ALARM DEVICE FOR WARNING AGAINST DANGEROUS IONIZING RADIATION

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Abstract: The quality control of welds in mechanical industry is successfully performed with procedures known as industrial radiography. This procedure includes exposure of the controlled weld on a powerful ionizing radiation. The most often used radiation sources for such purposes are gamma rays from ^{192}Ir or X- rays from industrial X-ray machines. Beside the fact that the control is done by professionals, accidents dangerous for the biological world in the controlled zone are always possible.

This paper gives analyses of the operation of the electronic device for control of the radiation in the vicinity of the ionizing radiation sources. The device is realized with a classical impulse detector for gamma and X-rays and appropriate measuring circuit with adjusted threshold for activating light or sound alarm for warning. The threshold for activating the alarm is according to the recommendations of ICRP (International Commission of Radiological Protection). The device is tested in real conditions. Repeated results are obtained when activating the alarm during its exposure on controlled dose rate.

This paper puts a special accent on the device operation in accidental circumstances. That is in case of dropping the isotopes from the container and in case when the sensor is saturated.

A systematization of the necessary characteristics for such devices is done. The proposed solution could be used as a recommendation for designing such devices.

Key words: ionizing radiation, dose rate, impulse detector, detector saturation

1. INTRODUCTION

The workers in industrial radiography working at building sites and similar working sites work in difficult conditions. There is a prevailing opinion that this category of workers are among the most exposed on ionizing radiation, although it is very difficult to give firm proofs about it. There is a great possibility, in a case of error, that they would be exposed on dangerous radiation.

Unfortunately, in undeveloped countries, the number of this stuff is rather significant. Besides, in many of these countries, the regulations for protection of ionizing radiation are not correctly carried out, or the measurements of the obtained dose are done primitively. For instance, in the Republic of Macedonia, about ten sources of ionizing radiation are used everyday ($^{192i}Ir, ^{60}Co$), as well as several industrial X-rays machines for defectoscopy in the mechanical industry. Almost without exception, the operational staff uses old-fashioned system for measuring the dose.

Although this category of workers are trained to work with sources of ionizing radiation and during their work they use control dosimeters, the practice confirms the fact that still there is a possibility for unwanted cases. The use of electronic alarm devices for warning against dangerous radiation undoubtedly improves the working security.

2. OPERATIONAL PRINCIPLE

Fig. 1 shows the basic block structure of the device. The device is portable and works with battery supply. Blocks 1,2,3 and 4 are used for supplying and providing work conditions in the detector unit. Power supply is an acu-battery of 12V, 6 Ah. The block AC/DC is a battery charger, and for additional security of the device operation, there is a block LOW BATTERY LOGIC. Because the device should work in field conditions (noisy surrounding and different light conditions) the ALARM LOGIC block should operate the LIGHT CONTROL UNIT and the output block BUZZER. The light control unit consists of two powerful flash lights with different colors (orange and red), and the sound alarm from the buzzer, with piercing sound of 80 dB, audible on distance of 3 m from the device. The block M shapes the pulses from the detector unit. In this block, depending on the dose rate, two different signals necessary for indication of "radiation" and "dangerous radiation" should be supplied. The Alarm logic block has a task to make a logic signalization of "no danger" or "danger" from ionizing radiation.

Therefore, it is important that the alarm device for warning against dangerous ionizing radiation recognizes two radiation levels: "no dangerous radiation" and "dangerous radiation". Visually, these two levels activate orange and red light signalization. In case of dangerous radiation, beside the red light, the sound alarm is activated for additional warning.

The blocks from fig. 1: 1,2,3, and 4, as well as the detector unit are usual and known solutions used for portable devises for measuring or detection of ionizing radiation [1,2,3]. The characteristics of this device are the block M (measuring circuit) and the alarm logic circuit. It is possible to design these blocks in different ways. It is important that they should enable the logic signalization of "no dangerous" or "dangerous" radiation level. Of course, the condition for repeated results should be enabled, and the device should operate reliably.

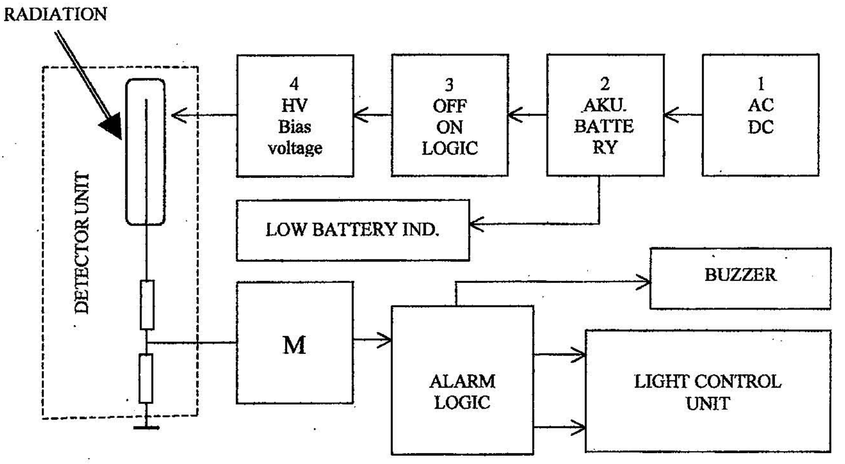

Fig. 1 block diagram

3. ALARM LEVELS DETERMINATION

In the proposed solution, the activating of the alarm levels is according to the so-called Maximum Permitted Dose (MPD). MPD are dose rates permitted for working in ionizing surroundings during a definite time. According to the latest recommendations from the International Commission of Radiological Protection (ICRP) [4,5], MPD for persons that are professionally disposed on radiation are: $5 \cdot 10^{-2} Sv$ per a year, $4 \cdot 10^{-3} Sv$ per a month, $10^{-3} Sv$ per a week, that is $2{,}5 \cdot 10^{-5} Sv$ per an hour.

(For nonprofessionals, the mentioned MPD are ten times lower).

Considering the data for MPD, it is accepted that the lowest dangerous level when the device alarm reacts is $25 \mu Sv/h$. For registration of such doze rate, a halogen quenched gamma radiation counter tube type ZP1200 [6] is used. This detector has a dose rate range from $(10^{-3}$ to $10^{2})$ mSv/h. The dose rate of $25 \mu Sv/h$ is in the linear part of the counting rate/dose rate curves. On the output of the detector unit for this limit dose, approximately 60 pulse/s are obtained.

4. DESIGN OF MEASUREMENT AND ALARM LOGIC PART

Fig. 2 shows a detailed scheme of the measuring and alarm circuit. With the purpose to make an analysis of these specific circuits operation, a simulation is made when the pulse detector is changed with a determining rectangular signal. This signal consists of pulses with constant amplitude, time duration, period, as well as rise time and fall time. During the simulation the mentioned parameters could be controlled and could correspond to the parameters of the real pulses from the used detector.

The analyses of the offered solution with a simulation certainly enable avoiding exposure on dangerous radiation.

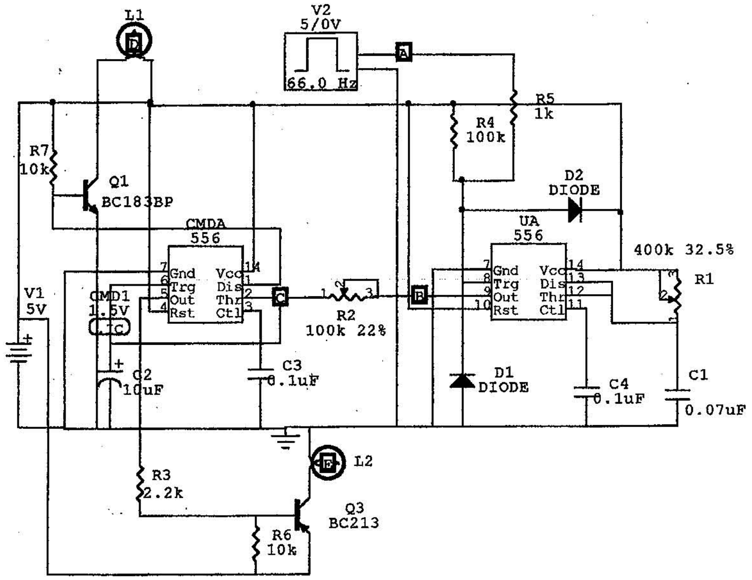

Fig. 2 Electrical scheme of characteristically part of the alarm devices

Fig. 3 and 4 show the time diagrams. On the left side of the figures the measuring points are marked and they correspond to the used points on fig. 2.

For shaping the pulses from the detector unit, 1/2 of the integrated circuits 556 is used in operational mode as a monostabile multivibrator. The multivibrator is triggered with the falling edge of the input (A) pulses. The time constant is defined with the values on C1 and R1 and in this case they are adjusted so that the pulse width of the multivibrator (point B) is $\tau \geq 10 \cdot \tau_{GM} = 1ms$. (Such chosen time duration is significantly longer than the dead time τ_{GM} of the pulse detectors that can be used for such purposes).

During the simulation, "the effect" of the detector unit is simulated with a periodical generator. In real conditions, it will be a rectangular pulse train with fixed time duration and random pause. But, it does not really have an impact on the analyses.

The second half of IC 556 is used as a logic circuit with complementary outputs on whose ends through the transistors Q1 and Q3 are connected the indicating lights for signalizing "no danger" (L1) and "danger" against ionizing radiation (L2). The circuit is designed to operate with hysteresis while going from one to another regime (3,33V when signalizing "danger" and 1,68V for "no danger").

For correct operation and errors elimination, at the input of the logic unit (due to statistic feature of the signal from the detector unit) the integrator R2, C2 is added.

After activating L2, the signal is treated with one more integrator. In this way, an additional time delay is realized, after which the sound alarm is activated, while the dose rate is unchangeable or it is rising.

The lights L1 and L2 are flashes, due to which their visibility field expands even in daylight conditions.

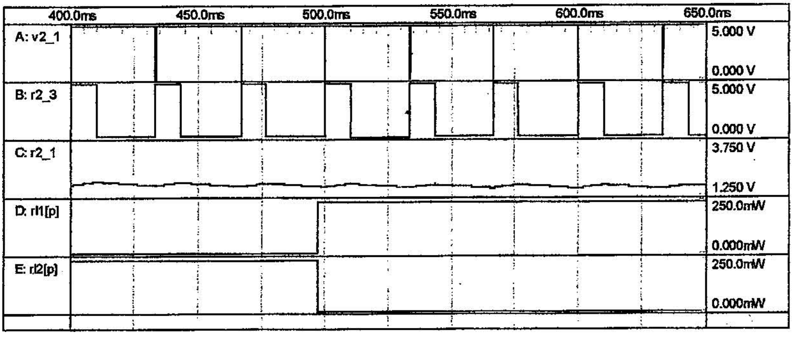

Fig. 3 Signal diagrams - transit regime from "danger" to "no danger" level radiation

The time diagrams shown on fig. 3 correspond to the transit regime from "no danger" to increased radiation and activating L2. Fig. 4 diagrams show the situation when from accident or dangerous radiation there is transition to "no danger" radiation and activating L1.

Changing the pulse frequency of the generator makes the simulation of the existing dangerous radiation.

The problem of activating the alarm during accidental situation (dropping of the isotope from the container) is situation when the detector unit could come to saturation. In the proposed solution, this problem is overcome using the detector with internal quenching, and additionally, every output pulse is shaped as a pulse with time duration much longer than the dead time of the detector. After the integrating of these pulses, the voltage in the point C increases, on out (pine 5) from 1/2 of IC 556, used as logic circuit, there is voltage that activates the transistor in whose circuit the signalisation L2 is included.

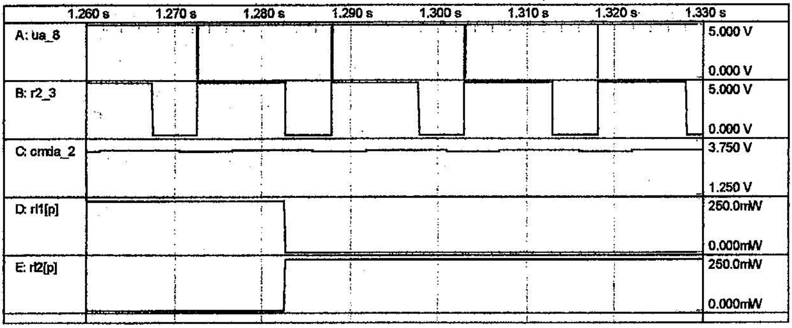

Fig. 4 Signal diagrams -transit regime from "no danger" to "danger" level radiation

5. CONCLUSIONS

The designing of such devices requires the following:

- The device should be reliable
- The device should operate with battery supply
- To recognize radiation when dose rate <MPD and the dangerous radiation when dose rate >MPD
- To activate the alarm when the detector unit is in saturation, too.
- The light alarm should be visible in various ambient light conditions
- The sound alarm for warning against direct danger should be with intensity that covers the surrounding noise.

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