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NEUTRON DETECTOR SUITCASE FOR THE NUCLEAR EMERGENCY SEARCH TEAM

by

E. J. Dowdy, C. N. Henry, R. D. Hastings, S. W. France

ABSTRACT

A portable high-efficiency neutron detection system has been constructed for the Nuclear Emergency Search Team. It includes an alarm system based on time interval measurements of the incoming neutron detection pulses. The system is designed for transportation by vehicle in searching for neutron-emitting radioactive materials.

INTRODUCTION

Elements of the Los Alamos Scientific Laboratory (LASL) act both operationally and as a research and development agency for the Nuclear Emergency Search Team (NEST). NEST is responsible for responding in a timely fashion to acts of extortion that involve threatened use of special nuclear materials (SNM) or other radioactive materials. One possible phase of the response to credible threats is to search for materials claimed to be held by the extortionist. A first move is to dispatch a few trained personnel with hand-held or otherwise portable instruments that can detect the latent radiations expected. The only radiations from radioactive materials detectable at a distance are neutrons and gamma rays, and all current search instruments are based on detection of these penetrating radiations.

This report describes a high-efficiency, portable, neutron detection system developed for the NEST. The system—detectors, amplifiers, discriminators, power supplies, batteries, battery charger, and detection logic circuitry—is packaged in a single 46 by 66 by 30 cm, custom-made aluminum "suitcase" that weighs approximately 32 kg. The three-section suitcase is shown in Fig. 1, and details of the various components are described in the following sections.

DETECTORS

In each outer section of the suitcase, there are eight ^{3}He-filled neutron sensitive proportional counters (4×10^5 Pa fill pressure) 5 cm in diameter with a 53-cm active length. They are in a planar array in each section, with the outer shells of adjacent detectors in contact. The detectors are bare on the outer side of the closed suitcase and are in contact with a 0.64-cm-thick sheet of polyethylene on the inner side. The bare side of the detector array is intended to be exposed in the expected direction of the radiation source. The rather small amount of moderating material near the detectors was chosen as a result of earlier neutron detector improvement studies,[1] as well as to save weight. The neutron suitcase was designed to be carried in a vehicle in normal traffic patterns, and the radiation source is expected to be remote and enclosed. Our studies indicate that the resultant neutron spectrum at the

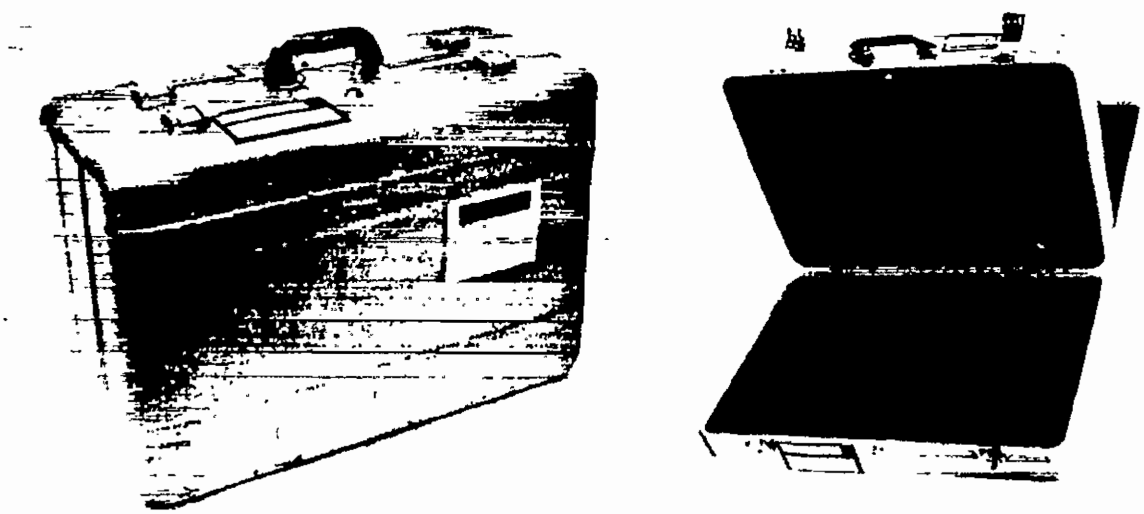

Fig. 1.
The neutron detector suitcase.

detector location is "soft," and too much moderating material would decrease the detection efficiency.

ELECTRONICS

All the electronic circuits, the batteries and battery charger, the signal conditioners, and the detection logic are contained in the center section of the suitcase.

A. Power Supplies

The low-voltage (12.5-V) power supply consists of 10 D-size, rechargeable NiCd batteries with an approximate 65-h lifetime between charges. The high-voltage (1410-V) supply consists of 47 B-size, nonrechargeable, 30-V carbon dry cells. The drain on the high-voltage supply is small, so the supply lifetime is essentially the shelf life of the batteries. Figure 2 shows the charger for the low-voltage battery pack partly removed from its storage compartment.

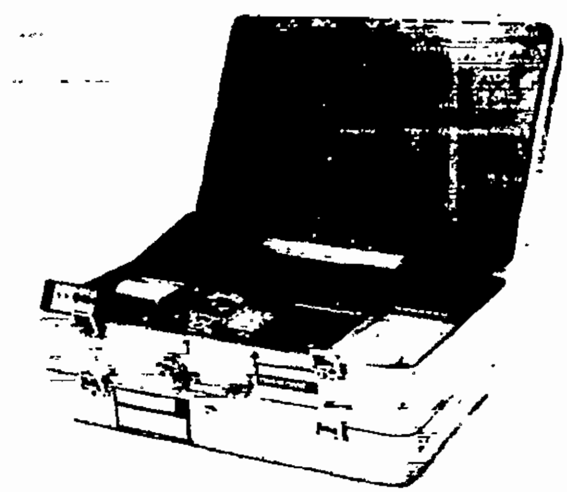

Fig. 2.
Charger for low-voltage battery pack lifted from its storage compartment.

B. Signal Conditioning

All 16 proportional counters are ganged together into a single amplifier and discriminator. With 1410-V bias on the counters, the amplitude of pulses from the counters due to the $^3He(n_{th}, p)T$ reaction is approximately 4 mV. The amplifier gain is approximately 10^3, resulting in an approximately 4-V pulse from the amplifier for the 4-mV input pulse. The discriminator threshold is variable, but it is normally set to provide a logic output pulse for analog signals above approximately 1 V.

C. Detection Logic

The detection logic is based on measurement of the time intervals between pulses as implemented by s-fold analysis.[3] This type of analysis was chosen for detector systems whose normal count rate is low. Successive short counting intervals should yield small numbers that would preclude Gaussian statistical analyses, and chance overlap of a counting Interval and the optimum time window for the source is highly improbable. The s-fold technique, based on the Poisson distribution, is a preferred method for analyzing source-related counts.

The s-fold circuit, diagramed in Fig. 3, produces an alarm output when a comparison scaler accumulates a clock count number smaller than the number that represents the average background count arrival rate, diminished by a certain amount to provide the proper "trip" level. The clock pulse scaler content is measured when the neutron pulse input scaler accumulates the number of pulses that the operator has preselected. In a normal mobile search, the background is expected to fluctuate; the logic circuitry automatically accounts for this "long-term" fluctuation. The primary clock frequency is adjusted digitally in direct proportion to the incoming neutron pulse rate. The "short-term" count rate is thus compared with a "longer term" but nonstationary background count rate. The false alarm probability per comparison is constant, but, because the number of comparisons between the incoming pulse rate and the current background rate is proportional to the average count rate, the false alarm rate per unit time is directly proportional to the average count rate.

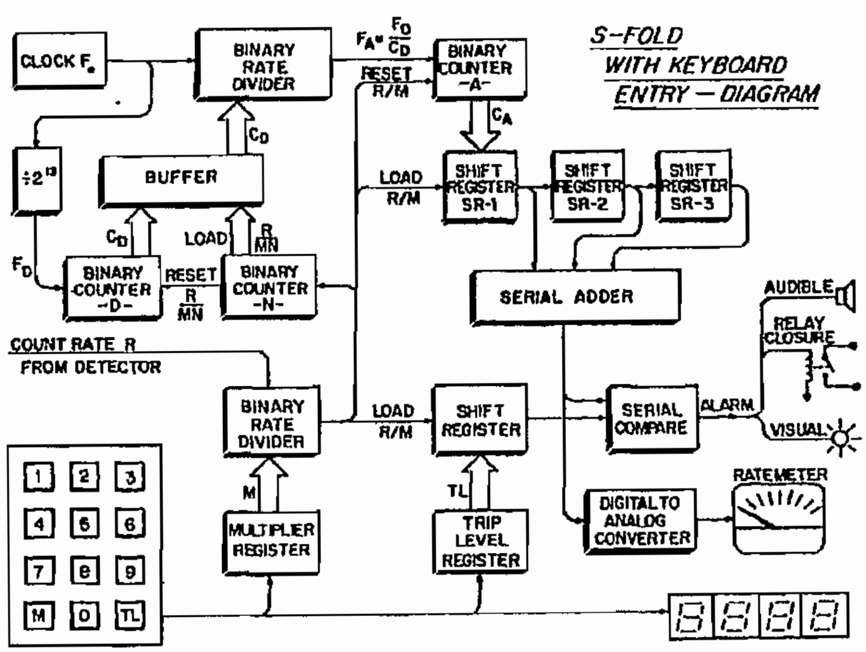

Fig. 3.
The s-fold circuit.

The logic circuitry (Fig. 3) operates as follows. The primary clock frequency, F_0, is approximately 1 MHz. This frequency is divided by 2^{13} before being scaled in binary counter D. The contents of binary counter D is loaded into the buffer when the contents of binary counter N equals 32, and binary counter D is reset. As Fig. 3 indicates, the number in binary counter N is M^{-1} times the number of input pulses from the discriminator. The load and reset pulses are generated whenever the content of binary counter N equals 32, which requires a certain elapsed time Δt. This Δt corresponds to M x 32 input pulses. The count accumulated in binary counter D in Δt is

$$C_D = \frac{F_0 \Delta t}{2^{13}} .$$

Binary counter A is presented with a pulse frequency

$$F_A = \frac{F_0}{C_D} = \frac{2^{13}}{\Delta t}$$

that is independent of the primary clock frequency, F_0, but is adjusted as Δt changes. This change in Δt provides for adjustments appropriate to "long-term" background fluctuations. Binary counter A receives a load and reset pulse *on the average* of every M/R seconds and transfers to shift register SR-1 an *average count* of

$$C_A = F_A \frac{\Delta t}{32} = 256 ,$$

When the incoming pulse rate increases near a neutron source, the load and reset pulses for binary counter A increase in frequency, momentarily causing a number *smaller* than 256 to be transferred to shift register SR-1. The count C_A is shifted out of shift register SR-1 into shift register SR-2 and into a serial adder. In the 3-fold circuit used in the suitcase, three such sequential time intervals are summed, and the sum is presented to the compare circuit, which compares the current sum to the operator-selected trip level. If the time between incoming pulses has been compressed enough, the trip level is reached and the alarm relay is activated.

CONTROL PANEL

The suitcase control panel is contained in a separate compartment in the center section which is removable from the center but is connected to the suitcase by 2.4-m-long cables. Figure 4 shows the control panel removed. Figure 5 is a closeup of the panel. The functions and indicators on this panel are as follows.

A. Power

A three-position rotary switch selects the power source for the suitcase. The OFF/CHG position is the normal OFF which is also used to charge the low-voltage batteries. There are two ON positions; one provides power from the internal batteries, the other selects the external power source that can be any +12-V dc supply of adequate power rating.

B. Internal Battery Test

A push-to-test switch and OK condition light are provided for the internal low-voltage batteries.

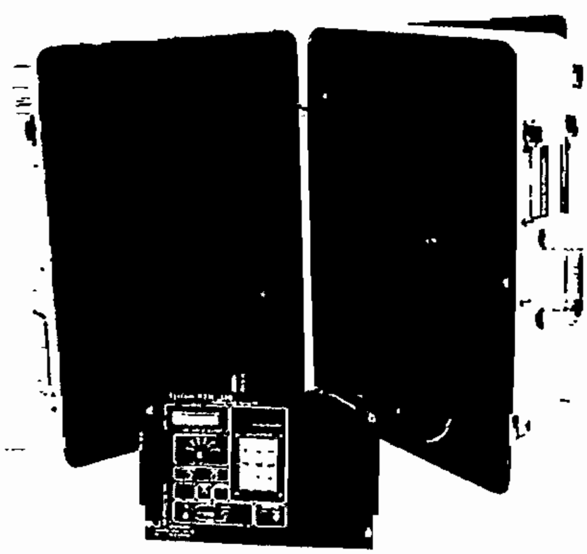

Fig. 4.
The control panel withdrawn from the suitcase.

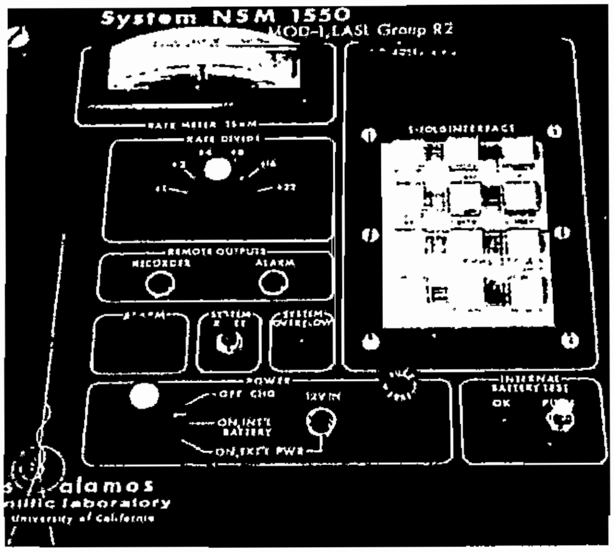

Fig. 5.
The suitcase control panel.

C. System Reset

A three-position toggle switch provides the following alarm-enable functions.

UP — The alarm is reset at the end of each sampling interval.

MIDDLE — The alarm is inhibited.

DOWN — The alarm is continuous, once activated, until reset. It is reset by placing the switch in the MIDDLE position and returning it to the DOWN position.

D. Remote Outputs

Recorder. An internal digital-to-analog converter produces an analog output of the 3-fold time interval for use with a strip-chart recorder.

Alarm. A relay is closed momentarily when the trip level is reached in the logic circuit. The resulting signal may be used as an event mark on a strip-chart record, or it can be scaled for alarm rate determinations.

E. Alarm

An audible signal is generated when the trip level is reached if the audible alarm is not inhibited. The signal duration is determined by the position of the system reset switch.

F. System Overflow

A light-emitting diode is activated if the selected M causes the capacity of the clock pulse binary counter D to be exceeded.

G. Panel Meter and Rate Divide

The time interval number from the serial adder is converted from digital to analog to provide a meter deflection for operator convenience. To reduce unnecessarily large meter deflections, the serial adder output can be divided by using the rotary rate divide switch.

H. S-fold Interface

A keyboard is provided for inputing appropriate values for the prescale multiplier, M, and the trip level, TL. The M and TL values are determined for the speed of the vehicle carrying the suitcase, background in the area, tolerable false alarm rate, and distance to the structures suspected of containing the device.

OPERATIONS

The neutron detector suitcase is deployed as shown in Fig. 4. The control panel is extracted from the center section and taken to the operator's seat. With the suitcase powered, the M and TL values are put in. These values are determined from the expressions

$$M = \frac{\overline{B}+S}{3} \times \tau ,$$

and

$$TL = \frac{\overline{B}}{S+\overline{B}} \times 768 ,$$

where B is the average background count rate, S is the minimum source signal above background expected for alarming (usually taken from Poisson tables consistent with an acceptable false alarm rate), and τ is the time over which the source signal is expected to be detectable above the background. In terms of the vehicle speed, v, and the distance to suspect objects, ℓ, the time, τ, is expressed as

$$\tau = \frac{2.8\,\ell}{v} .$$

The number 768 in the formula for TL is the number that normally comes from the serial adder shown in Fig. 3. It represents the sum of three measurements of C_A for a nonfluctuating input count rate; i.e., it represents the adder output that corresponds to an input detector count rate of $\overline{B}$. The number from the serial adder is reduced by the factor.

$$\frac{\overline{B}}{\overline{B}+S}$$

to give an input detector count rate that corresponds to the sum of the nonfluctuating background $\overline{B}$ and the source signal, S.

The mobile search can start when appropriate M and TL values have been registered.

REFERENCES

1. Group R-2 Quarterly Progress Report, October-December 1975, unpublished LASL data.

2. See, for example, R. D. Evans, *The Atomic Nucleus* (McGraw-Hill, 1955), p. 794.