A FIVE CHANNEL AREA MONITOR FOR GAMMA RAYS

A.R. Jones
Atomic Energy of Canada Limited
Chalk River Nuclear Laboratories
Chalk River, Ontario, KOJ 1JO, Canada

1. INTRODUCTION

An area monitor should permit dose rate estimates both by someone occupying an area and by a supervisor remote from it.

Since dose-rates generally vary over a wide range in the same area, an area monitor should be furnished with detectors at different places to avoid larger uncertainties in the dose rate estimate. If people can occupy the area while there is a danger of abnormal dose rates, there should be meters and alarms at the detector locations.

The response of the area monitor should be fast enough to alert those in the monitored area before they are significantly exposed. At the same time, the statistical precision must be adequate for estimating dose rates, bearing in mind other sources of error.

For reliable operation, the monitor must have reliable power supplies, preferably operable for limited periods without line power. To test operation of all parts of the monitor a convenient method of exposing the detectors to radiation is needed.

These considerations shaped the design of the monitor whose description follows.

2. DESCRIPTION

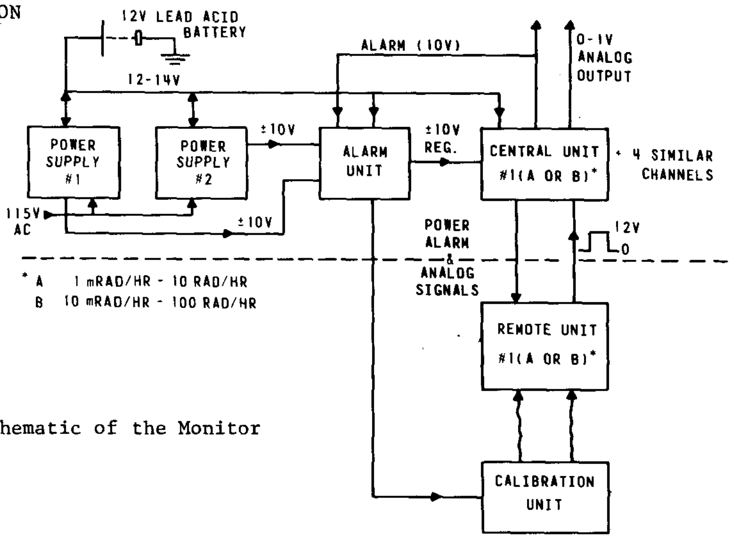

Figure 1. Schematic of the Monitor

Figure 1 is a schematic of the monitor and Figure 2 is a photograph of the different units which make up the monitor.

The units shown above the dotted line in Figure 1 are rack mounted in the plug-in modules illustrated in Figure 2.

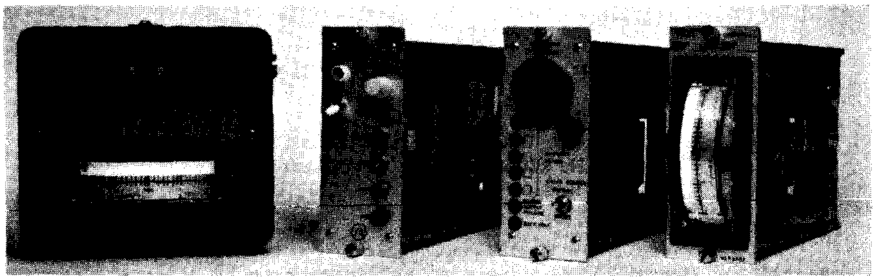

Figure 2. The Components of the Monitor

The two identical power supplies supply both + and -10 V, regulated, to the other units and keep a 12 V standby battery (Gel type lead acid) charged. Either power supply can fail in the short or open circuit modes without affecting operation. Line power can fail for up to 8 hours while the standby battery supplies energy even if all the five channels are in the 'alarm' condition.

The alarm unit:

- monitors the two power supplies and indicates when one of them has failed or if line power has failed.
- emits an audible alarm when any of the channels alarm. Five LED lamps are used to show which channel (or channels) is alarming. The alarm signals are reset from a switch on this unit.
- contains a switch for exposing the remote unit to the beta source in in its calibration unit.

The central units receive the pulses from the remote units (containing a GM counter) and provide an analog signal proportional to the logarithm of the mean pulse repetition rate over a range of four decades. In the low range version the range is 1 mrad/h - 10 rad/h and in the higher range one 10 mrad/h - 100 rad/h. (The unit of dose engraved on the meter scale is 1 rad = 0.01 gray). A five channel area monitor can be composed of low or high range channels or a mixture of both. The two versions have the same circuits but the meter scales are differently engraved. For safety, the low and high range channels have different connectors to prevent connecting a low range remote unit to a high range local unit or vice versa.

The analog output signals are provided by a logarithmic count rate circuit. The smoothing time constant (T) is controlled so that it is inversely proportional to the dose rate (D)

$$T = \frac{a}{D} = \frac{b}{n} \tag{1}$$

where n is the average repetition rate of the pulses from the detector which is proportional to the dose rate. The statistical fluctuation of a counting rate circuit is given by the relation (1)

$$\text{Standard Deviation} = \frac{100}{\sqrt{2Tn}} \; \% \tag{2}$$

$$= \frac{100}{\sqrt{2b}} \; \% \tag{3}$$

which is independent of the dose rate. The importance of the varying time constant is that it allows the use of a single GM counter as a detector over a wide range without loss of statistical precision. It does mean very slow response at low dose rates but at higher dose rates the response is accelerated so that people working near the detectors are not significantly exposed during the response period.

The analog output from the central units is available to drive external recorders, alarm circuits or a computer. It also drives a meter in the central unit and one in the remote unit. A variable alarm level can be set to trip at any point on scale. The alarm output (a 10 volt signal) is connected to the alarm unit and to the remote unit where a red lamp is energized.

The remote units contain GM counters (ITT type 3G70 or 3G500) which have the maximum sensitivity for their range consistent with low counting losses (10% at full scale). Each unit has a high voltage supply for the Geiger counter to avoid the need for high voltage cable connections and to insulate each channel against the effects of failure in another. The output pulse from the GM counter cathode after amplification to 12 V is transmitted to the central units which have a threshold between 3 and 7 V which is safely below the GM counter pulse while providing good immunity to noise.

The low and high range units only differ in the GM counter used.

The calibration units contain a 3.7 MBq $^{90}Sr/^{90}Y$ source mounted in a wheel which is normally positioned to shield the GM counter (and any personnel working on the monitor) from the beta rays emitted. The wheel can be rotated on a remote command from the alarm unit to expose the GM counter to the source. Between the detector and source there is an aluminum wedge whose position can be adjusted to obtain a desired output from the monitor.

3. PERFORMANCE

Figure 3 shows the energy dependence of each GM counter. It was measured in counts/Roentgen and energy dependent factors were used to convert the exposure to dose. The factors have been previously derived from measurements made with a realistic phantom (2). It can be seen that above 0.1 MeV the sensitivity of the filtered counters is approximately constant.

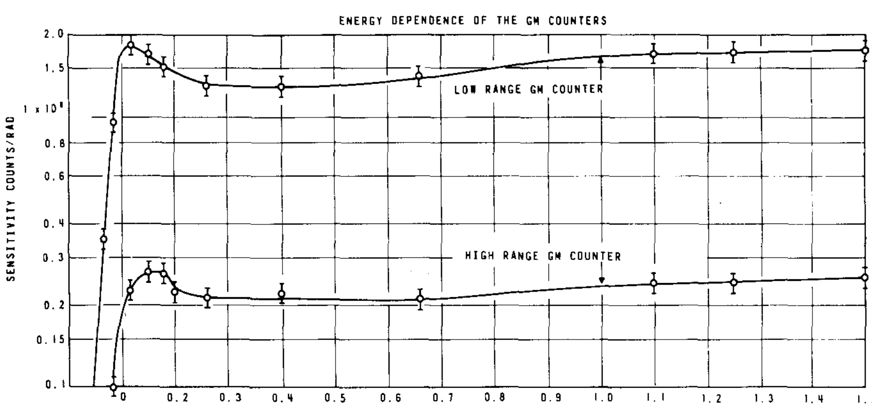

Figure 3. Energy Dependence of the GM Counters

The temperature dependences of the central and remote units were tested separately because it is likely that the remote units could be exposed to a wider temperature range. No change in response was observed in the central or remote units over the range -30^0 to +50^{0}C. To avoid temperature dependence in this range the logarithmic element in the central unit is thermostatically controlled. Exposure of both units to relative humidity in excess of 90% produced no change in response either.

Linearity of both high and low ranges was checked over the scale range. In addition the analog output is also proportional to the logarithm of the dose rate for one decade below the bottom of scale.

Both high and low range units were subjected to continuous exposure at 10,000 R/h and in both cases an off-scale indication was maintained.

The statistical precision of the monitor was tested by exposing the remote unit at various rates and sampling the output in a random manner while each rate was held constant. The results are shown below.

Standard Deviation in %

Indicated Dose Rate	Calculated s.d.	Measured s.d.
2.2 mrad/h	13.4	15
34	13.4	9
410	10.1	7
3.2 rad/h	3.9	4

The standard deviation was calculated using equation (3) with an additional fixed time constant of 0.2 s. The fixed time constant provides some additional precision at high dose rates without adding any appreciable delay (in comparison with human reaction time).

The response time is not defined by a simple time constant because it is changing during the transient from one dose rate to another (3). The table below shows the response time to 80% of the final reading for instantaneous changes from one dose rate to another. Also given is the dose absorbed during the response period.

Transient From To (mrad/h)	Time to reach 80% of final reading (Seconds)	Dose absorbed during response (mrad)
1 10	32	0.09
1 100	4.3	0.11
1 1000	0.32-1	0.09-0.28
1 10000	0.32-1	0.9-2.8

These measurements were made with the low range unit. The response times are similar for the high range unit but the absorbed doses are ten times higher. It can be seen that the response is very slow at the lower end of the scale but the dose absorbed while the monitor is responding is trivial.

4. ACKNOWLEDGEMENT

I wish to thank D. Enns, B. MacDonald and W.F. Richter for their help in developing the monitor.

REFERENCES

(1) W.J. Price. Nuclear Radiation Detection. McGraw-Hill. p. 67 (1964)
(2) A.R. Jones. Proposed Calibration Factors for Various Dosimeters at Different Energies. Health Physics 12, p. 663. (1966)
(3) A.R. Jones. A Linear Counting-Rate Circuit with Constant Statistical Precision. Nuclear Instruments and Methods 126, p. 313. (1975)