The usefulness of a beam loss monitoring system in diverse aspects of accelerator operation is documented with a variety of examples.

Introduction

The AGS Radiation Monitoring System, previously described, is reviewed here with a block diagram (Figure 1) and a list of detector characteristics (Table 1). Figure 2 shows the detector and the transmitted pulse. The schematic of the accelerator complex (Figure 3) shows the extent of the application, every significant segment is monitored.

**Table 1**

<table>
<thead>
<tr>
<th>Detector</th>
<th>Transformer</th>
<th>Splitter</th>
<th>Monitored Channel</th>
<th>Trigger</th>
<th>Linear</th>
<th>Integration</th>
<th>Computer</th>
<th>Display</th>
<th>Alarm &amp; Control</th>
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<tbody>
<tr>
<td>M.V.</td>
<td>scaler</td>
<td>logging</td>
<td>time &amp; space display</td>
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<td>Radiation Area</td>
<td>Central Processor</td>
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**Figure 1**

IPDIC PULSES - upper trace - 2 microsec/cm 1V/cm
lower trace - 50 microsec/cm 1V/cm

**Figure 2**

IPDIC PULSES - upper trace - 2 microsec/cm 1V/cm
lower trace - 50 microsec/cm 1V/cm

**Figure 3**

INTEGRATING PULSE DISCHARGE ION CHAMBER
CYLINDRICAL IONIZATION CHAMBER

~ 1000 cm³ Argon at 10 atmospheres
0.030" Chrome Plated Steel Walls

PULSE CHARACTERISTICS
1 Volt, 1 Microsecond into 1000 ohms
Pulse Pair Resolution 15-100 Microseconds

RADIATION EFFECTS
Sensitivity - Nominally 1 pulse = 1 mrad
Life > 10⁹ pulses
Radiation Damage - Functions After > 10⁸ Rads
Applications

The system was principally developed to detect large beam losses which would result in high radiation levels and damage to the accelerator. However, as an extensive source of information about machine operation, it has been used increasingly in roles other than protection. The initial portion, the ring system, employing only display, is described in Figure 4, with the output format shown in Figure 5.

The section capitalizing on the linear mode of operation in the detection of very short radiation pulses, (less than a millisecond) the Fast Extracted Beam System, is described in Figure 6. A typical display, (Figure 7) generated by computer, is used to monitor and tune the beam line. Beams characterized by slow extraction and losses distributed over hundreds of milliseconds are scanned by a subsystem employing the digital mode of operation (Figure 8). Displays, showing the time distribution of losses, used for tuning and monitoring, are shown in Figures 9 and 10. The Linac portion (Figure 11) has a dedicated digital display for qualitative overview of injector performance, and an instantaneous shutdown function on the linear circuitry for protection purposes. (Figure 12)

Figure 3

Dynamic Lamp Display of Ring Ion Distribution

Figure 5

Fast Extracted Beam System

Extraction of Full Energy Protons for Bubble Chambers
- Intensity - $10^{13}$ protons/pulse
- Pulse - Twelve 20 nanosecond bunches extracted in ~ 2 microseconds

Monitoring
- 22 - Two terminal detectors distributed along beam line with emphasis on critical locations
  - Linear signals integrated each pulse, a) tested by alarm discriminators for beam shutdown and b) transmitted to computer for generation of display

Figure 7

Spatial Distribution of Losses in the Fast Extracted Beam

Figure 13

Analysis Time 583.3 sec. - Ampl. Gain: Setting 32
Extraction of Full Energy Protons for Electronic Detectors
Intensity - $10^{13}$ protons/pulse
Pulse - hundreds of milliseconds

Monitoring
22 detectors distributed along beam line and spurs with emphasis on critical locations and targets
Digital signals transmitted to
1. dedicated display with alarm and shutdown options
2. computer for processing, generation of displays

BEAM
Protons accelerated to 200 MeV intensity - $10^{14}$ protons / pulse
Pulse length - 200 microseconds
Repetition rate - 10 pulses/second

MONITORING SYSTEM
32 detectors distributed along Linac, AGS Transport Line, Experimental Beam Line
Lamp display in control room, shutdown system on linear outputs of 8 detectors, Beam turned off within 10 microseconds of detection of excessive loss.

Future Applications
Now that the various techniques of data handling by computer have been demonstrated, it is appropriate to investigate the use of pattern recognition for diagnosis and automatic control. It is clear that the detection of secondary radiation, produced by primary beam losses, is a very sensitive technique which can be more powerfully employed in accelerator operation. This then implies that detector characteristics and performance must be better known.

Acknowledgments
The programming producing the computer generated displays was done by J. Claus, initially, and R. Wiltkover.

References