Decommissioning of CNS SF Cyclotron Facility

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The CNS SF cyclotron facility was decommissioned at the end of August 2000. The paper discusses the decommissioning procedures of the CNS SF cyclotron facility, especially describes the evaluation and separation of radioactive materials. The analysis of residual radioactivities in shielding, and transportation of activated materials are discussed.

1. Introduction

An operation of SF cyclotron was stopped at 13th Dec. 1999. Total amount of operation time was 36000 hours from the begging of first beam experiments. On Dec. 1999, decommissioning schedule was planned and disassembling of beam transport line was started at the beginning of Jan. 2000. The dismantling of SF cyclotron was finished at the end of June. 2000. The decommissioning program comprises, (1) a disassembling of SF cyclotron and beam transport line, and (2) a separation of activated material from the instruments and building. There were so many instruments in the SF cyclotron. Magnets, vacuum chambers, rf resonator, and their wiring and mechanical connection were tightly coupled with each other. Especially, SF cyclotron magnet was separated into four pieces of magnet yokes after dismantling the rf acceleration Dee. An identification and separation of radioisotope and their evaluation have been done on the basis of the "guide-line of decontamination for a particle accelerator". The measuring instruments and their calibration are ruled in the radiation safety control manual. Which are based on the guideline of IAEA, ICRP, and law of radiation protection in Japan [1-4].

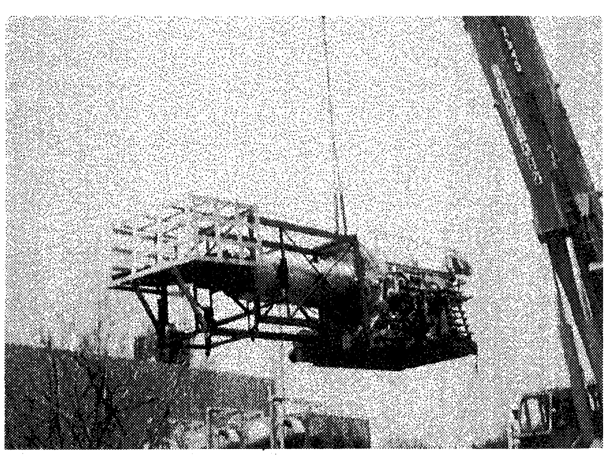

Fig.1 Lift-upped rf resonator of SF cyclotron to land on the KEK. The acceleration Dee (left side) was covered with Pb shield.

Figure 1 shows rf resonator transported from CNS-Tanashi campus. It is lift-upped to land on the KEK-Tsukuba. The decommissioning also includes a cleaning of the radioactive isotope in a ferroconcrete for a radiation shield. The radioactive isotope ^{60}Co, ^{134}Cs, and ^{152}Eu are generated and condensed in the ferroconcrete of the radiation shield. Especially, a fast neutron from the SF cyclotron activates wide area of the cyclotron room. The radioactive waste was transferred to the JRIA (Japan Radio Isotope Association). So, the planning of decommissioning was concentrated to the quantitative estimation of the radioactive material in the CNS SF cyclotron facility and determination of both the area and depth of decontamination of ferroconcrete.

This paper discusses the decommissioning of SF cyclotron facility. The severances and decontamination of the radiation shield are also discussed. A particle spectrometer was dismantled and has been moved to RIKEN. Dismantling of the spectrometer is discussed in the elsewhere.

2. Decommissioning procedures

The decommissioning comprises the survey of radioactive materials, disassembling the radioactive materials, severance of radioactive materials, transportation and storage of separated radioactive materials. There are so many radioactive materials in the SF cyclotron. For examples, a coaxial-type rf resonator, an acceleration Dee, a beam extraction channel, an axial injection system, a vacuum chamber and beam probes were activated with the accelerated ion beam.

During the beam acceleration, accelerated ion beam hit the electrodes such as the cone, Dee, deflector, and vacuum chamber at the exit of SF cyclotron. The beam hitting is a reason of the production of radioisotopes because of the gamma ray production and neutron capture. Due to the absorption of fast neutron, radioisotope is generated and remained in not only the cyclotron but also the steel bar for ferroconcrete in the radiation shield. The fast neutron is converted to the thermal neutron when it is passing through the water in the cooling water pipe.

Before the identification of the radioisotope, it was disassembled and moved to a low background area. The low background area was defined as the natural background room, where was providing a lift up instrument and was proofed against a heavy weight instrument. Using a NaI scintillation survey meter, and a GM counter the measurement of radioactive materials were carried out. The surface of instrument was checked by the smear method to identify the contamination of radioisotope waste. The radioactive waste is defined as the radioactive material from hospital, industry, and university, which is divided by Japanese law. The radiation worker who is given educational training of radiation protection contributed to separate the radioactive waste. The education of safety manual was ruled before the contribution. The radiation exposure received under the decommissioning was limited under 30 μSv/day.

There are so many beam instruments and vacuum chambers in the SF cyclotron. The extracted beam was switched into the four courses. Course 1 was used to produce the unstable nuclear beam (Cave1). Course 2 was devoted to TARN2 beam line (Cave2B). Course 3 and course 4 are located in the experimental room named Cave 2A. The course 4 was separated to the Cave 3A and Cave 3B, respectively. A beam stopper for RI production was located in the course 3. The radiation map of the SF cyclotron was made to identify the radioactive area. The measured radiation map showed that the center of course 4 was strongly activated. After the disassembling of the SF cyclotron, contamination of the building was evaluated by the high-sensitive and wide area radiation detector (CONTAMAT). We measured the composition and quantity of the radioactive nuclei in the ferroconcrete.

3. Separation of radioactive material

An identification of radioactive material was carried out based on the rules of IAEA. The NaI scintillation survey meter and GM counter have been used to measure the surface dose of the radioactive material. Using the Ge detector and multichannel analyzer carried out the mass analysis of radioisotope. For convenient, portable radiation monitor has been used to measure the radiation level. The measurement device was calibrated by ^{60}Co. In order to move the radioactive element to the KEK Tsukuba, surface dose of transported material should be controlled under the 5 μSv/h, named L-type transportation. The separation of radioactive elements was carried out by the following rules:

A Beam transport line was composed of the vacuum chamber. The vacuum chamber has no flange system because of screw-nut structure. It means that half of outer diameter of vacuum chamber was designed less than bore radius of Q-magnet. So, dismantling time of vacuum chamber was shorter than flange type vacuum chamber. On the other hand, the upstream of vacuum chamber in the H-type 120 degree analyzer magnet was higher radiation level compared with down stream of the vacuum chamber.

The higher radioactive element over the surface dose of 5 μSv/h should be moved to the JRIA. The 50litter "yellow can" was used to pack the radioactive waste. An oversized radioactive waste such as a long vacuum chamber was cut within the 50cm length. The cutting machine was used in the green house to avoid spreading the dust of waste. On the other hand, in case of the surface dose exceeds 500 μSv/h the acceptation of radioactive waste was refused by the JRIA. In that case, Pb shield was used to decrease the radiation level. The radioisotope in the accelerator components comprises mainly ^{60}Co. The energy of gamma ray from ^{60}Co is 1 MeV. The Pb with thickness of 10cm decreases the gamma ray intensity by the 1/100 of initial conditions. The radioactive instruments have been transported with a shield box.

4. Radioisotope in the ferroconcrete

The instruments in the experimental rooms were disassembled and moved to the KEK Tukuba. The surface of ferroconcrete wall, ceiling, and floor was surveyed by using the NaI scintillation survey meter. The background level of the experimental room was 0.06 μSv/h.

The clearance level of the radioactivity is recommended as 1/10 of natural background such as the ^{40}K, U, and Th. The radioisotope in the ferroconcrete was measured by using the Ge detectors. Figure 2 shows the example of radioisotope in the ferroconcrete. The activity peak was found at the 10cm depth from the ferroconcrete wall. The measured radioisotope level was 0.25 Bq/g. The background level was 0.45 Bq/g for ^{40}K. In case of vegetable, for example [5], spinach includes 0.15Bq/g and radish includes 0.048Bq/g. The cow milk includes 0.048Bq/cc. The ground (0-5cm) includes ^{40}K of 0.32 Bq/g. If only ^{40}K of 0.45Bq/g is involved in the ferroconcrete, the natural background becomes 0.06 μSv/h, which is calibrated by the NaI scintillation survey meter.

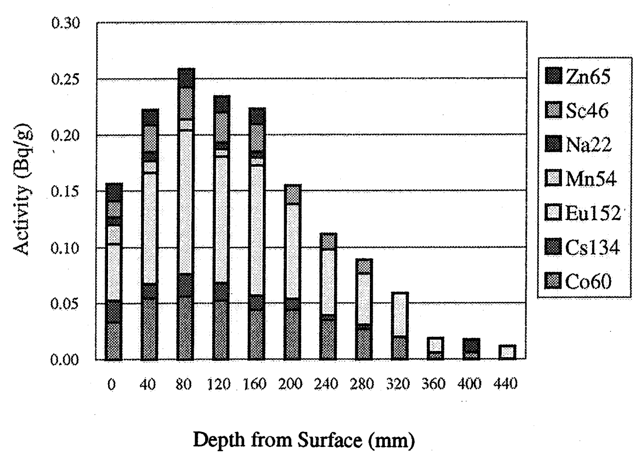

Fig.2 Depth dependence of the radioactive isotope in the ferroconcrete sampled at the wall near the deflector of SF cyclotron. The natural background of ^{40}K is excluded in this figure.

We also measured the radioisotope by using the ion chamber. The background level was 0.102 Bq/cm^2 at the floor of ferroconcrete. The ^{40}K was main activity in the natural background. The ^{40}K measured at ground surface (0-5cm) were 0.84Bq/cm^2. The ^{134}Cs measured at ground surface (0-5cm) was 0.25Bq/cm^2. We investigate the relation between the surface level and radioactive isotope intensity. It was found that linear curve was obtained. A calibration constant (Bq/g vs. μSv/h) is of (58.56x-3.617)E-2 for ^{60}Co, where x the measured surface dose, μSv/h.

The steel-bar in the ferroconcrete was activated. The γ-ray spectrum of the steel-bar sampled at the surface of ferroconcrete is tabulated in Table 1. In case of steel-bar in the ceiling where is 10 cm thickness, the steel-bar was activated up to 0.45 μSv/h. They are stressed to radioactive waste.

Table 1 γ ray spectrum of the steel bar. (Bq/g)

Sample	^{60}Co	^{59}Fe	^{54}Mn
F1	(3.5+/-0.4)E-1		(7.2+/-0.4)E-1
F2	(2.0+/-0.2)E-1	(5.8+/-1.7)E-2	(1.9+/-0.2)E-1
F3	(1.4+/-0.3)E-1		
BG	5.0E-2	5.6E-2	5.1E-2

BG=Back ground level of Ge detector.

5. Transportation of radioactive instruments

The radioactive instruments separated from the SF cyclotron were moved to KEK Tsukuba. The maximum weight of cyclotron magnet yoke is 48 ton, and side yoke is 13 ton. The weight of rf resonator is 26 ton. The surface levels of the magnet have been measured after the disassembling of the rf resonator and beam deflector. The portable gamma ray detectors have been used to measure the radioactive level around the magnet yoke. The measurement result shows that maximum level of gamma ray was 16μSv/h. It was so difficult to transport the heavy weight and partially activated magnet pieces because of limit of radiation level during the transportation [2].

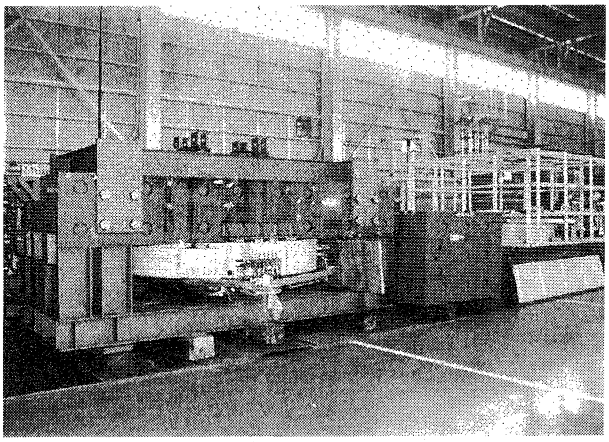

Fig.3 Upper magnet yoke of SF cyclotron moved to the KEK storage house (left). A supporting base and a lift-up hanger are also seen.

The radioactive instruments of the SF cyclotron have been settled in the building of KEK-Tsukuba. The amount of radioactive materials is tabulated in the Table 2 while the total amount of separated materials is 2557 pieces. The storage area was proofed against the heavy weight instruments. In order to storage the magnet yoke of the SF cyclotron, the floor of storage building reinforced with 25 mm thickness of the steel plate. The vacuum pump was housed in the woody box. The surface radiation level of the woody box was measured and confirmed to keep the surface radiation level of 5μSv/h. The woody boxes are piled on the floor up to 2.5 m higher because of construction of semi-second floor to increase the storage area. The ferroconcrete blocks, which were used to make the radiation shield, were radioactive materials with the surface dose of under 0.14 μSv/h. The radioactive instruments, which were used in the beam monitoring system, have been implemented in the steel-box. The photo of each instrument was taken to identify the radioactive instrument in the steel-box.

Table 2 Amount of radioactive materials moved to KEK

Source of material	No. of material	Ratio (%)
Cyclotron room	431	57.9
Cave 2A	185	24.8
Cave 3B	70	9.4
Cave 3A	23	3.1
Power Sup. room	19	2.5
Ion source	15	2.0
RF room	2	0.3
Total	745 pieces	100 %

6. Conclusion

The SF cyclotron was disassembled and transported to KEK Tsukuba. The radioactive waste from the SF cyclotron was mainly vacuum chamber for the beam transport line. The 57 % of the vacuum chamber was radioactive waste. The main part of SF cyclotron becomes radioactive. The ferroconcrete irradiated by the neutron beam was activated and their radiation level was investigated. The ^{60}Co, ^{134}Cs, ^{152}Eu are main components of the radioisotope in the ferroconcrete. The RI concrete was packed in the 200-litter drum can and total of 540 cans has been transferred to JRIA. The packing factor of RI concrete in the 200litter drum can was 57%.

Acknowledgements

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