

TRANSISTORISED, BATTERY-OPERATED 'DOOR-POST' RADIATION ALARM MONITOR, WITH AUDIBLE AND VISUAL WARNINGS

by

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A number of gas-fired incinerators were installed in individual wards in The London Hospital to deal conveniently and speedily with soiled dressings and other combustible waste. Although the main hospital incinerator had been fitted with continuous radiation-monitoring facilities to prevent the accidental incineration of radioactive materials (particularly radium sources), the installation of individual ward incinerators constituted a 'loop-hole' with potentially serious consequences in the event of the incineration of a radium source within the main hospital building. It was therefore decided to fit each incinerator cubicle door with a radiation monitor, the requirements for which could be summarized as follows:

1. Battery operation, thus avoiding the consequences of possible mains failure.
2. Triggering within (say) one second by 0.5 mg radium at (say) 50 cm.
3. Basic, audible warning to be produced by a method from which, for the sake of reliability, electro-mechanical contacts were eliminated.
4. Instant readiness, following switch-on by micro-switches fitted to the incinerator-cubicle door.

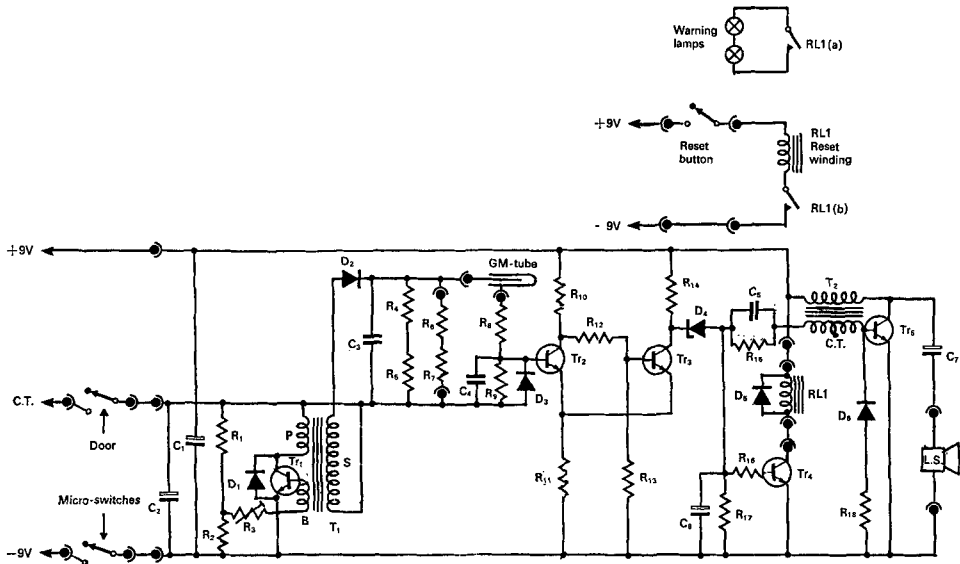
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5. Electronic 'locking-in' of basic audible warning in the presence of radiation, and resetting only when circuit is switched off by closing of cubicle door.
6. A secondary (visual) warning (not necessarily battery-operated), locking-in and remaining locked-in even after monitor switched off by closing of cubicle door.
7. Tolerant of background radiation variations, and freedom from the need for background tests.
8. No necessity for training of nursing and ward-orderly staff in any special operative routine.
9. Extreme reliability where not inherently fail-safe, and freedom from false alarms.
10. Simple and inexpensive circuitry to permit minimum maintenance and full duplication for reliability.

Circuit. Battery operation and instant readiness requirements indicated the need for a fully-transistorised circuit, in which the Geiger-Müller H. T. voltage is provided by a transistor 'ringing-choke' converter, enabling the whole circuit (apart from the lamps in the secondary warning device) to be run off one (18 V) battery (the converter in practice being run off the lower half only of the battery).

The circuit is shown in the accompanying diagram.

Triggering is catered for by a Schmitt pair, Tr 2 and Tr 3, and electronic locking-in is achieved by arranging the reset level of the Schmitt to be 'un-attainable' after the circuit has triggered. Thus the input signal voltage to the Schmitt comprises the p.d. developed across part of the G.M. load. This signal runs positive with respect to battery centre-tap, and the Schmitt is arranged to trigger at an input level of $\sim + 1.5$ V. The reset voltage is several volts below battery centre-tap, and although the base current taken by the input transistor of the Schmitt pair (via the high-resistance base circuit) is sufficient to bias back the base well below battery centre-tap, the base voltage is in fact 'clamped' by a diode and thus prevented from going lower than $\sim - 0.5$ V. The Schmitt, once triggered, can therefore be reset only by (at least momentarily) switching off the supply voltage to the circuit. The collector of the second transistor of the Schmitt pair is coupled via a zener diode to the bases of two further transistors, one of which (Tr 5) comprises a blocking oscillator, and the other (Tr 4) a conventional common-emitter current-amplifier stage. Both these transistors are normally 'off', the base circuits being returned to the emitter line. When the Schmitt triggers, the collector of the second transistor Tr 3 of the Schmitt pair rises towards the $+ 9$ V line, causing the zener diode to conduct and producing forward bias on the succeeding pair of transistors Tr 4 and Tr 5. The blocking oscillator



Circuit diagram of 'door-post' radiation alarm monitor.

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|----------------------------|---|
| R1 = 6.8K Ω | C1 = 50 μ F |
| R2 = 470 Ω | C2 = 50 μ F |
| R3 = 5K Ω (pre-set) | C3 = 0.1 μ F (1 000V) |
| R4 = 10M Ω | C4 = 0.47 μ F |
| R5 = 10M Ω | C5 = 0.1 μ F |
| R6 = 10M Ω | C6 = 50 μ F |
| R7 = 10M Ω | C7 = 32 μ F (100V) |
| R8 = 2.7M Ω | D4 = 13V Zener diode |
| R9 = 1.2M Ω | RL1 = 'Remanence' type relay |
| R10 = 1K Ω (2 %) | L.S. = Miniature (50 Ω) loudspeaker |
| R11 = 1K Ω (2 %) | T 1: Core: Mullard type LA1 |
| R12 = 2.4K Ω (2 %) | Primary (P): 25 turns (40 g) |
| R13 = 5.6K Ω (2 %) | Base (B): 220 turns (40 g) |
| R14 = 680 Ω (2 %) | Secondary (S): 2 500 turns (44 g) |
| R15 = 22K Ω | All wires 'Lewmex' insulated |
| R16 = 1K Ω | T 2: Ardente, type 3034 |
| R17 = 2.7K Ω | |
| R18 = 220 Ω | |

transistor is thereby switched on, causing a robust loudspeaker, condenser-coupled to its collector, to emit a strong note at a few hundred c.p.s. At the same time the current-amplifier stage energises a 'remanence' relay in its collector lead, which locks in, and, via its 'make' contacts, switches on the lamps in the visual warning indicator. This relay remains locked-in magnetically even after the circuit is de-energised, and can in fact be reset only by passing a current in the appropriate direction through its 'reset' winding, for which provision is made by means of a concealed 'reset' button which connects this winding momentarily across the circuit supply battery.

All the transistors are generously rated silicon n.p.n. types, and the diodes are also silicon types. No finer wire than 44 g is employed in the transformers, and both transformer windings are vacuum-impregnated. The batteries chosen are cheap and readily available, having screw terminals and soldered internal cell-connections. The G.M. tube chosen gives good geometrical coverage of the required doorway area with a 0.5 mg radium needle carried past at walking pace. In general, preset components have been avoided in the design, but in one or two places component selection may be necessary (e.g. the blocking-oscillator timing capacitor or resistance).

G.M. load circuit and Schmitt input circuit. The G.M. tube chosen was a 20th Century G60H, whose operating voltage is 400 V to 500 V. The load is a 2.7 megohm and a 1.2 megohm resistor in series, the latter providing the signal voltage, and having a 0.47 μ F 'tank' capacitor across it, to give a time constant of about half a second.

The potentiometer network connected to the base of Tr 3, the second transistor of the Schmitt pair, provides about 1.5 V at the base of Tr 3 at switch-on, and the commoned emitters of Tr 2 and Tr 3 therefore take up a voltage of $\sim +1.0$ V, with the base of Tr 2 at earth potential (Tr 2 therefore being cut off) in the absence of radioactive material. (The normal background count-rate develops no appreciable voltage across the 1.2 megohm resistor.)

When the presence of radioactive material raises the voltage at the base of Tr 2 to about $+1.5$ V a regenerative switch-over takes place, Tr 2 switching on, and Tr 3 off, very rapidly. It can be shown that after triggering, the base of Tr 2 would have to be lowered to between -2 V and -3 V for resetting to occur. As stated above, the diode D 3 prevents this, and once triggered the Schmitt pair can be reset only by removing the supply voltage momentarily.

When Tr 3 switches off as triggering takes place, its collector rises from about $+2$ V towards $+9$ V rail voltage, thereby applying a voltage in excess of the breakdown value to the zener diode D 4, the latter therefore conducting and putting forward bias on the bases of Tr 4 and Tr 5.

Blocking oscillator. An Ardente D 3034 transformer is used to back-couple the collector of Tr 5 to the base circuit (the timing circuit being in the base lead and consisting of a 0.1 μ F capacitor in parallel with a 22 k-ohm resistor, giving an oscillation frequency of about 350 c.p.s.). A 32 μ F 100 V capacitor couples the collector to a 50-ohm impedance 3" loudspeaker (situated in the top of the G.M. tube housing). The employment of an oscillator in conjunction with a loudspeaker avoids the use of a bell or buzzer, with their potentially troublesome electro-mechanical contacts.

'Remanence' relay. Once energized, the remanence relay RL 1 locks in magnetically and remains so even when the operating winding of the relay is subsequently de-energized. It can be reset by passing a reverse current through the 'reset' winding, for which provision is made by means of a press-button circuit across the 18-volt battery supply. This 'reset' button is inconspicuous and unlabelled, to avoid irresponsible switching-off of an alarm. (A 'make' contact on the relay itself is wired into the reset circuit to ensure a clean and definite resetting action.)

DC converter H.T. supply to the G.M. tube. This is a conventional 'ringing-choke' converter, the voltage output from which is controlled by the setting of R_3 .

The H.T. to the G.M. counter is set near the top of the plateau to allow for battery fade (the H.T. falling about 50 V per 1 V supply voltage drop).

To establish the correct value of H.T., the removeable 20-megohm chain across the reservoir capacitor is withdrawn and a 20 k-ohm/V meter on the 1 000 V range substituted for it. R_3 is then adjusted to give the correct value of H.T., and the 20 megohm chain replaced after removing the meter, thus compensating for the shunting effect of the latter.

Installation as ward incinerator monitors. Two complete monitors are installed at each incinerator, one on each side of the cubicle door.

Four single-pole micro-switches are fitted to the door, constituting two double-pole on-off switches, one for each monitor. These switches are in the battery centre-tap and negative lines respectively, to prevent spurious triggering of the Schmitt circuit at switch-on.

Each remanence relay has two 'make-contacts' available for switching the mains lamps in the visual warning indicator (installed over the cubicle doorway). The latter contains six 15-watt lamps, arranged in parallel and illuminating a suitable warning notice. The 'make-contacts' on the relays are wired in two parallel pairs so as to provide duplicated and independent switching of the lamps. A 'flasher' switch in series with the lamps provides an 'on' period of about 2 seconds and an 'off' period of about 1 second, and fails safe (i.e. with lamps on).

Conclusion

Several of these monitors have been in continuous use for nearly four years at The London Hospital and have throughout this period been completely reliable and trouble-free.

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SUMMARY

A simple and inexpensive transistorised 'door-post' radiation alarm monitor is described, which is battery operated, producing both audible and visual warnings. The audible warning 'locks-in' electronically, and the design eliminates potentially troublesome electro-mechanical contacts, such as those involved in electric bells and buzzers. A remanence relay is employed to lock-in the visual warning. Several of the monitors have now performed completely trouble-free for several years.

ZUSAMMENFASSUNG

Eine einfache und billige, transistorisierte "Tür-Pfosten" Warnanlage vor Strahlung, die Batterie-betrieben ist und durch Geräusche und visuell warnt, wird beschrieben. Die hörbare Warnung erfolgt elektronisch, und die Ausführung schliesst die potentiellen Störungen elektro-magnetischer Kontakte, wie sie bei elektrischen Glocken und Summern verwendet werden, aus. Ein Remanenz-Relais ist verwendet, um die visuelle Warnung einzuschalten. Verschiedene dieser Warnanlagen haben seit einigen Jahren vollständig störungsfrei gearbeitet.

RESUMÉ

L'auteur décrit un dispositif d'alarm aux radiations, transistorisé, simple et peu coûteux, fonctionnant sur pile qui produit des signaux auditifs et visuels. L'avertisseur sonore est enclenché électroniquement et sa construction élimine les contacts électro-mécaniques qui pourraient être gênants tels que ceux des sonnettes électriques et des vibreurs. Un relai à remanence est employé pour enclancher l'avertisseur visuel. Plusieurs de ces avertisseurs ont maintenant fonctionné pendant plusieurs années sans aucune difficulté.