

Comprehensive applications of the gas flow proportional counters for Radiological Surveillance

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ABSTRACT. Gas Flow Proportional Counters (GFPC) have been developed indigenously for various radiation protection applications. These detectors can be fabricated for 2" diameter filter paper sample counting applications to large area (~1500 cm²) detectors for surface contamination applications. Thin entrance windows allow non-penetrating type of radiations like alpha and low energy beta particles. Efficiencies (for alpha and beta radiations) are comparable to conventional detectors used to measure these radiations. Poor gamma efficiency (<1%) compared to ~30% beta efficiency provides a large β^2/γ ratio, a high figure of merit and enables efficient gamma background rejection. These detectors are quite suitable for Indian environmental conditions. Three systems have been developed and successfully incorporated in to the radiation surveillance program at various nuclear facilities. The systems based on GFPC detectors include (a) Multiple sample gross alpha counting system, (b) Laundry monitoring system and (c) Alpha hand contamination monitoring system. The first of these enables simultaneous gross alpha counting of five air activity filter paper samples. The area of the detector surface is optimized to cover the 2" sized filter paper samples routinely used for the purpose. Five numbers of GFPC's are arranged sequentially coupled to five individual amplifiers - microcontroller modules to process the signal from the five counters. The laundry monitor which is microcontroller based system consists of four large area multiwire GFPC detectors (700 cm² sensitive area) used to monitor alpha contamination of decontaminated laundry. Each detector uses a charge sensitive preamplifier coupled to I²C counter. The alpha hand monitoring system consists of four large area multiwire gas flow proportional detectors (330 cm² sensitive area each). A microcontroller-based module is employed to initiate the counting process automatically when the hands are inserted in to the suitably designed window slots and provides audio and visual alarm.

KEYWORDS: *Gas Flow Proportional counter, Contamination monitors, microcontrollers*

1. Introduction

Monitoring for alpha contamination is an essential component of radiation surveillance program in most nuclear facilities. Alpha contamination monitoring is a difficult and time-consuming process. The entry routes of alpha activity into the human body are inhalation and ingestion. Thus it is very essential to monitor the airborne alpha activity in locations, where significant quantities of alpha activity is being handled. The methodology normally employed to monitor the air activity is through air sampling followed by subsequent counting with an appropriate detector system designed for the purpose. The indigenously designed GFPC (Gas Flow Proportional Counters) are perfectly suitable for use in these types of applications.

Personal protective wears (like boiler suits, hand gloves etc) are used extensively by personnel working with radioactive substances. Contamination of these protective wear is unavoidable. Therefore these protective wear has to be checked for presence of radioactivity over its surfaces after decontamination process so that they can be reused later. Laundry monitors based on GFPC have been found to be best suited for this purpose. Also contamination monitoring of hands of plant/radiological laboratory personnel is very important as this could result in internal dose through radionuclide ingestion during food intake. Screening of the hands of the workers for alpha contamination at exit points can help in reducing these internal doses. The hand monitors being developed by the Division are specifically meant to serve this purpose. These three systems mentioned above have been developed and successfully incorporated in to the radiation surveillance program at various nuclear facilities.

2. Design aspects of the GFPC

GFPCs of different sizes (2" diameter filter paper sample counting applications to large area $\sim 1500 \text{ cm}^2$) are designed for various contamination monitoring applications. The systems developed and described here are for alpha activity measurement purpose and hence the detector entrance window should be as thin as possible. The detector window selected for these applications $\sim 0.5 - 1 \text{ mg/cm}^2$. The multi anode counter is designed using 50-micron diameter anode tungsten wire arranged in parallel with 10 mm spacing between two anodes[1-3].

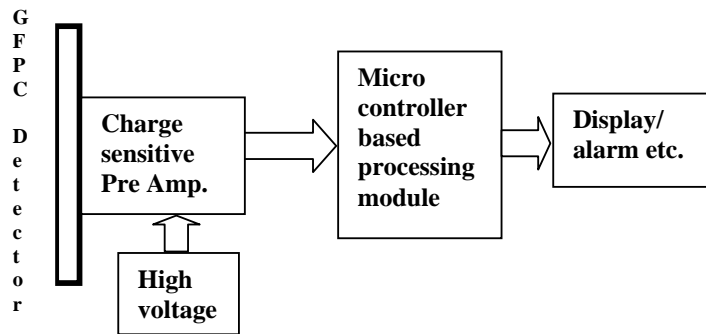
Since these gas flow type systems are to be operated continuously, selection of gas is very important. Avalanche multiplication occurs at low electric fields in high Z noble gases, hence they are better choice but for economic reasons Argon gas is preferable as primary counting gas. Argon gas is characterized by its non-volatility, chemical inertness and easy availability. A continuous flow of the filled gas is preferred to the sealed gas configuration so as to avoid the problems concerning microscopic leaks. Another important advantage with the flow type proportional counter is the allowance of a reduced window thickness permitting lower energy alpha particles to be counted [4,5].

A comparative study of the ZnS(Ag) based detector system and the GFPC based system for alpha detection is given in Table.1.

Table. 1: Comparison of ZnS(Ag) and GFPC based detector Systems

Parameter	ZnS(Ag) + PMT based system	Large area multiwire gas flow counter system
Detector sensitive area (cm^2)	~ 100	$\sim 20 - 1500$
Efficiency (%)	~ 25 at geometrical center	~ 24 (over the entire sensitive area)
Efficiency variation over the entire detector sensitive area	Less by 60 % at the edges compared to geometrical center of the probe	$< \pm 10$ % entire sensitive area compared to geometrical centre of the detector
Operating voltage (volts)	~ 800	~ 1300
Plateau	No Plateau	$\sim 150 \text{ v}$
Window thickness	$\sim 1 \text{ mg cm}^2$	$\sim 1 \text{ mg/ cm}^2$ Since light leakage not a problem here window thickness of 0.5 mg/ cm^2 can be fixed which will further increase the efficiency further.
Cost	PMT and ZnS(Ag) paper has to be imported.	Tungsten wire has to be imported.
General	Damaged PMT cannot be repaired. Decontamination of detector	Any part of the detector can be repaired in-house.

Figure-1 gives a general block diagram of the GFPC detector based counting system designed for use in all the monitoring application mentioned above. The two main blocks of the system are:



Analog system: It comprises of a charge sensitive preamplifier, followed by a discriminator and a mono stable multivibrator. The anode signal from each counter is fed to individual preamplifier-discriminator blocks, where they are first amplified and then converted in to TTL pulses. These pulses from individual counters are processed digitally in the microcontroller module.

Microcontroller based control system: The microcontroller module carries the required processing depending on the type of application and provides necessary output to the display and audiovisual alarm system.

3. Applications of the GFPC detector

3.1 Gross Alpha Counting System

A perspex material based multi-wire gas flow proportional counter design has been implemented for simultaneous gross alpha counting of five air activity filter paper samples. [6] The perspex medium scores over metal, as the contribution to the background from this medium is negligible in comparison to others. The sensitive area of the detector is designed to cover the 2" diameter sized filter paper samples routinely used for the purpose. The detector has a thin entrance window of the order of $\sim 0.5 \text{ mg/cm}^2$ (sealed ~ 2 " dia pancake type GM detectors with entrance window thickness $\sim 2 - 3 \text{ mg/cm}^2$ are commercially available for alpha detection but their background count rates are higher and are not recommended for this type of applications). Each counter is designed using six anode tungsten wires of 50-micron diameter arranged in parallel with a spacing of 10 mm.

This system incorporates a continuous flow ($\sim 20 \text{ cc/mt}$) of argon gas through five numbers of gas proportional counters arranged sequentially. The system has been designed as a once through type where the fill gas is vented to the atmosphere. The bias required for the total system is obtained from a commercially available, locally manufactured high voltage unit. The bias voltage ($\sim 1300 \text{ V}$) is applied commonly to the anode wires of all the counters. Five individual amplifier coupled microcontroller modules process the signal from the five counters. The timing aspect for the system is commonly arranged for all the five counters and is user selectable from a rotary switch provided on the front panel.

The samples to be counted are placed on five independent sample drawer type assemblies. Care is taken to maintain minimum distance ($\sim 4 \text{ mm}$) between samples to detector window. The drawer assembly has

two positions i.e. when drawer is pushed in, the sample will be counted and when pushed out, the detector will see small standard alpha source. This provision will be useful to check the efficiency of the detector when required.

The pre amplifier pulses are processed and converted in to TTL pulse for further analysis by microcontroller. The microcontroller module comprises of five identically programmed Atmel make 89C2051 microcontroller chip. Three timing modes are available to the user for setting the counting time for the counters, which are 60secs, 1800secs and manual. The counts from each of the counter are displayed on a 6 digit seven segment LED display. The elapsed time during the counting process is also displayed on a 6-digit seven-segment display in terms of seconds. The operating voltage of the detector can be viewed by pressing the EHT display button.

3.2 Laundry Monitor

One of the protective measures at all nuclear facilities for minimizing radioactive contamination is to wear personal protective wears (like boiler suits, frog suits, plastic suits, hand gloves, cotton overshoes etc). Laundry from various facilities is sent to Decontamination Centre (DC). These are to be checked for presence of radioactivity over its surfaces after decontamination process. After checking surfaces contamination, these protective wear (free from contamination) can be reused. Large quantities of these protective wears are being handled at DC. Considerable amount of man-hours are spent to monitor all these wears. In addition alpha contamination limits are almost one tenth of beta/gamma contamination limits which makes the monitoring much more stringent. This requirement can be fulfilled only by detectors, which have large area, good efficiency and are rugged. Since GFPC detectors can fulfill all these basic requirements, large area multi-wire gas flow detectors were used in development of this system.

Four large area multiwire gas flow proportional detectors (~ 700 cm² sensitive area each) developed in RSSD are used to monitor alpha contamination of decontaminated laundry. Each detector is coupled to charge sensitive preamplifier. Each preamplifier also contains I²C counter. Processor based counter timer circuit reads the counts accumulated in these counters. This block is also used to set the counting time and alarm levels.

With present system, time required for monitoring the laundry has considerably reduced. Since the entire system is indigenously designed, maintenance of the system is easy. Gas based system has uniform response over the entire sensitive area. Since the system requires commercial grade argon, which is readily available, replacement of cylinder is once in three months may not be a problem looking into its other advantages.

3.3 Alpha Hand contamination monitor

Another important radiation surveillance requirement in many nuclear facilities is the monitoring of hands and feet of working personnel at the plant before they leave the workplace. This includes radiation monitoring for alpha and beta/gamma contamination. At the waste management facility of BARC, the need for a hand contamination monitor was responded to with a GFPC based alpha hand contamination monitor. Four multiwire gas flow proportional counters were employed where two each were used to monitor two sides of one hand.

The detectors designed for the application have an area of 330 cm² and efficiency of ~ 24 % for alpha particle detection. The operating voltage for the systems is set at ~ 1300 V and the plateau length is observed to be ~ 150 V. Since large area, the window thickness for the detectors is kept at ~ 1 mg/ cm² so as to facilitate transmission of alpha particles and at the same time gives better protection compared to 0.5 mg/cm².

The detectors have been coupled to charge sensitive preamplifiers, the output of which get converted to TTL pulses. These pulses are fed as input to an Atmel make 89c2051 microcontroller module, and counted for predetermined time interval. An optimum counting time of 10 seconds has been fixed. The module has provision for displaying counts on each hand on two individual LCD display units. The system also has audiovisual alarms, which are set on whenever the contamination levels cross the preset limits. The counting process is initiated whenever any individual inserts his hands in to the slots meant for the purpose and any abnormal interruption during the counting process is also indicated through suitable audiovisual indications.

4. Conclusions

Gas detectors have been developed indigenously for various radiation protection applications. Thin entrance windows to allow non-penetrating type of radiations like alpha and low energy beta particles can be provided for GFPC detectors. The minimum detectable limit values have been computed for the three systems and are shown in Table 2.

Table-2: Minimum Detectable Activities

System	Background (Counting time normalized to 600 seconds)	Minimum Detectable Activity (for counting time:600secs)
Gross alpha counting system	2 counts	25 mBq
Laundry monitor	40 counts	0.12 Bq
Hand monitor	25 counts	0.14 Bq

Damage (this is quite frequent in plant operations) to these windows is easily repairable. Efficiencies (for alpha and beta radiations) are comparable to conventional detectors used to measure these radiations. The operating voltage for alpha detection is very much less than that for beta/gamma and hence the background counts will be low. These detectors are quite suitable for Indian environmental conditions. Gas handling in flow type of detectors is not a hindrance when compared to other advantages of these detectors.

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