# Radiation Monitoring System in Cyclotron Facility at TIARA

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## *Abstract*

A radiation monitoring system in the cyclotron facility at TIARA (Takasaki Ion Accelerators for Advanced Radiation Application) has been installed. This paper describes basic specification and concept, selection of the detectors, data acquisition and some operation results for this system.

## I. INTRODUCTION

The JAERI AVF cyclotron (K=110 MeV) system [1],[2] with two external ion sources has been already operated in TIARA facility since 1991. Various ions from proton to xenon in a wide range energy of 10−520 MeV have been also extracted successfully from the cyclotron. A radiation controlled area in the cyclotron building is divided into the first and second class ones, and radiation safety control has being carried out comprehensively assisting in a lot of radiation detectors of several kinds.

## II. BASIC SPECIFICATION AND CONCEPT

Basic specification and concept for the radiation monitoring system (RMS) are as follows:
(1) Since the RMS is central equipment for radiation safety control, it has to provide excellent reliability and stability. Dependable output signals from the RMS are required to construct an interlock sequence of the operations for the entrance doors and the cyclotron system, as shown in Fig. 1.
(2) The RMS can be operated continuously within several ten minutes after the stopping of commercial electric power by an uninterruptible power supply connected with engine generating power lines.
(3) Good performances such as maintenance-free and durability are also needed on the viewpoints that the RMS has to be always operated and a routine maintenance is scheduled only one time through a year.

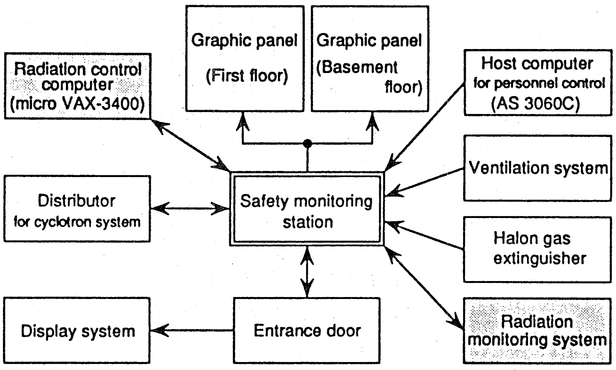


Fig. 1 A relationship among principal devices related to the safety control system.

(4) Module structure was adopted to improve the interchangeability and the working efficiency when the repairing or modification is necessary.
(5) Most of the radiation detectors was chosen some superior specifications more than JIS Z-4324 II class.

Principal specification and performance for the radiation monitor is shown in Table 1. In other specification items, errors of an indication and an alarm level setting are within ± 0.3 decades, the drift during 24 h is less than ±0.12 decades.

Table 1 Principal specification and performance for the radiation monitor.

| | Neutrons | High level γ | Low level γ | X - rays | Room gas | Room dust | Exhaust gas | Exhaust dust |
|---|---|---|---|---|---|---|---|---|
| Detector | BF3 | Ion. chamber | SSD | Ion. chamber | NaI scintil. | Plastic scintil. | Plastic scintil. | Plastic scintil. |
| Energy range (MeV) | ~17 | 0.08 - 3 | 0.08 - 3 | 0.03 - 1 | 0.3 - 3 (γ) | 0.3 - 3 (β) | 0.3 - 3 (β) | 0.3 - 3 (β) |
| Measuring range | $10^0$ - $10^5$ cps | $10^{-2}$ - $10^5$ mSv/h | $10^{-4}$ - $10^1$ mSv/h | $10^{-4}$ - $10^1$ mSv/h | $10^1$ - $10^5$ cps | $10^0$ - $10^4$ cps | $10^1$ - $10^5$ cps | $10^0$ - $10^4$ cps |
| Linearity (decade) | ±0.12 | ±0.20 | ±0.12 | ±0.20 | ±0.12 | ±0.20 | ±0.12 | ±0.12 |
| Indication | Digital | Digit./Anal. | Digital | Digit./Anal. | Digital | Digital | Digital | Digital |
| Sensitivity ($Bq/cm^3$) | — | — | — | — | $1 \times 10^{-3}$ | $5 \times 10^{-6}$ | $1 \times 10^{-4}$ | $1 \times 10^{-7}$ |

## III. DETECTORS FOR RADIATION MONITOR

Dose rate on the inner shielding wall surface at the cyclotron vault and the three light ion rooms was estimated at 4−16 Sv/h [3]; corresponding to maximum intensity of 10 μA of 90 MeV protons. Operation time converted into maximum intensity for a year is evaluated at 108 h based on an operation program, so an accumulated dose per one year is calculated about 430−1730 Sv at those positions.

The detector including a $BF_3$ tube for neutrons is assembled to a pre-amplifier which is consisted of MOS-IC. Since the radiation resistance of MOS-IC has been reported about $10^2$ Gy order [4]-[6] for gamma-rays and the measuring range is $1-10^5$ cps ($3-3\times10^5$ μSv/h), we predicted that it was very difficult to measure directly at above higher counting (dose) rate.

These radiation detectors are set up to reduce the radiation damage of themselves at suitable places in the cyclotron vault and three light ion rooms, where the dose rate due to generated neutrons and gamma rays will reach to higher level, because the detectors are composed of semi-conductor element like MOS-IC.

For measurement in high level gamma-rays field, detector which has been excluded semi-conductor elements is used. This detector of 76.2 mm diameter and 298 mm long is made of aluminum cylindrical chamber with filled in argon gas of 5 $kg/cm^2$. Ionization current induced by radiation is measured directly using a picoamperemeter. However, low level gamma-rays detectors of silicon semi-conductor detector type are put in the heavy ion rooms, working areas and passages.

In addition, one X-rays detector contained in the pre-amplifier is arranged at outer surface of the iron plate shield around an ECR ion source (OCTOPUS) [7],[8]. Radioactive noble gas and dust detectors consisted of plastic and NaI scintillators are also installed for environmental monitoring in light ion rooms and exhaust tower. One detector for exhaust gas monitoring was improved to be able to measure certainly the concentration of 0.37 $mBq/cm^3$ which is 1/10 of the value regulated by a law.

Ten detectors for gamma-rays are positioned on the shielding wall near the entrance part of the ion rooms for personal security. For neutrons, 5 detectors in the heavy ion rooms are mounted in the front of a target port in order to get higher sensitivity, 3 detectors are arranged at maze part in the light ion rooms, and another 2 detectors in the cyclotron vault and cyclotron pit room are evacuated at shadow space behind of the shielding wall as before reason. Number of all detectors attain to 35 channels finally.

## IV. GAS AND DUST MONITORS

A flow chart of sampling system for gas and dust monitors is illustrated in Fig. 2. Sampling gases are measured separately to 3 lines via sampling header by the course change using magnetic valves, but discharging gas from the exhaust tower is always monitored by exclusive line directly. The flow rates of sampling gases are monitored by 4 mass flow meters to calculate radioactivity concentration, then gases are sent to the exhaust line by the operating of one of the 2 root blowers with 1 $Nm^3$/min capacity. The operation of sampling system is possible either in remote mode or in situ.

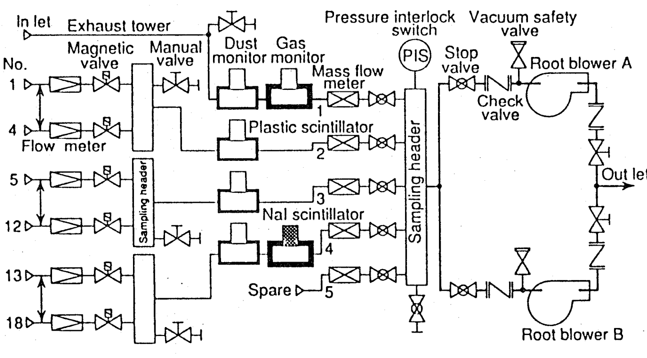


Fig. 2 A flow chart for gas and dust sampling system.

## V. DATA ACQUISITION

A connection diagram between the monitoring data and a radiation control computer (μVAX-3400) is shown in Fig. 3. Numerical data from neutrons, low level gamma-rays, gas and dust monitors are taken out in turn by way of 4 scanners from 30 digital rate meters. In the analog type monitors for high level gamma-rays and X-rays, these data are treated via 5 logarithmic digital rate meters. The operating commands and changeover signals of 15 magnetic valves, gas quantities from mass flow meters are also acquired through switch/control unit HP3488A and data acquisition unit HP3421A.

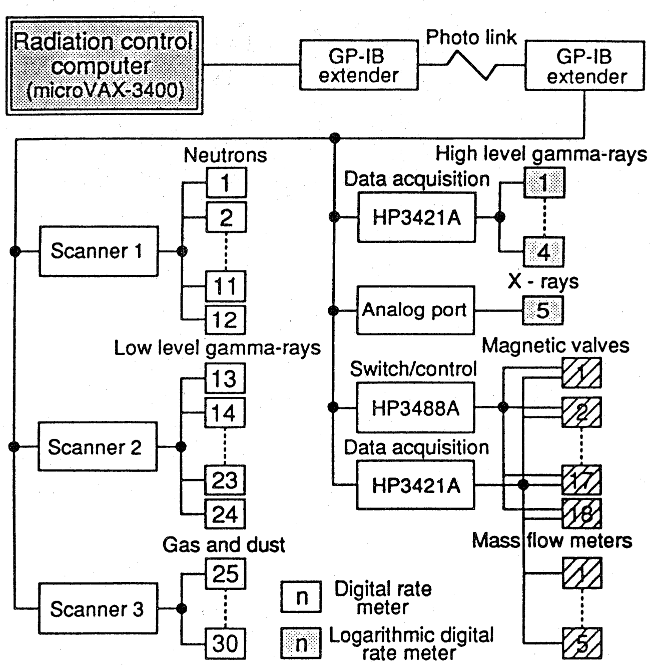


Fig. 3 Connection diagram between the radiation monitoring system and the radiation control computer.

Measuring values of the RMS are transferred every 30 s to the radiation control computer through two GP-IB extenders communicated by photo-link interface. Several meteorological data such as temperature, humidity, rainfall, velocity and direction of the wind, quantity of solar radiation etc. are also sent to it every 2 min. These data are stored in two 400 Mbyte hard discs and utilized to CRT status display or making on various materials for radiation safety control.

## VI. SOME OPERATION RESULTS

The RMS has being operated steadily since an installation in March of 1991. Four monitoring racks installed at the cyclotron control room are shown in Photo. 1. Two racks of the left side assemble into many modules for the digital rate meter and the high voltage power supply for several ion rooms, the right side two's equip with them for passages and working areas, gas and dust. Four hybrid recorders are also composed at middle part in the each rack.

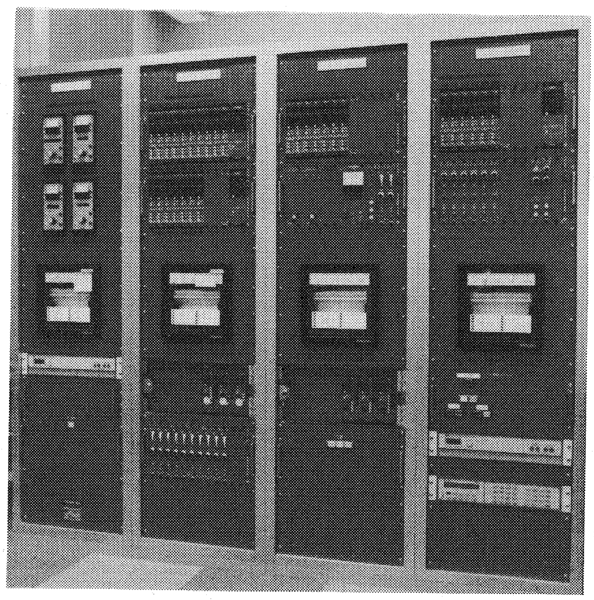

Photo.1 Front view of the monitoring racks for the radiation monitoring system.

Counting rate of the neutron monitor in the cyclotron vault is shown in Fig. 4. Proton beams accelerated to 10−90 MeV were stopped completely in the Faraday cup (TS1) made of thick copper plate positioned at 9.3 m downstream from the cyclotron chamber. The detector of the neutron monitor is installed at 12.4 m away from the TS1, along the direction on the deflection angle of 101 degrees. This neutron detector has been calibrated with averaged energy of 0.33−4.5 MeV by means of $^{241}$Am-Be source. The measured neutron count accords with the tendency of calculated total neutron yield [3].

Furthermore, an example of the indication change of the gamma-rays monitor mounted in the cyclotron vault is shown in Fig. 5. Although rapid reduction of the indication was observed first within 30 min after the proton beams of 2.8−3.2 μA with energy of 70 MeV were extracted about 72 h in total from the AVF cyclotron, it took more than 20 h until the indication was dropped down below the alarm level (50 μSv/h) in the interlock sequence for the entrance door opening.

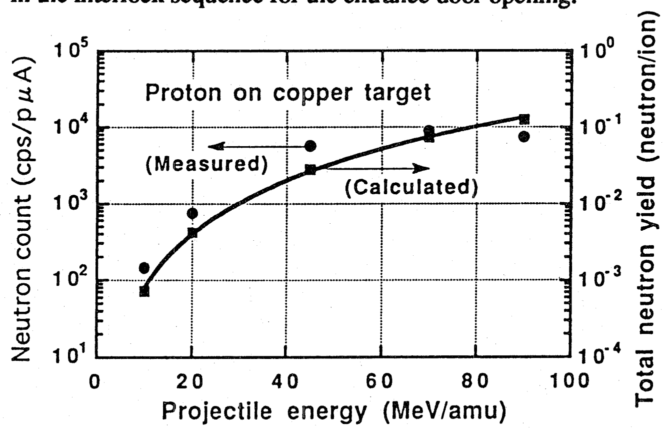


Fig. 4 Neutron count of radiation monitor in the cyclotron vault. Proton beams were stopped in the Faraday cup into the TS1 diagnostic station after the cyclotron.

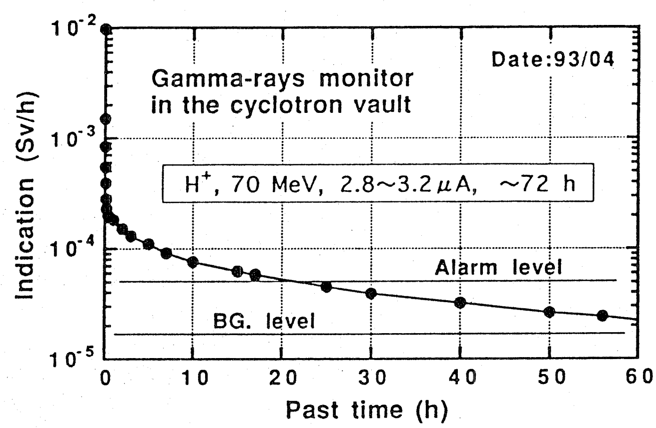


Fig. 5 Indication change of the gamma-rays monitor after the stopping of cyclotron operation.

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