FAIL-SAFE ION CHAMBER ERRANT BEAM DETECTOR TAILORED FOR PERSONNEL PROTECTION

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Introduction

This fail-safe ion chamber system is designed to be part of the personnel safety system (PSS) for the Los Alamos Neutron Scattering Center (LANSCE) at the Los Alamos National Laboratory. Its job is to protect the occupants of the experimental areas from large radiation doses caused by errant beam conditions during beam transport from the Proton Storage Ring (PSR) to the LANSCE neutron spallation target. Due to limited shielding between the beam transport line and the experimental area, personnel can safely occupy the experimental area only if the beam losses in the transport line are very low. The worst case beam spill scenario is calculated to result in a personnel exposure of about 0.01 Gys/s (1 rad/s). Although the preferred solution is to increase the bulk shielding between the beam line and the experimental area, the physical dimensions of the site do not permit an adequate amount of shielding to be added.

The solution adopted is a layered system of three types of highly reliable detector systems: a current limiter system located in the beam line, a neutron detector system located in the experimental areas, and an ion chamber system located on the walls of the beam line tunnels. The ion chamber system is capable of shutting off the beam in less than 0.5 s, resulting in a worst case personnel exposure of 0.005 Gys (0.5 rad).

Features

The most important feature of this system is that it is fail-safe. By fail-safe we mean more than the usual notions of redundancy and conservative engineering practices. We also mean that any single component failure that could permit a radiation level greater than 20% above the threshold level will cause the unit to trip. This includes failure of the high or low voltage power supplies, the connections to and within the ion chamber, the cabling, and of course all the components in the electronics. A self test is performed once per second (dead time is 0.1 seconds) to check for any failures. For large losses, the total time to shut off the beam, including this system and the speeds of the beam plugs and the associated circuitry, is estimated to be 0.5 s, resulting in an estimated maximum personnel exposure of 0.005 Gy (0.5 rad).

Other features are a 100:1 dynamic range, redundant digital electronics, and low stress on electrical components. If the module does trip, the cause, either errant beam or time out (self test not passed) is latched and displayed on the front panel of the unit. There is no computer control, but a computer does monitor the status and the signal and threshold levels, and checks that the threshold level is set correctly.

We chose an ion chamber filled with 160 cm^3 of N_2 gas at 1 std. atm., so that if it leaks, the pressure will drop to about 3/4 std. atm. (local atmospheric pressure), the gas will still be mostly (78%) N_2, and the system will still operate safely. Tests of this will be conducted in May 1989. All the ion chambers are mounted in rugged brackets, and the signal and HV cables are located in conduits dedicated to this system. For further redundancy, the ion chambers are placed close enough together that any errant beam spills will be detected by at least two ion chambers.

Details

A block diagram of the system is shown in Fig. 1 and a photograph of the electronics is shown in Fig. 2. The front end of the electronics is comprised of an op-amp (U1) with a filter R_2C_2. The five second time constant of the filter is chosen to give an op-amp output level that is approximately the same for pulsed beam losses that can occur at rates from 1 to 120 Hz. When the output of U1 exceeds the threshold level the unit will trip and indicate an errant beam fault.

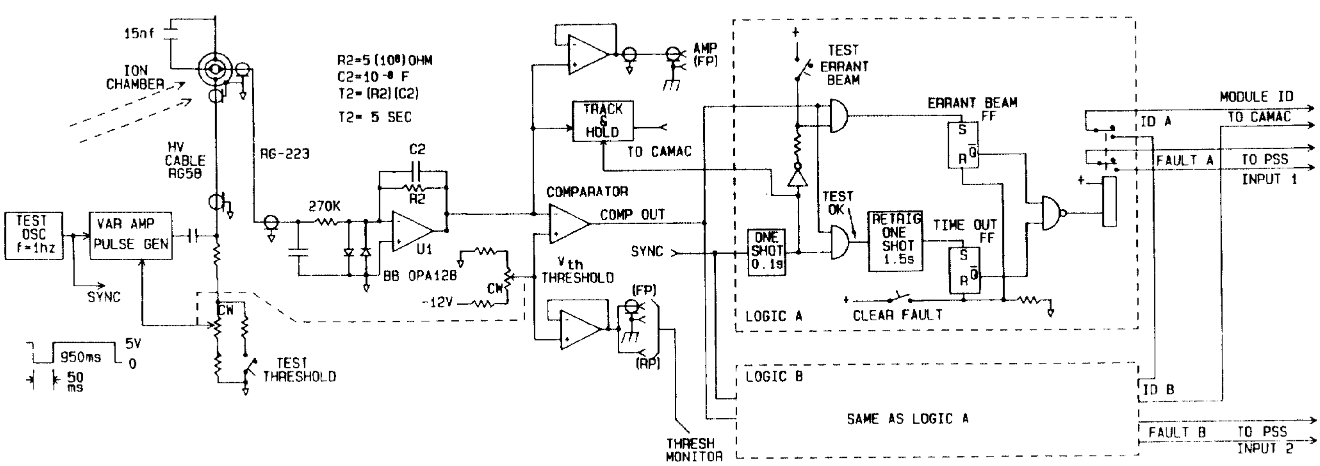

Figure 1: Block diagram of electronics.

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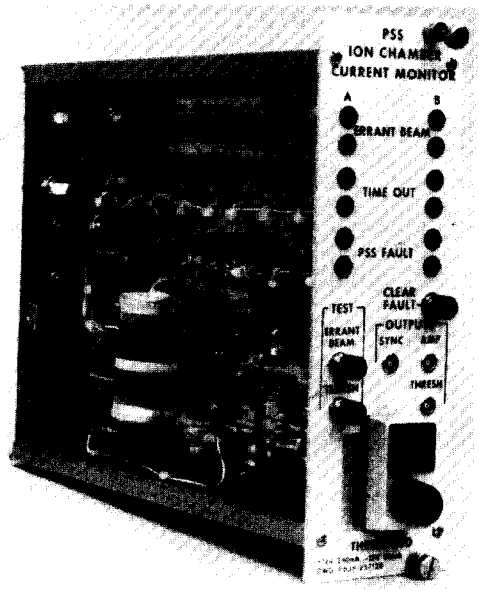

Figure 2: Photograph of the electronics.

Once per second, the unit performs a self test by injecting a 50 ms pulse onto the HV cable. At the ion chamber, a 15 nF capacitor couples this pulse onto the signal cable, which transmits the pulse to the electronics. The pulse amplitude is determined by the high voltage and by the threshold. Although it is large enough to cause the threshold to be exceeded by 20%, this does not trip the unit because the digital portion of the electronics is disabled for 100 ms during this check. If the threshold has not been exceeded by the test pulse, a 1.5 s timer will not be reset, and the unit will trip and indicate a time out fault. The 15 nF capacitor on the ion chamber is connected to the ion chamber as shown in Fig. 3, so that if either the signal or HV cable is disconnected, or if there is a loose connection inside the ion chamber, the test pulse will not reach the front end of the electronics. Also, if the high voltage is reduced for some reason, the amplitude of the test pulse will not be sufficient to exceed the threshold, and the unit will trip. The test pulse therefore checks that the ion chamber is connected, that the HV is present, and that the analog portion of the electronics is working. The digital portion of the electronics is not self checking, but is redundant.

Two front panel test buttons check the time out and errant beam circuits. The time out test lowers the amplitude of the test pulse by 40% so that it cannot exceed the threshold, thus testing the 1.5 s retriggerable one-shot circuitry. The errant beam test allows the test pulse to simulate an errant beam condition by disabling the portion of the circuit that ignores a trip condition for the duration of the self check.

Performance

The ion chambers were tested using four different voltages at the REX facility at the Los Alamos National Laboratory. Intense X-Ray pulses are produced by a 4 MeV, 5 kA, 50 ns electron beam striking a 0.056 cm thick tantalum target. The maximum dose using this facility is about 0.02 Gys (2 Rads), as shown in Fig. 4. We chose to use an operating potential of +1000 V. Later tests at PSR showed that the maximum dose under normal operating conditions is 0.003 Gys (0.3 Rads), so we are operating in the linear region. The next generation will use an operating potential of -1000 V.

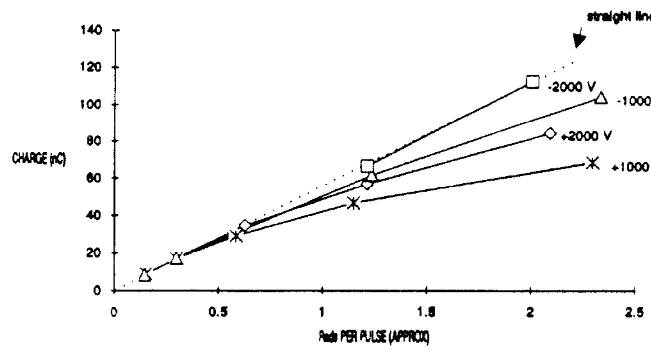

Figure 4: Collected charge vs. dose for various potentials.

During the 1988 run cycles from June through October, this system performed very well. Many errant beam conditions were caught, and no failures were noted. An upgraded system is currently being installed along several secondary beam lines at LAMPF.

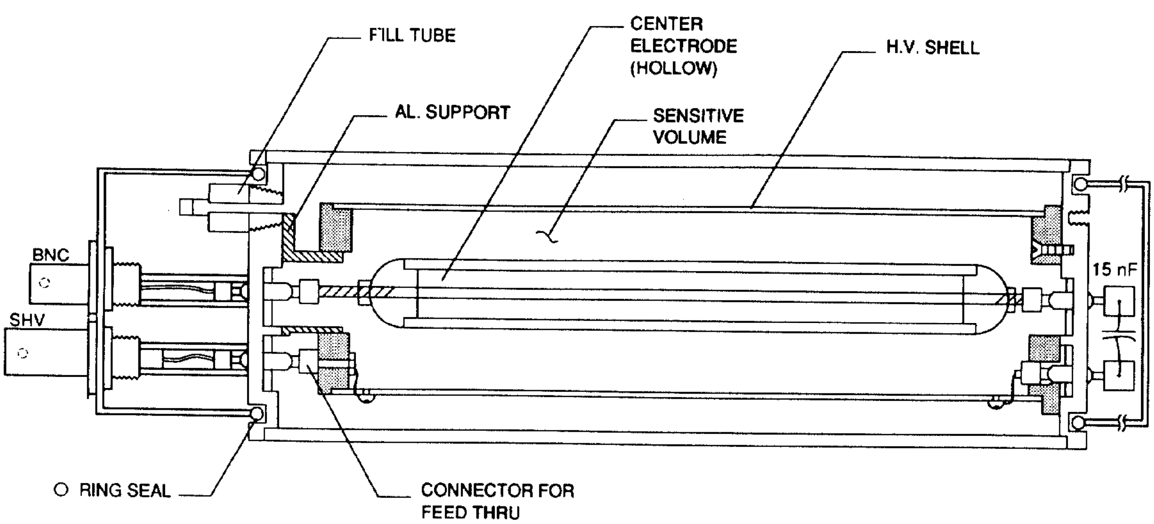

Figure 3: Ion chamber.

Future

The next generation electronics is currently under construction. Instead of a 15 nF capacitor on the ion chamber, a 50 GΩ resistor generates a DC current that is subtracted by the electronics. Thus, the presence of the current checks that the high voltage is the correct value and is connected to the ion chamber, that the signal cable is connected, and that the value of R_2 is correct. The need for high voltages inside the electronics is also eliminated in this scheme. The test pulse will now be entirely internal to the unit, and it will check the AC portion of the front end electronics and also the digital portion, as it did for the old version. The ion chamber will also operate at -1000 V.