Characterization of Pressurized Ionization Chambers

Monitoring Gamma Radiation in the Environment

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Introduction

The objective of this summary report is to highlight significant characteristics of pressurized ionization chamber gamma radiation detector (PIC) for monitoring intensity of gamma radiation in the environment. The physical structure of the system previously was reported (GE, 1987). The detector bias is nominally provided by a 300-Volt dry cell (Eveready # 493 carbon-zinc)[2]. The Reuter-Stokes (RSS-1012) Environmental Monitoring System Operation manual describes in detail the specifics of the system design, associated electronics, and the procedure for operation of RSS-1012 system.

This report has the following sections:

1. Detector Bias Voltage;
2. Response of PIC to radiation intensity;
3. Response of PIC to radiation energy;
4. Effects of ambient temperature and humidity on the response of PIC

Response as a Function of Detector Bias Voltage

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[2] Reuter-Stokes system uses a 300 volts dry cell for the bias supply. We replaced this cell with a high quality electronic power supply. The output of dry cell is dependent on the ambient temperature. Whereas, the output of the power supply was independent of the ambient temperature.

Pressurized ionization chambers were calibrated using ^{137}Cs gamma radiation, using a shadow-shield to correct for scattered radiation. The detector was calibrated using a bias of 300 volts, and a laboratory ambient environment of 20 degree C, and 30% relative humidity. The PIC response (volts) was converted into an equivalent response in exposure rate (R/hour).

The specifics of the power supply to provide detector bias was previously reported (Merriman, 1984). The detector response as a function of the bias voltage was measured (Table 1).

Table 1

Response (mR per hour) of PIC (RSS-1012) Exposed to ^{137}Cs gamma radiation

	Exposure (mR per hour)				
Bias (volts)	**10**	**600**	**1000**	**4500**	**9000**
60	10.0	575.9	865.8	2633.0	4108.4
70	10.0	593.8			4408.6
80	10.0	593.8	865.8	3026.9	4765.0
100	10.0	594.7			5356.0
120	10.0	594.7	993.3	3696.7	5909.4
140	10.0	594.7			6425.3
160	10.0	594.7	994.3	3977.1	
180	10.0	594.7		4221.0	7382.1
200	10.0	594.7	994.3		7832.3
240	10.0	594.7	996.2	4483.6	8610.8
280	10.0	594.7	998.0	4521.2	8929.8
300	10.0	594.7	998.0	4521.2	8976.7
320	10.0	594.7	998.0	4521.2	9014.2
340	10.0	594.7	998.0	4521.2	9025.4
360	10.0	594.7	998.0	4521.2	9042.3
380	10.0	594.7	998.0	4521.2	9042.3
400	10.0	594.7	998.0	4521.2	9042.3

The exposures were measured using tissue-equivalent ionization chamber (Victoreen Model 550-3 detector and Model 500 integrating electrometer), calibrated by the National Institute of Standards and Technology.

At an exposure rate of 10 mR per hour, the response of the detector was identical for bias voltages of 60 volts to 400 volts. Whereas, at an exposure rate of 9000 mR per hour, as the bias voltage increased from 60 volts to 350 volts, the response of the detector gradually increased. DeCampo et al. (1972) reported PIC response as a function of applied bias. They exposed PIC to 1 mR/hour radiation field. Their data would be similar to our data (Table 1) for the 10 mR/hour exposure rate. We recommend a bias of 300 volts for measurement of background environmental radiation.

Response as a Function of Radiation Intensity

Figure 1 shows response of PIC as a function of exposure rate to ^{137}Cs gamma radiation. PIC response is a linear function of the exposure rate within a range of background to 9000 mR/hour.

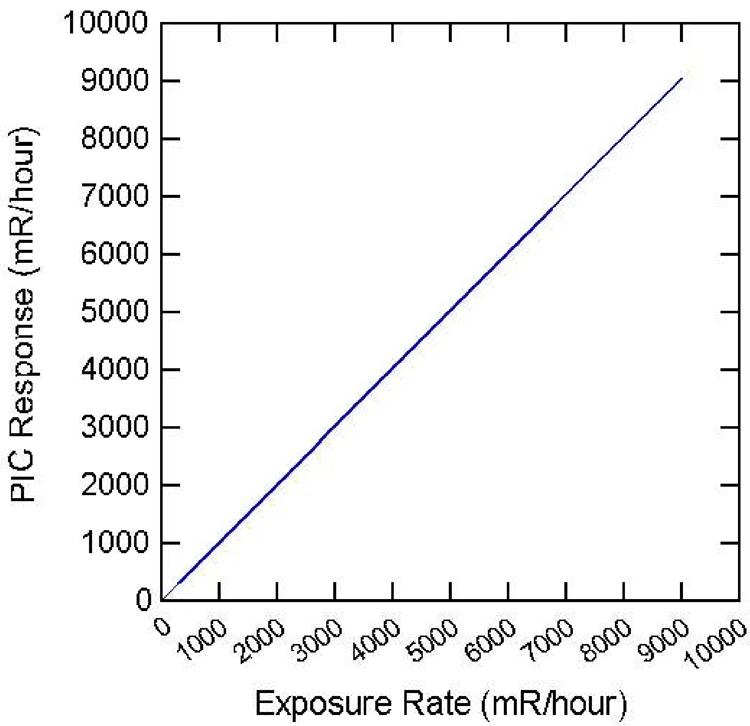

Figure 1. PIC response as a function of exposure rate to gamma radiation from ^{137}Cs

Response as a Function of Gamma Radiation Energy

PIC responses as a function of exposure rate to gamma radiation from ^{241}Am, ^{109}Cd, ^{60}Co, and ^{137}Cs sources were measured.

Figure 2 shows the average PIC response per mR/hour as a function of average gamma radiation energy. The responses were normalized to the response to gamma radiation from ^{137}Cs (662 keV).The PIC responses are the average of responses from four pressurized ionization chambers. For energies less than 75 keV, the responses are highly energy dependent. PIC response at 1250 keV is about 75% of the response at 100 keV.

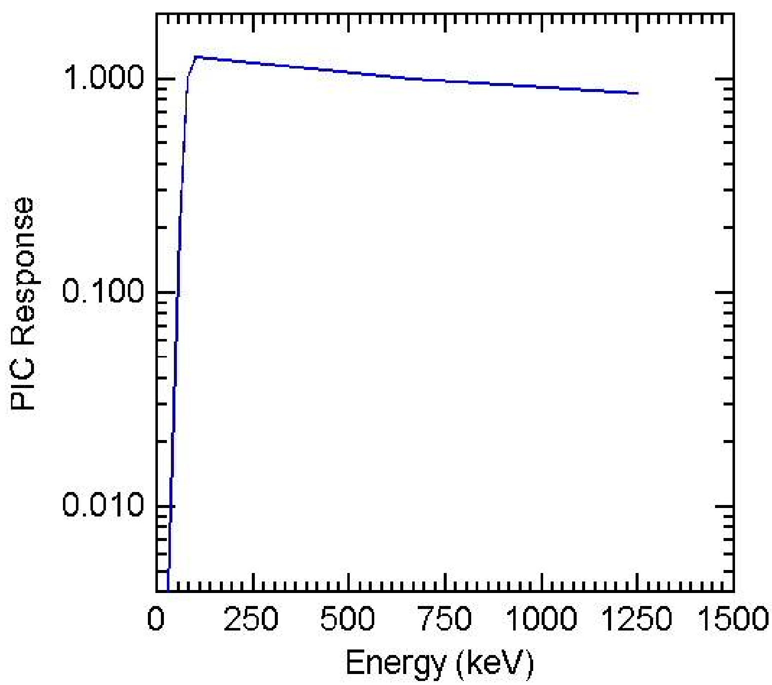

Figure 2. Average PIC responses as a function of gamma radiation energy normalized to the average response to 662 keV from ^{137}Cs

Four pressurized ionization chambers were also exposed to x-radiation (150 kVp, 1 mm added aluminum filtration)). The average of the PIC responses to the exposure rates was 0.26. This reduction in the response partially is due to a preferential attenuation of lower photon energies by the steel shell of the ionization chamber.

Response as a Function of Ambient Temperature and Humidity

Ambient temperature may affect individual components of the Reuter-Stokes system. In order to separate the temperature dependence of the electronics from the detector (PIC), we investigated the response of PIC under the following two physical environments:

1. The entire system was placed in an environmental chamber
2. Only the detector (PIC) was placed in the environmental chamber; whereas, the electronics were placed under the laboratory ambient conditions.

The temperature of the environmental chamber was set at –16 F, or 70 F, or 127 F. The relative humidity was constant at 30%. The entire system, or PIC alone, was kept in the environmental chamber for about 12 hours prior to exposure to 10,000 mR per hour. At each temperature, the effect of bias on the PIC response was measured (Figures 3 and 4).

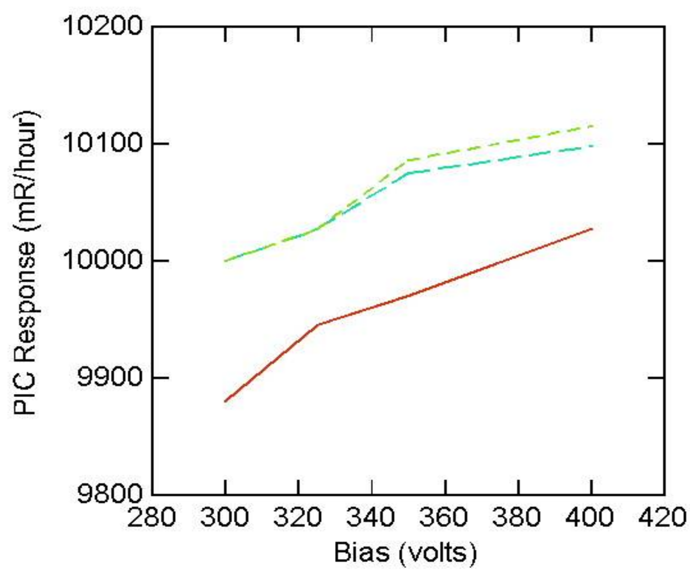

Figure 3. PIC response as a function of temperature and at a constant relative humidity of 30% for the entire system (PIC and the electronics)

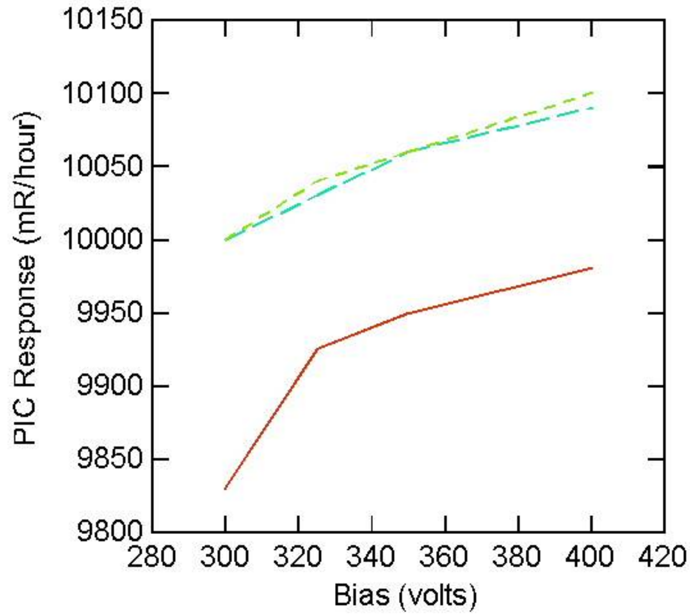

Figure 4. PIC response as a function of temperature and at a constant relative humidity of 30% (PIC alone)

For both Figures 3 and 4, the lower curve represents the data measured at 127 F. The upper curve represents the data measured at –16 F. The other data, the middle curve, was measured at 70 F. The data indicate that PIC response would increase with decreasing ambient temperature. A comparison of the data, Figures 3 and 4, would indicate that some of the electronic components incorporated into the structure of Reuter-Stokes, RSS-1012 model, ionization chamber are temperature dependent.

The effect of humidity (dry to 50% relative humidity) on the response was also measured. Similar to the investigation of the temperature effect, either the entire system or only the PIC was placed in the environmental chamber. The data indicate that Reuter-Stokes system would not be dependent on humidity within the range of our measurements. The chamber and electrometer are hermetically sealed; however, should the seal fail, moisture could affect the function of the electrometer.

Discussion

In this report, the effects of temperature, humidity, radiation energy, and applied bias voltage on response of pressurized ionization chamber gamma radiation detection system (RSS-1012) were presented.

RSS-1012 system for measurement of natural background gamma radiation would require correction for dependence on the ambient temperature. This correction would be either by physical placement of the system in a controlled temperature environment, or correction of the PIC response using temperature-specific correction factors. Otherwise, for a constant radiation environment, a diurnal variation of radiation intensity could be reported.

The data also indicate that the response of PIC is dependent on the energy of gamma radiation. This energy dependence partially is due to the construction of RSS-1012 pressurized ionization chamber using a steel shell.

RSS-1012 pressurized ionization chamber is very sensitive to low gamma radiation intensities, such as natural background gamma radiation. But, the steel shell of the chamber preferentially removes lower energy photons before they could be detected by the pressurized gas. Thus, response of RSS-1012 would under report the intensity of the natural background radiation.

Radiation fields affected by skyshine and ground scattering, such as the natural background radiation and accidental releases from a nuclear reactor accident, are not mono-energetic. Unless the PIC has been calibrated using a suitable source of radiation, it could underestimate contribution of lower energy photons (less than 75 keV).

References

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