national accelerator laboratory

TM-274
1105.12

AN INEXPENSIVE BEAM LOSS MONITOR FOR USE AT NAL

M. Awschalom, H. Howe, R. Shafer & D. Theriot

October 30, 1970

The fundamental premise in the design of all the biological shielding surrounding the accelerator of the National Accelerator Laboratory is that the beam losses will be monitored and controlled in such a way that the remanent exposure rates after the accelerator is turned off permit the performance of all the necessary maintenance without undue exposure to the personnel. Thus, the biological shielding was designed for such limited beam losses and not more. Here, we describe a very inexpensive beam loss monitor (BLM) capable of monitoring the beam losses such that the remanent exposure rates will be tolerable, namely 3-100 mR/hr at one foot after one hour of "cooling".

The unit consists of a 931A photomultiplier and dynode resistor divider mounted inside a one quart paint can. The can may be filled with an oil base liquid scintillator[1] for increased sensitivity over "dry" operation (i.e., without liquid scintillator). The lid of the paint can, on which all

Operated by Universities Research Association Inc. Under Contract with the United States Atomic Energy Commission

components are mounted, makes a light-tight as well as an oil-tight seal. The total cost of each unit, including phototube and scintillator, is estimated to be $25 plus labor.

The 931A is operated at negative high voltage to allow direct coupling of the anode to any associated instrumentation. Since the 931A is a relatively fast phototube, pulse widths are about 15 n sec wide and up to 100 millivolts high (into 50 ohms). The anode current may be read directly by a nanoammeter or may be integrated for delayed readout.

We have measured the response of about a dozen representative tubes in the current mode. We found that the optimum operating voltage is about -1 kV. At higher voltages the tube gain increases but the signal to noise ratio decreases.

Using ^{60}Co gamma-rays, typical responses are:

dark current	0.25 nA
1 rad/hr dose rate, "dry"	9.0 nA
1 rad/hr dose rate, "wet"	2.6×10^3 nA

(1 rad/hr is approximately equal to 8700 minimum ionizing particles/cm^2-sec.)

Tube-to-tube variations can be as large as 6 to 1 in sensitivity. Occasionally a tube is found to have excessive dark current.

Several "wet" detectors were exposed to 10^8 rad total dose at the Argonne gamma ray irradiator (10^8 rads is equivalent to 1000 rads/hr continuously for 10 years). We followed the loss of sensitivity by measuring the detector response to a small source every 5×10^6 rads and found that over the entire exposure the detector sensitivity decreased by approximately an order of magnitude for these "wet" units. The only visible radiation damage was some darkening of the phototube's glass envelope. "Dry" units were not tested in this manner, but are expected to show a smaller loss of sensitivity.

In order to observe the detector's response to actual beam loss conditions, we placed a unit near a "lossy" section of the ZGS. In a 50 mR/hr remanent radiation field, the "wet" detector read 94 nA (a sensitivity of 1.9×10^3 nA for a 1 rad/hr dose rate). This sensitivity is in reasonable agreement with those quoted previously for ^{60}Co gamma-ray response. Under beam-on conditions the current in the "wet" detector increased by a factor of 453. The detector was moved to various locations near the "lossy" point such that it was shielded by a ZGS magnet. The beam-off sensitivity (nA per rad/hr) remained nearly unchanged for the different locations. The beam-on to beam-off ratios varied from about 500 to 1, to

100 to 1, being lower for the better shielded locations, but were reproducible for any given location.

Using these numbers we can estimate[1] the response of the wet detector under operating conditions at NAL.

Accelerator Condition:	Off (Remanent Field)		Beam-On
	Exposure Rate	Current	Current
Booster	20 mR/hr	50 nA	5-25 μA
Main Accelerator	3 mR/hr	8 nA	0.8-4 μA

The sensitivity of the "dry" detector to beam-on conditions is about 300 times smaller than that of the "wet" one. The "dry" detector can be used for beam losses monitoring. However, it is not reliable for remanent field measurements because of poor signal to noise ratio due to the relative high dark current of the 931A.

CONCLUSION

These inexpensive beam loss detectors can be used to monitor the beam losses during operation and to limit them to values that lead to tolerable exposure rates after beam shut-off.

APPENDIX

In these measurements we used a mineral oil base liquid scintillator, LS/MO[2], which costs about $9 to $10 per gallon. Webb[3] offers the formulation below as a low cost liquid scintillator for neutrons:

PPO	491.0 grams[2]
MSB	9.82 grams[2]
TS-28M	5.2 gallons[4]
Primol 187	51.9 gallons[5]

The density is 0.87 g/cm^3. MSB is a wavelength shifter.

REFERENCES

1 - M. Awschalom, NAL-TM-186 (8/18/69) and NAL-TM-241 (5/25/70)

2 - New England Nuclear, Pilot Chemical Division

3 - R. C. Webb, et al., Princeton-Penn Acc. Report PPAR-26 (June 1970)

4 - Shell Oil Company

5 - Humble Oil Company