NOVEL INSTRUMENTATION FOR RADIATION MONITORING AT NAL

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Summary

Since the radiation safety policy adopted by NAL is a departure from conventional practices at other accelerators, special instrumentation had to be developed to implement it. The policy and the instruments are described briefly.

The Radiation Safety Program

To understand the philosophy of the instrumentation being developed, one must first understand how the radiation safety policy at NAL differs from practices at other accelerators. Briefly the policy is:

1. Beam losses shall be limited to levels which will lead to such exposure rates from induced remanent radioactivity that all necessary maintenance shall be possible without remote manipulators or special shielding.

This policy is very important because there is a direct relationship between remanent radioactivity while the accelerator is off and the protons, neutrons and muons created while it is on. The limitation on remanent radioactivity sets a limit on the required biological shield. A monitor of radiation produced during accelerator operation will provide a measure of the remanent radioactivity.

2. Each employee shall be responsible for his own radiation safety as well as the safety of other personnel working under his supervision.

This implies the need for instrumentation for radiation survey and monitoring with extreme simplicity in operation and interpretation as well as ruggedness.

Instrumentation

The new instrumentation may be classified as follows:

1. Beam loss monitors
2. Radiation area monitors
3. Survey meters
4. Miscellaneous

Beam-loss monitors\(^1\) are being installed along all accelerators and beam transport systems. They consist of a one pint paint can (3 1/2 inch diameter, 4 inches high) with an RCA-C31028 photomultiplier and voltage divider mounted under the lid, and filled with approximately 300 cm\(^3\) of liquid scintillator. This device has the following characteristics:

- operating voltage = -1 kV
- dark current = 0.5 nA (typ)
- current (using Co\(^{60}\)) @1 R/hr = 2 μA (typ).

Our measurements at the Argonne ZGS show that at any point in an accelerator enclosure, remanent radioactivity exposure rate 1 hour after shutdown is about 500 times smaller than the average "beam on" dose rate in rads at the same location. Hence, if a certain remanent exposure level is desired, the current in the beam loss monitor corresponding to the average allowable beam losses is calculable. For high radiation areas, the units may be operated without liquid scintillator, in which case the sensitivity is reduced by about a factor of 400.

Radiation area monitors are being installed in occupational areas adjacent to all beam areas. The detectors are single-scale, large dynamic-range instruments with easily interpreted audiovisual displays. These instruments are also multiplexed to a data collection station near the accelerator control room via a system independent of the accelerator control system. One neutron monitor consists of a thin wall GM tube wrapped in Ag foil, and a second GM tube without Ag foil, in a 10 inch diameter polyethylene moderator (in the shape of an octagon of revolution). The energy response has been discussed in many places.\(^3\) Neutron activation of the Ag foil produces radioactivities with lifetimes of many seconds, hence overcoming the duty cycle limitations inherent in many types of detectors. Signals from the two GM tubes are used to derive net neutron flux rates. The color-coded meter scale is a log display calibrated in occupation time per day as well as mrem/hr. Flashing lights color-cued to the meter allow approximate reading from large distances. A dose integrator permits integrating the accumulated dose on an electromechanical register. An audible alarm sounds if either the exposure rate exceeds 80 mrem/hr or the accumulated exposure exceeds 20 mrem. Digital

output pulses at the rate of 1 pulse per 2.5 microrem allow interfacing to a multiplexed data collection system.

The color coding for the meter and lights is:

<table>
<thead>
<tr>
<th>Dose Rate</th>
<th>Occupation Time</th>
<th>Color Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2.5 mrem/hr</td>
<td>8 hrs</td>
<td>Green</td>
</tr>
<tr>
<td>2.5+20</td>
<td>8 hrs+1 hr</td>
<td>Yellow</td>
</tr>
<tr>
<td>&gt;20</td>
<td>&lt;1 hr</td>
<td>Magenta</td>
</tr>
</tbody>
</table>

We are developing a similar instrument which uses an ionization chamber with a radiation response to neutrons, muons and gammas, and with a single-scale dynamic range exceeding 10 to 1. The present design includes a current-to-frequency converter with good linearity over the current range 10^{-9} to 10^{-3} amps. This unit has all of the features of the other instrument, including signals for interfacing to the multiplexer system.

The site-wide data collection system is a multiplexed digital system in which every detector is scanned about 75 times per second. Each detector is assigned to one of 512 time slots in which it may transmit a single data bit. This dedicated-time-slot system prevents any single detector from interfering with the data collection from other units. Communication is performed over three twisted pairs at a 10KHz bit rate; the pair assignments being for clock synchronization, data bits and data bits. The third signal is used as a parity check to ensure that all multiplexer channels are responding properly, even though a data bit is not being transmitted. The data is collected in a core memory which is used to generate exposure rate displays as well as providing integrated exposure data for bookkeeping purposes. The entire system is independent of the accelerator control system and is hardwire rather than software controlled. Depending on the location of the detector, data bit calibration corresponds to 2.5, 25 or 250 microrem per pulse.

Surveys of the portable, battery-operated beta gamma variety are being developed in conjunction with conventional equipment manufacturers. The required dynamic range of approximately 10 to 1 makes it necessary to have either an extra long logarithmic meter-scale or two movements in one meter body or temporary (momentary) range switching. If the temporary range switching is adopted, light emitting diodes will emphasize on the meter scale that the higher range has been chosen.

Other instrumentation includes remanent radioactivity "classifiers" as well as pocket radiation alarms and testers.

Wall-mounted instruments with large logarithmic color-coded scales for classifying radioactive materials coming out of beam areas have been designed. These instruments use as detectors a GM-tube mounted on the end of a long cable. The meter face gives the exposure rate in mR/hr as well as the classification number for the object.

The remanent radioactivity classes are:

<table>
<thead>
<tr>
<th>Class</th>
<th>Distance</th>
<th>Exposure Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>contact</td>
<td>D₀ &lt; twice background</td>
</tr>
<tr>
<td>1</td>
<td>contact</td>
<td>D₁ &gt; twice background</td>
</tr>
<tr>
<td>1</td>
<td>1 ft</td>
<td>D₁ ≤ 1 mR/hr</td>
</tr>
<tr>
<td>2</td>
<td>1 ft</td>
<td>D₁ &lt; D₂ &lt; 10 mR/hr</td>
</tr>
<tr>
<td>3</td>
<td>1 ft</td>
<td>D₂ &lt; D₃ &lt; 100 mR/hr</td>
</tr>
<tr>
<td>4</td>
<td>1 ft</td>
<td>D₄ &gt; 100 mR/hr</td>
</tr>
</tbody>
</table>

Also, annunciator lights instruct the operator as to the action he must take, such as "OK" (do not label), "Attach Label" or "Call Radiation Physics". If the object is not OK, an audio alarm sounds, indicating that some action must be taken.

The use of pocket radiation alarms ("chippers") has been found very effective in reducing personnel exposures. They are always "ON" to avoid accidental shut-off. Therefore, a battery-operated chirper tester using a radioactive source, a microphone and a rate-meter has been developed to test the chirping rate as well as the battery under load. These testers are placed at every entrance to a radiation area.

**References**

2. New England Nuclear, Pilot Division, Type LI/MO.