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Development of Radiation Alarm Monitor

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Abstract - A Radiation Alarm Monitor has been developed and manufactured in order to protect radiation workers from overexposure. A visual and audible alarm system has been attached to initiate evacuation when accident occurs such as an unexpected change of radiation level or an overexposure. The Radiation Alarm Monitor with micro-processor installed can record the information of radiation field change between 90 min. before the alarm and 30 min. after the alarm and also provide the data to an IBM compatible computer to analyze the accidents and to set a counterplan. It features a wide detection range of radiation field (10mR/h-100R/h), radiation field data storage, portability, high precision (5%) due to self-calibration function, and adoption of a powerful alarm system. According to ANSI N42.17-A, the most stringent test standards, performance tests were carried out under various conditions of temperature, humidity, vibration, and electromagnetic wave hindrance at Korea Research Institute of Standards & Science (KRISS). As a result, the Radiation Alarm Monitor passed all tests.

Key words : Radiation Overexposure, Microprocessor, ANSI N42.17-A, Portability, Self-calibration Function, Light/Sound Alarm, Data Storage

1. Introduction

Various radiation detection equipments have been in use according to the working conditions and the characteristics of radiation field in Korea. Moreover, the gradual increase in use of radiation detection equipments is anticipated by the additional construction of NPP's for stable electricity supply in Korea.

Recently, the necessity for developing advanced featured radiation detection equipment has been increasing because of strong regulation against environmental pollution by radioactive material in Korea. Especially, the demand for a multi-functional and portable radiation measurement system such as radiation alarm monitor developed has been increased to protect radiation workers against over-exposure under the circumstance of unexpected radiation accident, to analyze the overall exposure dose to the worker after accident, and to set a counterplan against such a accident in future.

The radiation alarm monitor developed has upgraded function such as a wide detection range of radiation field (10mR/h-100R/h), radiation field data storage, portability, high precision (5%) due to self-calibration function, and adoption of a powerful audible and visual alarm system.

In Korea, the standard and the specification for radiation alarm monitor have not been established up to now. Thus, the basic requirements used for the design, manufacture and performance test of the radiation alarm monitor were determined after having reviewed fifteen foreign standards pertinent to the development of radiation measurement system such as ANSI N42.27A, JIS Z4324 and etc.[1 – 15]. The opinions of radiation working personnel in NPP's about the developing monitor were collected before the detail design step and reflected in detail design.

2. Design of Portable Radiation Alarm Monitor

Generally, the radiation monitor to measure the exposure from X or γ - rays can cover the energy range between 80 keV and 1.5 MeV. However, it is sometimes required to expand this energy band. Angular dependence of survey meters should be minimized and the response time to rapid change of radiation field should be cut down. Considering radiation alarm monitor's durability for neutron, the radiation alarm monitor should be composed of the materials which minimize the effects of neutron activation. Also, radiation alarm monitor should not be affected by electric wave and DC electricity supply should be adapted to use dry cell for maximizing the advantage of portability. The exterior case of radiation alarm monitor should be resistant to temperature and humidity and be decontaminated easily.

2.1 Selection and Performance test of Detector

Generally, an area monitor and a survey meter measure the exposure from β, X or γ rays using GM tube. After having reviewed several standards, GM tube was selected as a detector because of its generality and good detection efficiency. Instead of self-development, GM tubes (Berthold, ZP1313) suitable to the developing purpose was purchased and used in manufacturing our alarm monitor. Of course, the measurement of plateau, the response test to Cs-137 at standard radiation field, the energy dependence test and the angular dependence test were performed before their use.[16]

2.2 Determination of Calibration Function and Constant

Calibration equations were determined to elevate detection accuracy of the radiation alarm monitor. Error range in converting the count rate to the dose rate was adjusted within ± 5 % by inputting a first-order equation in low radiation field and a second-order equation in high radiation field.

After having obtained the dose rates as function of count rates in standard radiation field, a characteristic curve was plotted as shown in Fig. 1. The region of a characteristic curve is divided two parts and the boundary point (BP) is the encountering point of two parts. When the equation below BP is a first-order equation and the equation above BP is a second-order equation, the detection error is within ± 5 % which gives the smallest value.

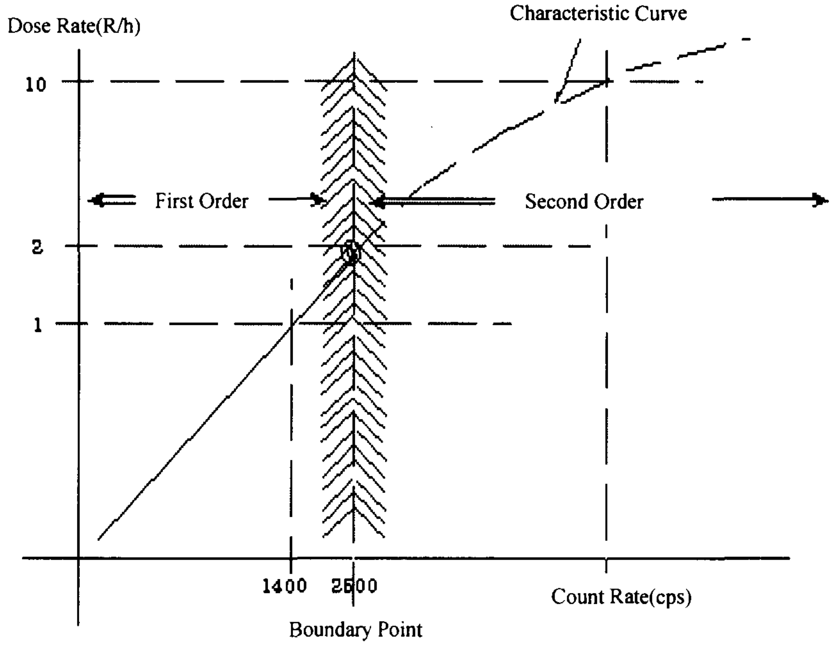

Fig. 1. Region of First and Second order equations in the Calibration Function

The equation below BP is described as $y = a_1x + a_2$ and above BP is described as $y = b_1x^2 + b_2x + b_3$, where y is dose rate (R/h) and x is count rate of pulse (kcps). Therefore the constants for calibration curve are BP, a_1, a_2, b_1, b_2, b_3. The fitting result for those equations is listed in Table 1.

Table 1. Constants for Calibration Equation

BP	a_1	a_2	b_1	b_2	b_3
2,500	0.809	– 0.0056	0.0186	0.52	0..0465

2.3 Design of Central Processor

A central processor is the most important part and governs the performance of Radiation Alarm Monitor. It operates Radiation Alarm Monitor using Intel 80C51 chip as Central Processing Unit. It consists of memory part, micro-processor part, digital input/output part, serial communication part, real time clock part, display part and pulse counter part. The block diagram of central processor is shown in Fig. 2.

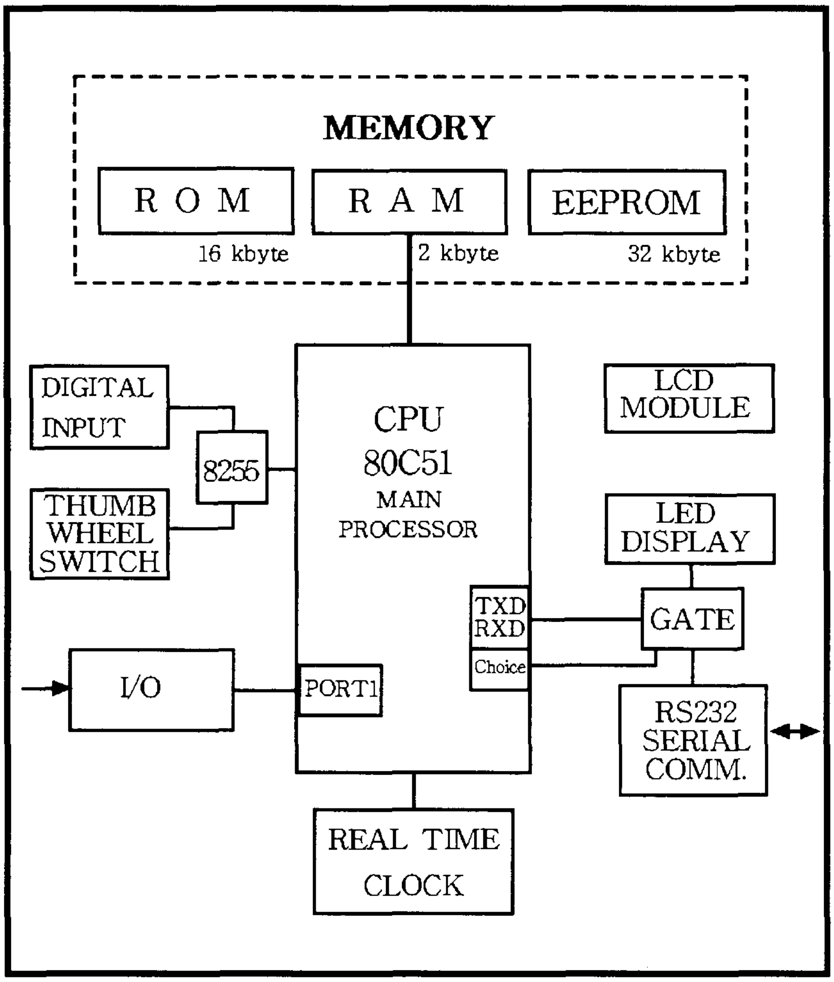

Fig. 2. Block Diagram of Central Processor

Memory part uses three kinds of memory chips such as RAM(2 kbyte, 6166), ROM(16 kbyte, 27C128), and EEPROM(32 kbyte, DS1230Y/AB). RAM keeps the data which comes from radiation input temporarily and ROM keeps Radiation Alarm Monitor's operation program permanently. EEPROM keeps radiation input every one second and operating condition of Radiation Alarm Monitor. In the case of occurring alarm, the data kept in EEPROM can be provided to an external IBM compatible PC to analyze the accident and set a counter plan.

The micro-processor part is a main part for the performance of the system operating program and uses a 8 bit P80C51DH chip as CPU. The 80C51 chip has three ports that communicate processing data to a external computer and a display panel. Therefore, digital input/output is easily controlled.

Signal input/output between CPU and other device uses 80C51 chip's three ports partly but this has some limitation. So parallel input/output port IC, 8255 chip, can be used to expand digital signal.

Real time clock part uses a real time clock IC, Dallas DSI287, to set time and data, initiate alarm, keep calendar for 100 years and perform programmable interrupt management function.

Serial communication part uses RS 232C 9 pin connector and controls signal's direction to an external computer or a display part. In case of providing data to an external computer, this part initiates the data analysis program installed in ROM.

Display part consists of LED and LCD parts and the communication route to each part is designed as follows : LED receives data by the serial communication port and LCD is connected to CPU to receive data directly,

The number of pulse produced in the GM tube due to radiation is recorded at the counter in CPU and converted to dose rate using the installed program after reading every one second by the real time clock. Fig. 3 shows the front panel of Radiation Alarm Monitor.

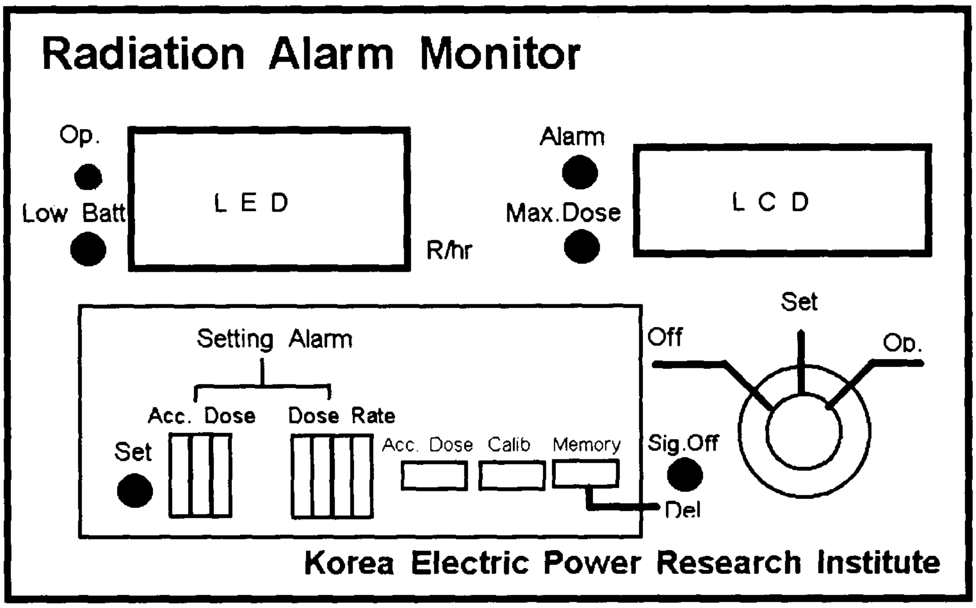

Fig. 3. Front Panel of Radiation Alarm Monitor

2.4 Design of Radiation Detection and Alarm Part

Radiation detection part consists of a GM tube which detects radiation, a pre-amplifier which amplifies small signal from GM tube to appropriate electrical signal and a pulse converter which converts pre-amplifier's signal to pulse for preventing malfunction by electric noise.

The above parts should be located together inside the detector case so a pre-amplifier and a pulse converter are installed on one electric circuit and a GM tube is connected with this circuit board directly. Therefore, that all parts are lumped together inside the case facilitate to conveniently use radiation detection part with a 20 m cable connected with the main part. A schematic draw of radiation detection circuit is shown in Fig. 4.

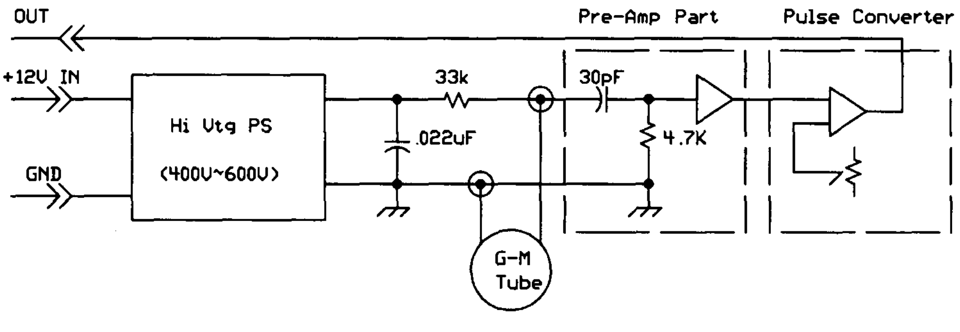

Fig. 4. Schematic Diagram of Radiation Detection Circuit

Three types of pre-amplifier circuits such as transistor type, OP-amp. type and Dual N-MOS FET type were considered and the pulse characteristics of these three types were measured after design and manufacture. After having analyzed their pulse spectrum, it was found that the transistor type gave electric noise and wide pulse. Also, OP-amp. gave rise to severe electric noise. But Dual N-MOS FET type showed stable pulse, so this type was selected as pre-amplifier circuit.

The circuit construction of pulse converter should be varied according to the characteristics of GM tube, therefore the pulse converter is designed and manufactured with accordance of our purpose by ourselves. Fig. 4 shows the electric circuit that converts current to pulse.

Alarm part consists of a buzzer which can bring about audible alarm and a flash lamp which can give rise to visual alarm intermittently. The buzzer uses a ceramic vibrator as sound source and the sound level at 1 m is 105 dBA/12VDC. The flash lamp uses high light intensity lamp to indicate alarm in a bad working condition and the flashing interval is 1 second.

3. Test of Radiation Alarm Monitor

After having manufactured Radiation Alarm Monitor, performance tests were carried out according to ANSI N42.17A mentioned before.

3.1 Temperature

In this test, temperature is varied from –10 °C to 50 °C to measure dose rate according to the change of temperature and a Cs-137 is used as radiation source. The testing equipment, Heraeus(Votsch), has the temperature range between –20 °C and 70 °C and its resolution is ± 0.5 °C. After a Cs-137 source was located near Radiation Alarm Monitor, the change of dose rate according to the change of temperature was measured. Radiation Alarm Monitor was located on the midplane of the Heraeus and fixed at the height of 15 cm to maintain stable temperature. The results did not show variation of dose rate according to the temperature.

3.2 Humidity

This test requires the humidity range between 40 – 95%RH at 22 °C. The closing cover of detector case was the most sensitive part to humidity, so rubber O-ring was inserted to closing cover to protect radiation detection part from humidity. Also, for water-proof of main part, anti-humidity material was attached to the back of front panel. Humidity test was performed for 16 hours in 95 %RH situation and the results did not show any problem.

3.3 Vibration

The vibrator of Korea Research Institute of Standards and Science was used in this test and the testing range of ANSI N42.17A, 1 A/m – 1000 A/m, is consisted with the IEC's vibration test range. Dose rate was varied within ± 10 % according to the vibration condition, therefore Radiation Alarm Monitor passed this test.

3.4 Hindrance of electromagnetic wave

The range of static electric field test is under 5000 V/m but the test was performed at high electromagnetic field such as 5000 V/m, 10000 V/m and 20000 V/m. The results did not show any problem.

An electric wave test was performed inside of the non-magnetic field chamber which is located in Korea Research Institute of Standards and Science. Only the equipment for test is allowed to exist in the chamber, therefore the measuring data cannot be read directly. Data in the memory circuit of chamber can be read after test. Dose rate did not vary for hindrance of electric wave.

A magnetic field test was performed after locating Radiation Alarm Monitor at the magnetic field ranged below 800 A/m. The magnetic field generator of Korea Research Institute of Standards and Science was used in this test and dose rate did not vary for hindrance of electric wave.

4. Conclusions

A Radiation Alarm Monitor has been developed and manufactured in Korea. The Radiation Alarm Monitor with microprocessor installed can record the information of radiation field before and after accidents and also provide the data to an IBM compatible computer to analyze the accidents and to set a counterplan.

It features a wide detection range of radiation (10mR/h-100R/h), radiation working data storage, portability, high precision (±5%) due to self-calibration function, and adaptation of a powerful alarm system. In order to protect radiation workers from overexposure, light and sound alarm has been designed to initiate when accident occurs such as an unexpected change of radiation level. It then records the change of radiation field such as dose rate and accumulated doses for between 90 min. before the alarm and 30 min. after the alarm. In addition, the Radiation Alarm Monitor interfaces with a computer so that the accident can be analyzed.

After the testing standards used in other countries for the radiation alarm monitor were compared, the most stringent test standards, ANSI N42.17-A, was selected. And according to these standards, performance tests were carried out under various conditions of temperature, humidity, vibration, and electromagnetic wave hindrance by Korea Research Institute of Standards & Science (KRISS). Furthermore, field adaptability tests under the environmental conditions of NPP sites was performed. As a result, the Radiation Alarm Monitor passed all tests. From then on the Radiation Alarm Monitor had been reviewed by radiation workers at NPPs and their opinions had been collected.

Conclusively, the newly developed Radiation Alarm Monitor has many different characteristics comparing to existing ones such as data storage and treatment, interface with computer, and use of direct current. Manufacturing cost for this radiation alarm monitor is very reasonable.

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