World Academy of Science, Engineering and Technology
International Journal of Physical and Mathematical Sciences
Vol:17, No:3, 2023

Investigation of the Effect of Pressure Changes on the Gas Proportional Detector

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***Abstract*—**Investigation of radioactive contamination of personnel working in radiation centers to identify radioactive materials and then measure the potential contamination and eliminate it has always been considered. Various ways have been proposed to detect radiation so far and different detectors have been designed. A gas sealed proportional counter is one of these detectors which has special working conditions. In this research, a gas sealed detector of proportional counter type was made and then its various parameters were investigated. Some parameters are influential on their working conditions and one of these most important parameters is the internal pressure of the proportional gas-filled detector. In this experimental research, we produced software for examination and altering high voltage, registering data, and calculating efficiency of the detector. By this, we investigated different gas pressure effects on detector efficiency and proposed optimizing working conditions of this detector. After reviewing the results, we suggested a range between 20-30 mbar pressure for this gas sealed detector.

***Keywords*—**Gas sealed detector, proportional detector, gas pressure measurement, counter.

I. Introduction

DIFFERENT types of detectors with different sensitive materials to the radiation have various applications. The type of detector used determines the application of the device. Detectors can detect different beams depending on the environment used and the goals they pursue. Gaseous detectors are applied in many works from medical to industrial areas [1]-[9]. A proportional detector is a kind of multi-wire detector that works according to the principle of ion-pair production when interacting with incident ionizing radiations [10], [11]. After the interaction of incident radiation to the detector, ion-pairs will be produced and collected because of the internal electrical field due to the high voltage that exists between anode and cathode. This counter such as Geiger-Muller works in pulse mode and relies on the phenomenon of gas multiplication to boost charges created by ion-pairs formed in the gas [12]-[16]. This pulse is significantly larger than a pulse generated by an ion chamber in the same terms [17]. An important application of proportional counters can be in detection and radiation spectroscopy of low dose/low radiation [18]-[21]. The proportional detector has working conditions and these conditions should be defined and evaluated before each measurement. The most important parameter is the plateau diagram of the detector which gives the operating high voltage (HV). Some parameters such as gas purity, gas pressure, ambient temperature, size, anode diameter and HV affect the plateau diagram. In our experimental research, we investigated the pressure changes and its effect on plateau diagram, efficiency, and some other working conditions. We consider that other parameters like gas purity and temperature are constant in this research.

II. Materials and Method

When the radiation passes through the detector window and enters the active volume of the detector, interacts with the detection materials. This detection material here is a gas-type material, and when an incident particle or ionization photon interacts with that, ionization occurs.

The higher the particle energy and the higher the source activity, the higher the ionization rate. Due to the electrical field inside the detector, ion-pairs are generated and create an electric current, which is then processed and can be used as a spectrometer or counter, which here we will work with the counter. The operation of the detector in the plateau area ensures that HV changes do not have much effect on the detector efficiency. Therefore, accurate calculation of the plateau area is of great importance for all types of detectors. Proportional gas detectors have different types and, in this research, the wide-area type has been used. If we want to categorize this detector more accurately, it is a type of multi-wire wide-area proportional detector in which gas is sealed. A wide-area counter has this outstanding feature that can measure a wider area and is suitable for a fast scan. The type of anode wiring in this detector is such that there is a similar and uniform electric field in the whole volume of the detector. Wide area gas sealed proportional detector examined in this research and the active surface of a detector (entrance window) is about 250 cm^2. The gas of the detector is Argon-CO_2 type with the purity available in the market. The gas-filling method in this research is manual and in current laboratory conditions. This means that a series of simple and basic equipment has been used to create a multi-way for the entry and exit of gas, and after a few minutes of gas flow, we blocked the entry and exit of gas and made it gas sealed.

Anode wire is a kind of Molybdenum micro-wire and the window material is very thin aluminized Mylar foil with protective steel mesh.

By determining different plateaus at different pressures and comparing them, the valuable and influential parameter of the optimum pressure at which the detector must operate is achieved.

Evaluation of different pressures to achieve detector's

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operating point and its optimum pressure was done at room temperature. The standard Am-241 alpha radioactive source with an activity of 16.8 KBq was placed in contact with the detector's entrance window for all studies, Fig. 1. The background is approximately 8 counts per second (CPS) in our laboratory. Filled gas is Ar-CO_2 and various pressures that have been injected into the detector are 10 mbar, 20 mbar, 30 mbar, 40 mbar, and 50 mbar, respectively.

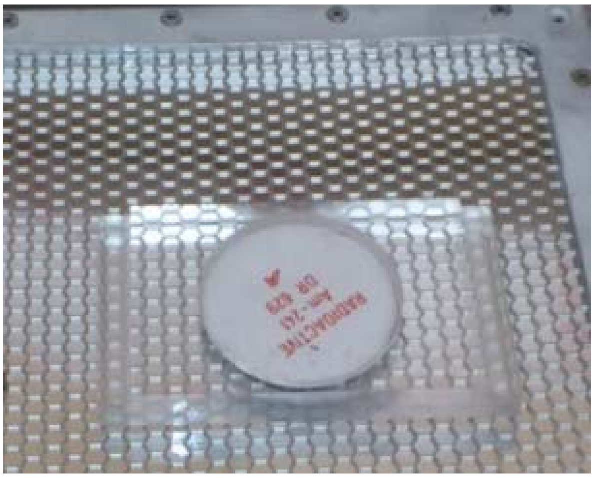


Fig. 1 Radioactive source in contact with the detector

III. Measurement Procedures

We used a simple program to measure and make the necessary changes. Pre-measurements are performed after each change and before recording the main measurements in the presence of a radioactive source. At this stage, without the presence of a radioactive source, the amount of background radiation is measured for a certain period and is used as the initial value to start the measurement operation. The default value of this parameter is 6 seconds, which of course can be changed in the software. Obviously, the longer this time, the more accurate the values that are initially shown as background radiation values.

Fig. 2 shows schematic diagram of the whole measurement system. In the pulse processing unit, the pulse received from the detector is processed. One of the tasks of this unit is to match the impedance between the detector and the electronic circuits. The received pulses are slightly amplified in this part because they have a small amplitude. According to the design principles of electronic boards, the noise level for the received pulses is determined. Therefore, in this unit, the pulses that are above this level are considered as correct data, but the pulses below this level are considered as noise and are deleted. Thus, the pulses above the noise level are registered as correct counts of the incident photons. After applying HV to the detector via software and ending the pre-measurement operation, the background radiation counting process begins. HV used here is adjustable module and the HV input is analog, it is 0-5 volts DC and the digital output of the module is 0 to 2000 volts DC. The cable of HV sends the HV amount to the detector and simultaneously, collects the charges and transfer the current to the electronics section. Processor unit will count square pulses and display it. In order to simplify the project and use the memory to store information, an IPC (Industrial PC) and its monitor have been used. The program written for this project is on the computer and the necessary changes are given in the software of this research. Once applied the changes, the data are exchanged between the electronics and the computer via RS-232 communication port.

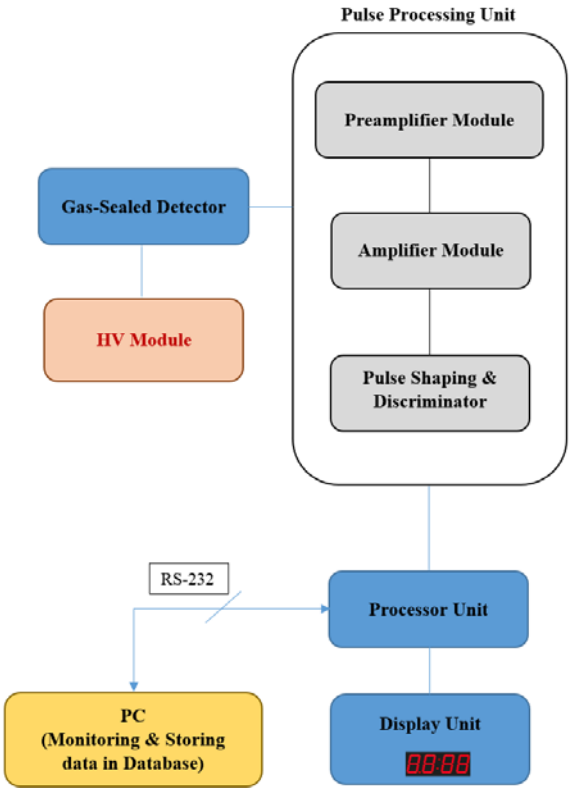


Fig. 2 Diagram of measurement for gas sealed detector

The nature of the radiation that reaches the detector is random. For this reason, there are many statistical fluctuations in the data recorded by the detector. In order to be able to evaluate the results of radiation recording or to determine the alarm limit for them, these statistical fluctuations due to the random nature of cosmic and radioactive radiation must be mitigated. The method used in this research to soften the detector CPS is the exponentially weighted moving average (EWMA) method [3].

The method of using EWMA to reduce statistical fluctuations is a computational method to control and soften the counts recorded by the detector. This means that the data recorded by the detector show the instantaneous values and by using this method, the number of statistical fluctuations is reduced. In this process, the instantaneous values of the detectors are received and a kind of averaging is performed on these values. This type of averaging actually smooths the rapid statistical changes. In this averaging, a parameter called Rate Meter Factor is effective. The range of this parameter is between 0 to 1. The closer this parameter is to zero, the greater the dependence of the calculated counts on the last instantaneous value, and the less the effects of the previous values are seen. As a result, if the value of this parameter is very small, the registered count per second changes is very large, and in fact, it is something like the instantaneous values. But the closer this parameter is to one, the smaller the effect of the last instantaneous value on the average and the greater the effect of the previous values instead. As a result, the calculated average changes are greatly reduced. In other words, the averaging in this case follows the instantaneous values with a slope of small changes. The default value of this parameter in software is 0.97. After starting the measurement process, the background radiation calculation operation is performed continuously and the calculated values are updated every second until the stop command is issued through the software. Fig. 3 shows software view of this experiment.

The plateau of each detector specifies the working area of that detector. In this study, after each change, the detector plateau was recalculated to evaluate the changes and their effect on the working conditions of the detector.

For ease of measurement, in the software written for this research using C# programming, plateau parameter changes are performed automatically as shown in Fig. 4.

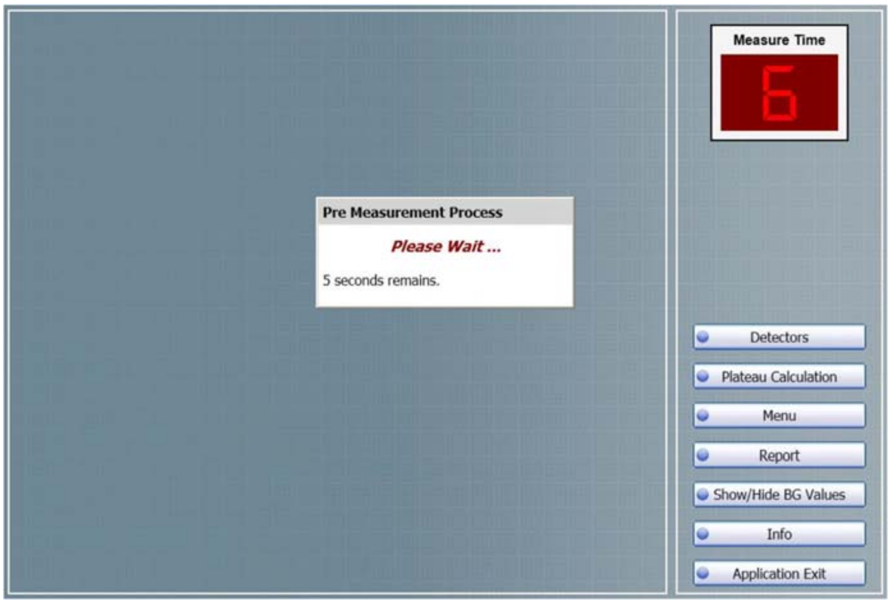


Fig. 3 Software window of measurement system

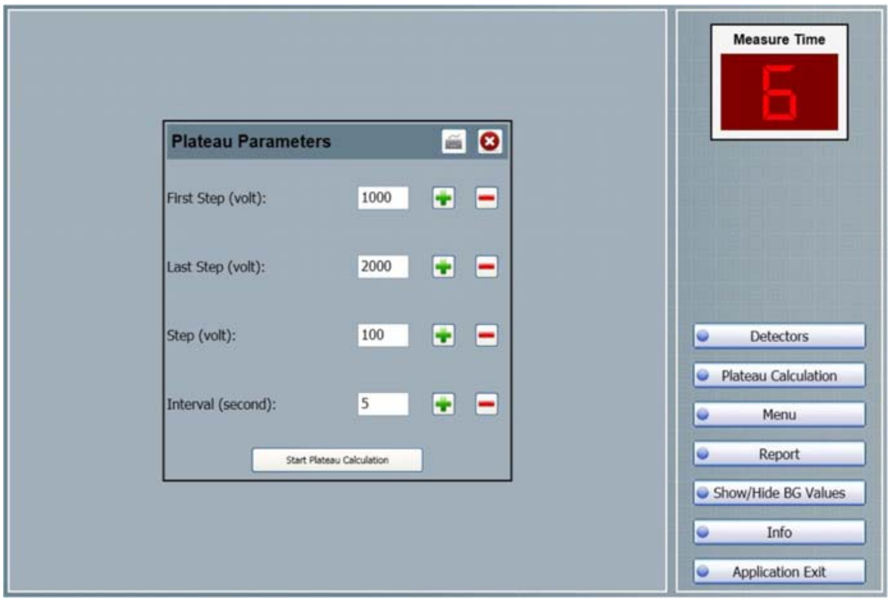
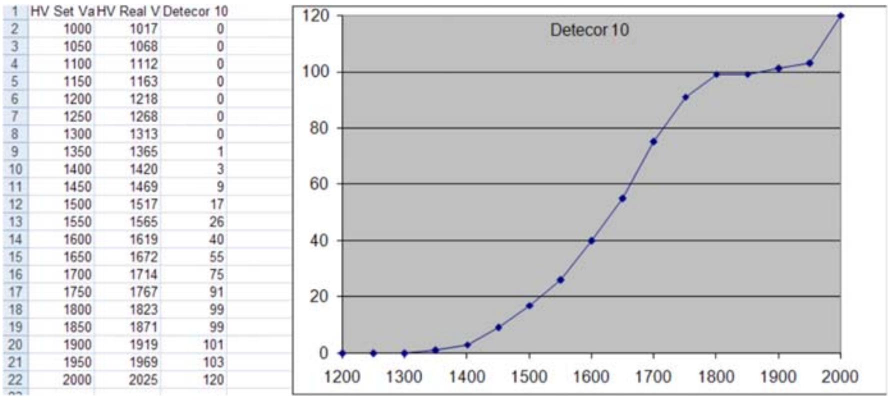


Fig. 4 Plateau calculation parameters

After setting these parameters, which include the initial voltage, end voltage, HV increase in each step, and data recording time in each step (interval), by clicking on the Start Plateau Calculation button, the process of changing and storing the plateau data begins (Fig. 5). The shorter the step between each HV step, or the longer the sampling time, the more accurate the plateau calculation. Therefore, in this study, the values of these parameters have been selected in such a way that the measurement error does not increase remarkably.

It is also possible to cancel the plateau calculation operation at each step, and after the calculation of the plateau curve is completed, the calculated values are plotted on a graph according to Fig. 6. For the alpha particle, the plateau length is much longer than the beta particle.

Fig. 5 Plateau calculating process



1	HV Set Va	HV Real V	Detecor 10
2	1000	1017	0
3	1050	1068	0
4	1100	1112	0
5	1150	1163	0
6	1200	1218	0
7	1250	1268	0
8	1300	1313	0
9	1350	1365	1
10	1400	1420	3
11	1450	1469	9
12	1500	1517	17
13	1550	1565	26
14	1600	1619	40
15	1650	1672	55
16	1700	1714	75
17	1750	1767	91
18	1800	1823	99
19	1850	1871	99
20	1900	1919	101
21	1950	1969	103
22	2000	2025	120

Fig. 6 Typical plateau curve for Sr-90 radioactive source

IV. Results and Discussion

After reviewing several diagrams relating to plateau in various pressures, the results of this study indicate that by increasing gas pressure, recorded CPS reduces, then efficiency will reduce, too. For compensation of efficiency reduction, we should increase the amount of working HV to enlarge the gas propagation coefficient. Another important result is that the length of the plateau decreases by increasing the filled gas pressure. This means that, increasing the internal pressure of gas sealed detector, could not be considered as an advantage. Then by increasing the gas pressure inside the gas sealed detector, we will expect to record the same CPS in a lower plateau operating range. Results are given in Table I.

TABLE I
Results of Different Parameters of the Detector According to the Pressure Changes

Pressure	10 mbar	20 mbar	30 mbar	40 mbar	50 mbar
Average CPS	18500	18174	17707	16851	15304
Efficiency	11%	10.8%	10.5%	10%	9.1%
HV	1720	1720	1760	1770	1805
Plateau length	890v	810v	810v	810v	750v

According to Table I, working condition of the proportional detector changes with the pressure changes. Moreover, as an adversarial event, the high voltage of the proportional counter has been increased to compensate the CPS reduction. Increasing working HV of the detector is a negative effect itself. Excessive pressure over 50 mbar on the detector's internal gas causes the detector Mylar foil to rupture and the protective metal mesh to deform.

V. Conclusion

The optimal pressure seemed to be 10 mbar for working with a gas sealed proportional detector. But it should be noted that these tests have been done in the conditions that the source is in contact with the detector's window. So, because the window thin foil is made of a thin flexible material, 10 mbar pressure does not fulfill the detector volume completely, so it is not applicable when there is a distance between detector and source. Because pressure changes from 30 mbar to 40 mbar cause a 0.5% change inefficiency, which is a great change, this pressure is not acceptable, too. Finally, in our study, the pressure between 20 mbar to 30 mbar is determined as the optimum gas pressure. We notice that in this range of gas pressure, conditions and results that describe and compared in this experiment are close to each other.

Acknowledgment

The authors thank Pars Isotope Company for its support of our study. We would also like to express our solidarity with the Iranian people and show our support for uprising in Iran "Woman, Life, Freedom".

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