AREA RADIATION MONITOR SYSTEM WITH LOGARITHMIC INDICATION AND AUDIO-VISUAL WARNING

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Summary

For five years a neutron detection system (utilizing BF_3 detectors with moderators and vacuum tube amplifiers and count-rate circuits) has been in useful service at the Los Alamos large Van de Graaff accelerator. During this time difficulties with the need for increasing counting rate capability as well as component failures have led to a desire for improvement. In addition, the detectors were sensitive to thermal neutrons to an extent which made it difficult to get a legitimate measure of biological danger with various neutron spectra.

An improved system was developed to give a more believable measure of biological danger (referred to "first collision tissue damage" described in NBS Handbook 63[3]). The system was to be made more reliable through the minimization of vacuum tubes and relays. The problem of indicating varying levels of neutron flux without changing ranges was solved by a logarithmic count rate meter with a range from 1-5000 mrem/hour.

The indicating system was to be expanded to give rapid visual information at the control room and other locations as well as audio alarms in the experimental area.

By transistorizing all the electronic circuits and using only low voltages, both reliability and safety is improved.

A gamma system, with a range from .01 to 10 r/hour, utilizing ionization chambers and an electrometer tube, is an integral part of the radiation system. It energizes the same alarm system as the neutron detectors.

The system block diagram is shown in Fig. 1.

Neutron System

Detector

T. W. Bonner[1] has described a neutron counter consisting of a lithium-iodide crystal surrounded by a sphere of polyethylene to moderate the neutrons. The detector response for a 10" sphere appears to be proportional to the tissue damage for neutron energies below 8 or 10 MeV. The response of the detector as a function of neutron energy has been experimentally verified by D. E. Hankins[2] and theoretically verified with machine calculations by George Bell of this laboratory.

Neutron detection at each station is achieved with an 8-mm diam by 4-mm thick $Li^6I(Eu)$ scintillator surrounded by the 10-in. diam sphere of polyethylene as moderator. Light from the scintillator is coupled to a 6199 photomultiplier tube through a 1/2-in. diam quartz light pipe. The PM tube is magnetically shielded with several layers of Conetic AA foil.

Electronics at each station includes a high voltage dc-to-dc converter* with shunt regulator to furnish PM voltage, and a charge-sensitive pulse amplifier with output 93-Ω driver. Power required at each station is derived from a common 20-V dc line.

Anode pulses from the PM tube are shaped in the amplifier which has a decay time constant of 5 μsec, adequately long to allow full pulse amplitude from the slow scintillator. Pulse output levels from the line driver are set by adjusting photomultiplier tube voltage. Each station is adjusted to give 0.6-V pulses from neutrons, and a typical photomultiplier operating voltage is 700 V. With these conditions pulses from Co^{60} gammas will be about 0.2 V with a typical good scintillator. These amplitudes are large enough to trigger the sensitive discriminators at the count-rate meter without further amplification.

Discriminator

A low level, linear discriminator of standard design is used to determine the appropriate counting level and shape the pulses feeding the count rate meter. The level is adjustable between 0.050 V and 1.0 V.

The discriminator chassis also furnishes 20 V dc to operate the line drivers and photomultiplier high voltage supplies.

Count-Rate Meter

Neutron intensities at the Van de Graaff facility are such as to vary from zero to 1000 mrem per hour. Since we are not interested in levels below 1 mr/hour, a factor of 1000 range is of interest. Previous problems of range-changing and accuracy uncertainty with linear count-rate meters led us to develop a logarithmic rate meter which has suitable accuracy of indication at all neutron flux intensity levels. A three-stage diode pump circuit was employed which indicates over a range of about four decades (from .5-10,000 counts per second). In our particular system, tissue equivalent damage levels can be indicated from 1 to 5000 mrem/hour quantitatively.

The basic Cooke-Yarborough circuit is as shown in Fig. 5. Positive pulses are delivered to the input, charging capacitor C_1. This charging current must flow through D_1 and C_2, charging it. If a

*Components Corporation Model 59-2.

resistor, R, is placed across C_2, the voltage developed across C_2 is nC_1 VR, for the equilibrium condition that $i_1 = i_2$, where n is pulse repetition rate, and V is input pulse height.

Now, it is seen that i_2 is proportional to n, the pulse repetition rate. The desired characteristic is $i_2 = K \log n$, and it is possible to obtain perhaps 5 decades from 1 to 10^5 pulses per second on a linear meter scale without switching. For any decade, this is accomplished by saturating the circuit, by making R large so that the voltage across C_2 approaches the input pulse voltage, V. Then one adds a number of these circuits in parallel, each with a certain value of C_1 chosen for a particular decade. All currents, i_2, add through a common meter.

The pulses, V, are delivered to the circuit from a Schmitt trigger, so that they are of a fixed amplitude and shape. Diode D_2 is for the purpose of discharging C_1 after each pulse when the input pulse V drops negatively from its maximum positive value to zero.

Alarm Circuit

The components of the alarm system are: localized warning bells and flashers in the radiation areas; and remote warning lights mounted on a map display of the area.

In the neutron system, the light control is provided by silicon controlled rectifiers (SCR's), as shown in Fig. 3. A signal for these is taken directly off the count-rate meter, from a 75 K resistor, which is applied to an emitter follower and thence to the SCR. Currents of a magnitude of 50-250 μA are sufficient to turn on the type 3B30S SCR.

In order to provide turn-off control of the SCR's, it is necessary to provide full-wave, unfiltered anode power, which goes to zero twice each power line cycle and allows the SCR's to turn off in the absence of a control signal.

The green lights are turned on by an SCR which is biased on. If the signal from the count-rate meter is such that the yellow light turns on, the green light is turned off by means of a veto signal applied to its control SCR. Similarly, when the red light turns on, veto signals are applied to both SCR's controlling the yellow and green lights. Also a signal is obtained from either of these SCR's to ring alarm bells and operate a large rotating flashing light in a local radiation area or room. Circuitry is such that a flashing light outside the building or at any other desired point can be actuated if any local alarm is activated. The circuit for activating the alarms is shown in Fig. 4.

Gamma System

Detector

The gamma and x-ray monitor system uses air ionization chambers as detecting elements. These chambers are of thin-wall aluminum with about 600 cc volume. Ionization currents range from less than 5×10^{-13}A to nearly 10^{-9}A for radiation intensities from several mr/hr to 10 r/hr.

The circuit used to measure the chamber currents is an adaptation of the familiar Neher-White configuration. The 5886 electrometer tube circuit (see Detector Unit section of Fig. 6) is operated at a negative potential with respect to the chamber wall to give positive ion collection at the circuit. The quiescent operating grid voltage of the tube is established by the resistor value in the F^- return. This is selected so that the bias very nearly corresponds to the floating-grid potential. From this "zero" starting point, for about 7 decades if one desires, the Eg-Ig characteristic is logarithmic by virtue of the log diode effect from grid current flow.

In this circuit the very low end response is linear due to the 10^{12}-grid return for system zeroing, but for about 90% of the system range essentially all the ion chamber current flows via the grid giving logarithmic conversion. Grid voltage change (about 0.2 V per decade change of Ig) is sensed by measuring the plate current, yielding about 15 μA per decade. The plate metering circuit includes a bucking network for cancelling quiescent plate current, and a shunt for adjusting full scale response range.

Electrometer tubes must be aged for several hundred hours to assure stable operation. As an additional precaution, the turn-on switch sequence applies heater voltage before plate voltage. Resulting stability allows operation for periods as long as 5000 hours without detailed calibration checks.

Alarm Circuit

The gamma system is tied into the same alarm system as the neutron system. In this system control for the alarms is derived from a contactless type of meter relay manufactured by Assembly Products, Type 302-L. Control within this unit is obtained by means of a fiber optics system providing illumination to a photoresistor. Depending on the position of the meter point relative to a "set" pointer, the resistance value of the photoresistor is high or low, with a relatively sharp transistion at the set point. In the gamma system, meters with two set points, one for the yellow and one for the red alarm, are used. These meters provide signals for a transistor circuit controlling the lights and alarms. This circuit is shown on Fig. 6. Relays are needed in the alarm circuitry to provide isolation between the low-voltage transistor circuitry and the 115V ac alarm bells and flashers. Relays will be eliminated in the near future when the proper dc alarm components are obtained.

References

1. Bramblett, R. L., Ewing, R. I., and Bonner, T. W., "A New Type of Neutron Spectrometer," Nuclear Instr. and Methods, 9, 1 (1960).
2. Hankins, D. E., Los Alamos Scientific Laboratory Report LA-2717 (1962).
3. "Protection Against Neutron Radiation up to 30 Million Electron Volts," National Bureau of Standards Handbook 63.

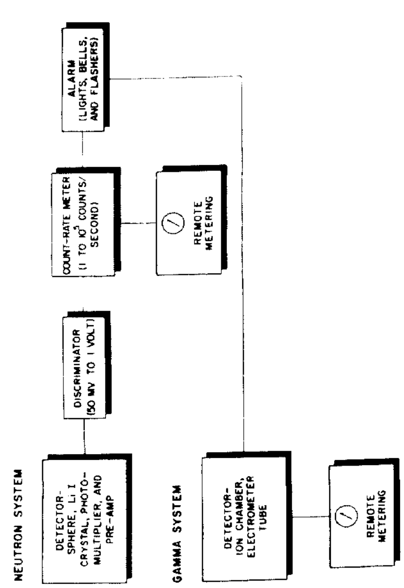

Fig. 1. System Block Diagram.

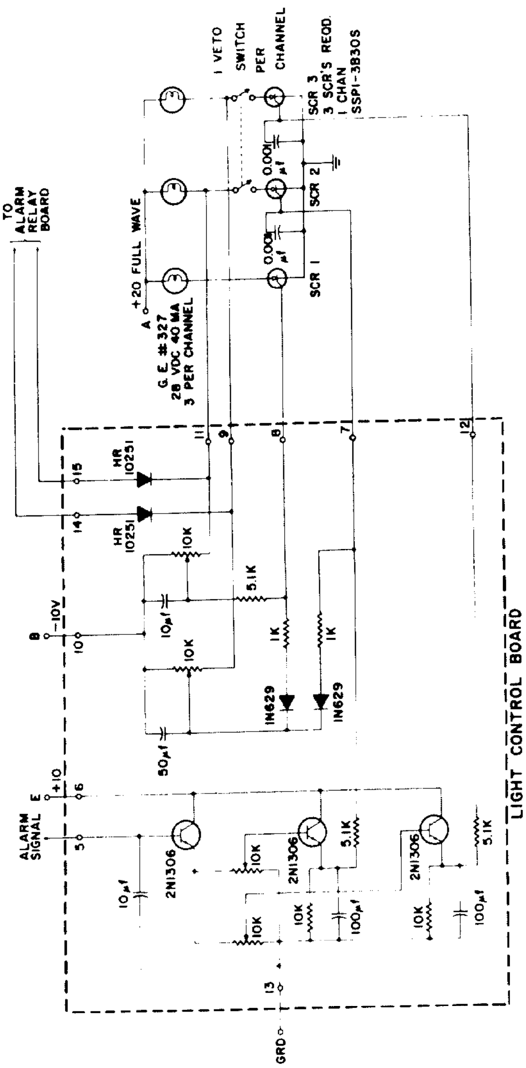

Fig. 3. Neutron System Light Control Board.

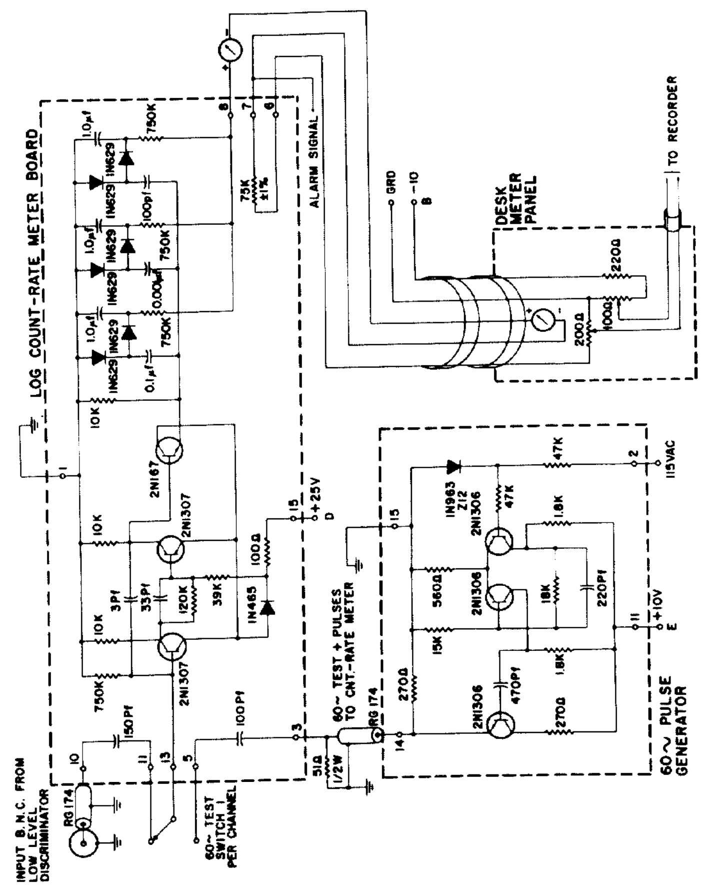

Fig. 2. Neutron System Count-Rate Meter.

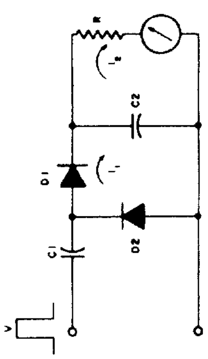

Fig. 5 Neutron System Diode Pump Circuit.

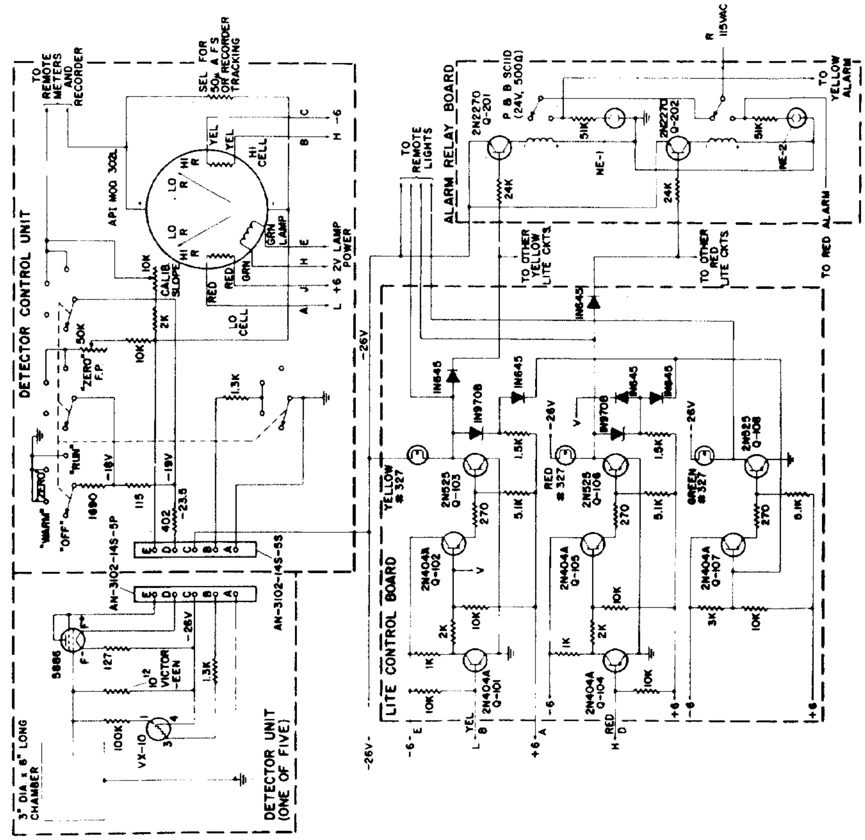

Fig. 6 Gamma System.

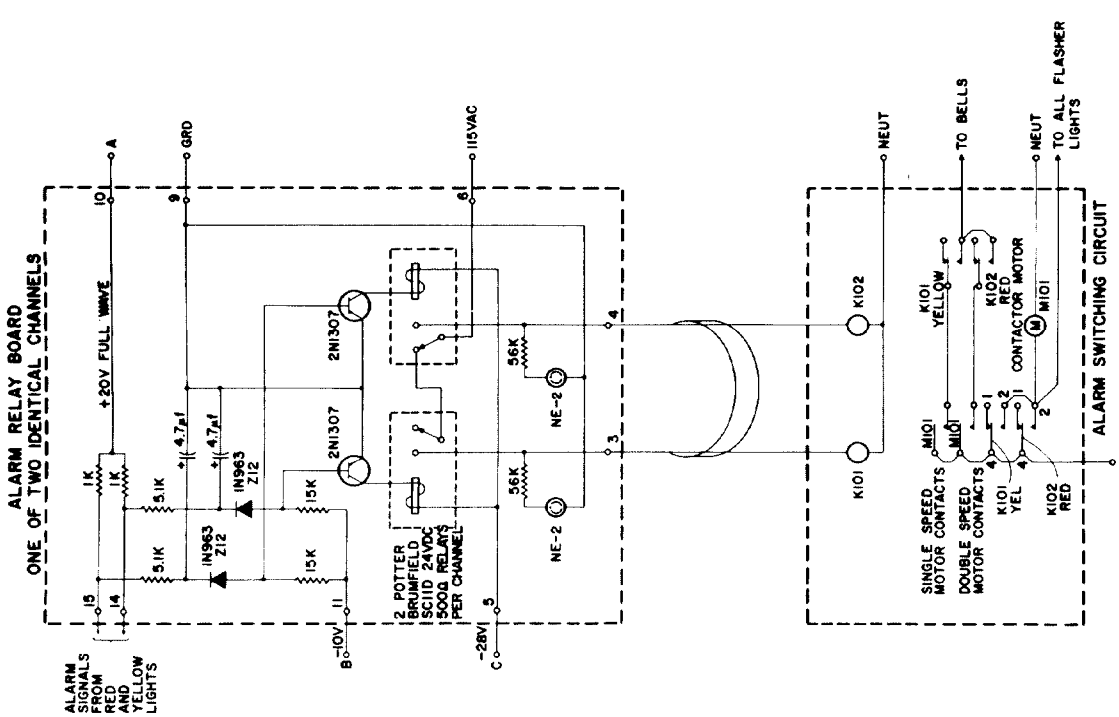

Fig. 4 Neutron System Switching Alarm Circuit.