull.Inst.Chem.Res.,Kyoto Univ. Vol.52,No.1,124 (1974)
3) A.B.Phillip et al..:Health Phys.,Vol.51,No.3,337 (1986)

Table 4 Assigned radio-nuclides in the γ-ray spectrum measured at the sample smeared out from the a point.

Peak energy (KeV)	Nuclide	$T_{1/2}$
67	^{182}Ta	115d
100	^{182}Ta	
162	^{183}Re	70d
209	^{184m}Re	166d
252	^{184m}Re	
292	^{184m}Re	
511		
646	^{185}Os	94d
1115	^{65}Zn	244d

Table 5 Assigned radio-nuclides in the γ-ray spectrum measured from smeared samples

smeared sample	Nuclide
a	^{65}Zn, ^{182}Ta, ^{183}Re, ^{184m}Re, ^{185}Os
b	^{65}Zn
c	^{22}Na ^{65}Zn
d	^{22}Na, ^{60}Co, ^{65}Zn
e	^{60}Co, ^{65}Zn, ^{182}Ta, ^{183}Re, ^{184m}Re
f	^{22}Na, ^{60}Co, ^{65}Zn, ^{182}Ta, ^{183}Re, ^{184m}Re, ^{185}Os
g,h,i,j	^{65}Zn
k,l,m,n	^{65}Zn
o	^{22}Na ^{65}Zn
p	^{22}Na
q	^{22}Na
r	^{65}Zn

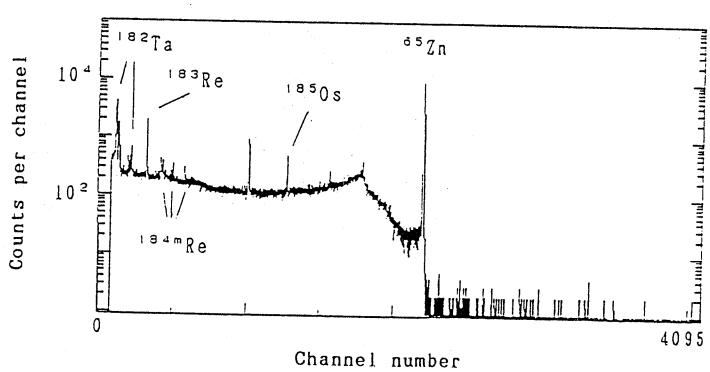

Fig.3 γ-ray spectrum of the sample a smeared out from the deflector electrode.