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RADIATION MONITORING AND DOSIMETRY WITH INTEGRATING PULSE DISCHARGE

IONIZATION CHAMBER DETECTORS

by

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A B S T R A C T

Recently available Integrating Pulse Discharge ionization chambers have been successfully used as detectors for portable dose integrators, environmental area monitors, and for a high energy pulsed accelerator monitoring system.

The ion chamber physically consists of a pressure vessel, internally mounted gas discharge tube, anode support structure, and optional plastic inner lining. Chambers are available with either a Freon or Ethylene gas filling of about 10 atmospheres. Gamma sensitivity depends on the filler gas and liner, and is 0.25 and 0.6 mrad for Freon and Ethylene gas respectively.

The gamma and neutron energy response characteristics, together with rate dependence effects, have been investigated and are discussed.

A transistorized, portable, dose integrator, with adjustable alarm level, has been developed as an aid in controlling mission exposure to either gamma or mixed field radiation. The device can be set to alarm at any absorbed dose between 0.25 and 600 mrad in increments of 0.25 or 0.6 mrad.

Cosmotron area monitoring consists of a sixteen channel system designed to alarm above about 1.2 mrem/hr. In each channel pulses are integrated on two registers, one resettable after appropriate data recording, and the other continuously running. The information presented on the Cosmotron area monitoring system will be of outline nature as the information will be published elsewhere.

Radiation Monitoring and Dosimetry With Integrating Pulse Discharge

Ionization Chamber Detectors*

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A common characteristic of most of the world's high energy accelerators is that they are pulsed and therefore produce pulsed radiation fields. The Brookhaven Alternating Gradient Synchrotron and Cosmotron are no exceptions. Repetition periods are in the 1 to 10 second range for all of the higher energy machines excepting the Stanford Linac. Most of the radiation occurs after the particles reach full energy and during the time the particles are made to impinge on the target. This can occur over a time period varying from about 2 μ sec for certain external beam experiments to over 400 msec to accommodate counter experiments.

Repetition period is a prime factor to be considered in selecting a radiation dosimeter. Unfortunately, typical repetition periods of two to five seconds per pulse are not optimum for either rate meter type of instruments or D.C. responding devices. For this reason, integrating radiation detectors are a necessary feature of most pulsed high energy accelerators.

The Integrating Pulse Discharge Ionization Chamber, hereafter referred to as IPDIC, is a device that possesses the latter characteristic. Figure 1 is a schematic diagram of an IPDIC unit⁽¹⁾ manufactured by the Geophysical Measurements Corp.⁽²⁾ The outer case of the device is constructed of .76 mm steel and is filled to high pressure with an appropriate gas mixture. The inner steel cylinder is insulated from all other components. A neon glow lamp and low leakage capacitor are connected between the outer case and the cathode. In addition,

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* Work done under the auspices of the U.S. Atomic Energy Commission

a signal coupling capacitor is also connected to the cathode and led through the chamber case.

When power is first applied to the chamber the potential difference between the cathode and outer case will be zero, while a maximum potential difference will exist between the cathode and the inner cylinder. The ionization occurring as a result of absorbed radiation will cause the potential of the cathode to rise with respect to the outer case assuming that the rate at which charge is delivered by radiation exceeds the leakage rate across the capacitor and glow lamp. When sufficient potential difference exists, the glow lamp will break down, establishing a low impedance path to discharge the cathode and shunt capacity, down to the extinguishing voltage of the glow lamp. The discharge pulse will be transmitted by the signal coupling capacitor and will be registered by the scaler. For short cables, with a capacitance of about 100 pF, the output pulse, as sensed by the scaler, will have an amplitude of about 5 V and a pulse width of about 50 μ sec. After the first pulse the pulse rate will be constant in a constant radiation flux.

For Brookhaven use, Geophysical Measurements Corp. has lined the sensitive volume with collodial graphite-coated polyethylene and supplied the detector filled with ethylene gas under ten atmospheres pressure. This device has a ^{60}Co sensitivity of about 0.6 mrad of absorbed dose per output pulse. The vendor also supplies similar IPDIC devices that are unlined and filled with Freon gas. These have a ^{60}Co sensitivity of about 0.20 mrad per pulse and will have very different neutron response characteristics compared to the polyethylene-lined, ethylene-filled chamber.

Figure 2 shows the dose rate response of both chambers to ^{60}Co radiation, and natural background with a polarizing voltage of 1600 volts. The chambers have an essentially flat response over 6 decades. The deviation noticed at low dose rates is explained by leakage effects. This part of the curve was

determined by comparing the response of the chambers with a dynamic capacitor electrometer and ion chamber. The dynamic capacitor electrometer has been used for about 15 years and its leakage and response characteristics are known to be good. The remainder of the curve was standardized against Victoreen thimble chambers. Aberration from ideal response at about 100 R/hr is due to the increasing importance of recombination.

Figures 3 and 4 show the saturation characteristics of the Freon and ethylene chambers respectively, obtained with a ^{60}Co source. In either case, operating at higher voltage materially reduces saturation effects.

The x-ray energy response characteristics of the two chambers were studied. The chambers were exposed to very heavily filtered x-rays from 50 to 250 keV. Filtration was arranged to attenuate the unfiltered beam by about 10^5 . This technique hardens the beam sufficiently so that absorption determinations indicate x-ray energy levels near the peak voltage applied to the tube. The energy response characteristics of the ethylene and Freon chambers are shown in Fig. 5. Use of IPDIC devices with soft radiation would require careful calibration. Gamma radiation components below 100 keV are of little dosimetric importance at high energy synchrotrons so the low energy response was not considered to be of great importance.

The neutron response of the ethylene chamber was investigated using mono-energetic neutrons produced by the Brookhaven 4 MeV positive ion Van de Graaff generator. Tritium and lithium were bombarded with protons to produce mono-energetic neutrons in the range of about 150 keV to 1.5 MeV⁽²⁾. Deuterium and tritium targets were bombarded with deuterons to produce mono-energetic neutrons in the range of 4 - 16 MeV⁽²⁾. Comparisons were made between an IPDIC unit and a tissue equivalent chamber and are shown in Fig. 6. It should be noted that the responses of the IPDIC detector and the tissue equivalent chamber are indistinguishable.

IPDIC devices have been adopted as detectors for the Cosmotron area monitor by Cottingham and Grossman of the BNL Cosmotron Department. The system consists of sixteen separate channels. The detectors are placed in the various inhabited radiation areas throughout the Cosmotron that experience changing radiation levels. Basically, the device consists of an IPDIC detector, amplifier, register drive circuitry and timing mechanism. Each channel is independent and a pulse received on any channel will start its timer. If the next pulse occurs before the timer has completed its cycle, the channel will alarm. For mixed high energy radiation one may safely assume a quality factor of 10. This establishes a system sensitivity of about 6 mRem/pulse and pulses one hour apart reflect an average dose rate of 6 mRem/hr. Timer settings of an hour would cause an alarm condition to be registered for dose rates in excess of 6 mRem/hr.

The detector, amplifier and register drive components are shown in Fig. 7. One of the four readout and timer panels is shown in Fig. 8.

The IPDIC device is also being used in a portable integrating radiation monitor and alarm with the acronym IRMA. Two IRMA devices are shown in Fig. 9, and schematically in Fig. 10. Both devices consist of IPDIC units, register drive circuits, self-contained high voltage supplies, internal testing oscillators, and solid state alarms. Use of a back counting Sodeco predetermining impulse counter allows the health physics technician to dial in an acceptable radiation exposure. In use the pulses accumulate and when the register back-counts to zero a continuous alarm is sounded. A Sonalert manufactured by Electropac is used as the audible alarm. The Sonalert is also triggered during the register drive cycle producing a "peep". Excessive radiation levels which could cause register jamming would appear as a single tone, seeming to indicate that the maximum allowed exposure had been received. The maximum dose rate that the unit can respond to is limited by the operating time of the mechanical register and is

about 20 rads/hr. The two units are similar except that the unit on the left has a 20 impulse per second register and a 100 mrad chamber. This dosimeter will not saturate at levels of several thousand R/hr and is a companion to the high range emergency instrumentation available at Brookhaven.

Chamber sensitivity was found to be independent of dose history. Exposure of 5×10^6 R have caused no change in sensitivity. After a two year running period sensitivities of the 16 Cosmotron area monitoring system detectors have experienced a slight decline. This reduction averages 5%, with a 10% decline in the worst chamber. The decrease with time is probably due to ethylene gas absorption in the polyethylene liner and gas leakage.

Maintenance can be easily performed on the detector. A single threaded fitting allows the withdrawal of all of the internal components, facilitating repair and repressurization. This will tend to reduce the long term unit price since replacements should not be needed. No maintenance has been necessary on any of the operational detectors in accumulating about 30 detector-years of trouble-free service.

IPDIC units are being studied for other applications including an in-ring AGS spill monitor, a ring personnel safety monitor and AGS area monitors.

In summary, the principal advantage of IPDIC devices is that they offer all of the dosimetric advantages of ion chambers while requiring only simple GM type electronics. Furthermore, integrating ionization chambers usually requires vibrating reed or electrometer circuits and high impedance means of discharging the integrating capacitance. The cost complexity and maintenance requirements of the usual accelerator ion chamber monitoring system can be greatly reduced with IPDIC devices.

References

- (1) U.S. Patent 3,177,363, filed May 26, 1961
- (2) Geophysical Measurements Corp., Tulsa, Oklahoma
- (3) J.B. Marion and J.L. Fowler, Fast Neutron Physics, Part I, 1960

Figure 1 Integrating Pulse Discharge Ionization Chamber

Figure 2 Dose Rate Response of Integrating Pulse Discharge Ionization Chambers

Figure 3 Saturation Characteristics of the Freon Chamber

Figure 4 Saturation Characteristics of the Ethylene Chamber

Figure 5 X-ray Response of the FC Type Integrating Pulse Discharge Ionization Chambers

Figure 6. Coresponse of an Ethylene Filled, Polyethylene Lined, IPDIC Device and a Tissue Equivalent Chamber to Mono-energetic Neutrons

Figure 7 Cosmotron Radiation Monitoring System Detector

Figure 8 Cosmotron Radiation Monitoring System Readout and Timer Panel

Figure 9 Integrating Monitor and Alarm Units "IRMA"

Figure 10 Schematic Diagram of IRMA