AN ACCELERATOR RADIATION PROTECTION SYSTEM[1]

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Accelerator induced radiation presents a hazard to personnel that is generally controlled by adequate shielding of the accelerator and experimental areas and by removal of the charged particle beam from an area when personnel must have access to it. In the past, radiation detectors and warning devices (flashing lights, buzzers, etc.) have been used to indicate areas of danger, and prudent personnel have successfully worked with accelerators without harm. These procedures still form the first line of protection against excessive exposure to radiation at ORNL High Voltage Accelerator Laboratory. However, a second line of defense involving automatic protection by accelerator shutdown has been added to the Tandem Van de Graaff facilities in consideration of the enlarged number of both experimental and servicing personnel using the facility. The system permits time limited access to areas where radiation is present, but tends to prevent personnel receiving excessive exposure by requiring that radiation producing beams be removed from the area when a specified integrated dose of gamma and neutron radiation has been monitored.

System Description

This system provides a delayed automatic shutdown of the accelerator beginning when a door to a hazardous area is opened. The delay time is inversely proportional to the radiation level in that area except in a limiting case in which accelerator shutdown becomes instantaneous upon opening the door. Thus, limited monitored access to reasonably low-level radiation areas may be had without interruption of an experiment in progress.

The components of the system are as shown in Fig. 1. Ionization chambers were chosen as the radiation detectors for two reasons; experience in reactor control applications has shown them to be far more reliable than almost any other type of sensing element, and, unlike a counter, it is impossible to "jam" a chamber at high radiation levels. The chambers used in this case have volumes of one liter; the filling is 76 cm Hg $^{10}BF_3$ (96% ^{10}B enrichment) plus 76 cm Hg argon. A thin outer coating of Cd and a thick jacket of polyethylene are used to balance the response of the assembly so that neutrons and γ rays of equal biological dose rates produce equal currents in the chamber. The current in the chamber is a fairly accurate indicator of the total biological hazard. The chambers in each area are placed approximately 3 meters from the source of radiation. The radiation field at one-half this distance from the source (4 times the field at the chamber) is used as a basis for determining the amount of accumulated dose to cause accelerator shutdown. The maximum allowable integrated dose for an 8-hour period is 0.5 rem at this distance. Thus, a radiation level of 0.125 rem at the chamber for 1 hour in an insecure area would cause accelerator shutdown.

The ionization chamber current is converted by an electrometer amplifier to metering signals which drive "allowable entry time" meters at appropriate doors and duplicate meters for each area at the main control console. A reading of 60 min. on the meter face corresponds to a radiation level of 0.125 rem at the chamber. The full scale meter reading of 6 min. corresponds to 1.25 rem and would cause instantaneous accelerator shutdown if the area door were opened.

The amplifier outputs are also connected to a signal comparator circuit which selects the maximum amplitude signal and feeds it to an integrator. The integrator produces an output pulse-rate proportional to input voltage and drives an electro-mechanical register. The register has a preset number in it corresponding to the permissable integrated dose. Since the integrator produces 100 counts per minute at a radiation level of 0.125 rem at the ion chamber, the preset register number is 6000 for accelerator shut-down to occur in 1 hour. Every 8 hours the register is reset by a timer whether it has counted down or not, allowing another 8-hour integrated dose to be accumulated. It is to be noted that this is an accumulative system, integrating counts produced by each separate entry even though by different personnel in different areas.

In the event the radiation level in a secured zone is high enough to limit entry time to < 6 min., the integrator count-down trip procedure is superceded by an instantaneous accelerator trip when a door to that zone is opened. This is performed by a preset contact meter relay in an electrometer amplifier at the main console.

A procedural arrangement built into the system calls for personnel guarantee that a hazard area is clear. Door interlocks are so arranged that not only must all doors to an area be closed but a "secure" button outside that area must be pressed to disconnect the amplifier output signal from the integrator. When both conditions are met a green "secure" light comes on at the main console and the operator understands that a certification has been made that no one is in the area.

As to operating procedure, if for any reason the accelerator is tripped by radiation integration two things must happen. First, an investigation would be made and new procedures enforced to prevent a recurrence. Second, for the remainder of the 8-hour period until the integrator resets itself the accelerator may be operated only with all zones "secure."

The details of this system are described by the following ORNL drawings which are available on request to educational institutions and other government research laboratories.

Ionization chamber -- Q-2289-1

Electrometer amplifier -- Q-2338-5, Q-2336-6

Signal Interconnecting and Grounding Relays -- Q-2338-4

Signal Comparator and Selector -- Q-2338-3

Preset Timer and Counter -- Q-2338-2

System Block Diagram -- Q-2338-1

Operational Experience

This system has been in operation in the ORNL Tandem Van de Graaff facility for more than 1 year. In no instance has the count down feature caused accelerator shutdown. Experimenters have respected the system which allows them reasonable entry for adjustment and alignment of apparatus. Servicing personnel have respected the "secure" aspect of areas they need to enter and requested entry time from the operator when necessary. Only 3 "incidents" have occurred in which personnel entirely unfamiliar with the area have inadvertently opened a secure zone. In two of these cases the beam was immediately removed from the area by the operator and an investigation made of the unauthorized entry. In the remaining case, the area entered had an upper limit of radiation (< 6 min. entry time). The system automatically tripped the accelerator shutdown relay, thus preventing any exposure.

Maintenance on the system has consisted principally of replacement of the electrometer tube in the ion chamber signal amplifier. This is done when a monthly check of amplifiers by the Health Physics Division indicates a weak response to a radioactive source brought near the ion chamber. The system has performed its intended function with 100% reliability at reasonably little maintenance effort.

The most important feature of the system has been that there has never been a temptation to disable it in any way. No interlocks have been by-passed and no detectors have been disabled; the reason is that the system does not interfere with entry except where entry is obviously very unwise. The fact that all doors are unlocked means that, in case of fire or other non-radiation emergencies, immediate entry will merely trip the accelerator while attention is paid to the emergency itself.

Reference

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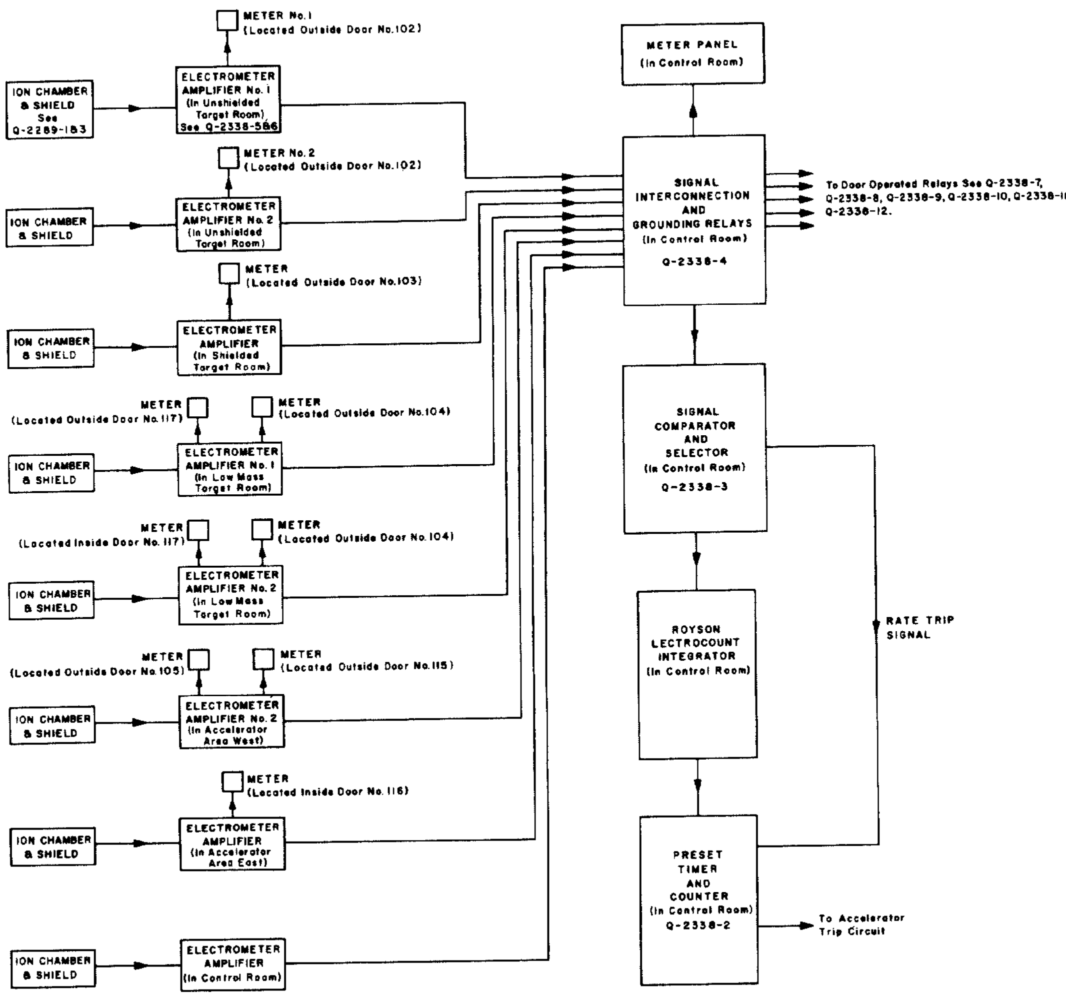

Fig. 1. Radiation Protection System Block Diagram.