ORNL/CP-100040

HRIBF Tandem Accelerator Radiation Safety System Upgrade

RECEIVED
NOV 24 1998
OSTI

R.C. Juras

Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6368

J. L. Blankenship

Joint Institute for Heavy Ion Research, Oak Ridge, TN 37831

The HRIBF Tandem Accelerator Radiation Safety System was designed to permit experimenters and operations staff controlled access to beam transport and experiment areas with accelerated beam present. Neutron-Gamma detectors are mounted in each area at points of maximum dose rate and the resulting signals are integrated by redundant circuitry; beam is stopped if dose rate or integrated dose exceeds established limits. This paper will describe the system, in use for several years at the HRIBF, and discuss changes recently made to modernize the system and to make the system compliant with DOE Order 5480.25 and related ORNL updated safety rules.

INTRODUCTION

Although the Holifield Radioactive Ion Beam Facility (HRIBF) Tandem Accelerator is allowed to produce radiation levels of up to 92 R/h, most tandem accelerator beams produce little or no radiation and experimenters frequently desire entry into areas with beam present when it is safe to do so. Safe entry into accelerator areas with beam present is assured by a combination of administrative controls and the HRIBF Tandem Accelerator Radiation Safety System (RSS).

The Tandem Accelerator RSS came into operation with the Tandem Accelerator in 1982, and in the intervening years has been enhanced and extended into several new experimental areas. Major upgrades, which are discussed in following sections, have included a system to detect whether any electrometer in the system has failed, total redesign of electrometer electronics, and a number of upgrades to comply with DOE and ORNL safety orders.

DESCRIPTION OF THE SYSTEM

Tandem accelerator beam transport and experimental devices are located in nine shielded areas. Each area is equipped with at least two boron-trifluoride radiation detectors that, together with associated electrometer electronics, are designed to provide output voltages proportional to incident neutron and gamma-ray dose rates at detector locations. Neutron moderators designed to make detector outputs approximately equal for equivalent neutron and gamma dose rates in rems surround the detectors. These detectors are placed in locations where they may be expected to receive a dose rate, which is greater than or equal to that which might be received by a person working in the associated area.

Each area is equipped with a rotating yellow beacon which illuminates at a detected dose rate of 2.5 mrem/h. Each area is also equipped with two red beacons and two warning horns. The red beacons illuminate and the warning horns sound for thirty seconds whenever (1) the highest dose rate in the area exceeds 100 mrem/h or (2) the area is placed in the SECURE or TOTAL SECURE modes (described below).

Adjacent to each door of each area is a local control panel which has (1) an "entry time" meter for each detector located within the area; (2) a yellow caution light; (3) a red caution light; (4) a "secure" button; (5) two green secure lights; and (6) a "lamp test" button. The entry time meter provides an indication of the time (min) required for the detector in question to receive an integrated dose of 20 mrem. That is, the entry time meter indication is equal to (20 mrem $\times$ 60 min/h)/(dose rate at detector (mrem/h)). Entry time indications for all detectors are replicated in the control room.

Each area can be operated in one of three modes: (1) UNSECURE; (2) SECURE; and (3) TOTAL SECURE. Operation in the SECURE mode is initiated by actuation of the secure button on the local control panel following search and closure of the associated area. Operation in the TOTAL SECURE mode is initiated by actuation of controls in the control room after an area has been put in SECURE mode. The difference between TOTAL SECURE and SECURE is that entry into a TOTAL SECURE area immediately causes beam to be removed from the area, whereas entry into a SECURE area causes a

DISCLAIMER

control-room alarm and causes the room to revert to the UNSECURE mode.

"Auctioneer" circuits automatically sample the dose rate measured by all detectors located in areas operated in UNSECURE mode and select the highest dose rate for integration. The highest dose rate and the integrated dose are used for interlock actuation as described below:

Interlock actuation results from any of three conditions:

(1) An integrated dose which exceeds 20 mrem in an 8-hour period.

(2) A dose rate greater than 150 mrem/h.

(3) Entry into a TOTAL SECURE area.

Interlock actuation results in two levels of corrective action:

(1) Beam transmission through the tandem accelerator is immediately stopped by insertion of a Faraday cup in the injection beam line; and

(2) if, 30 seconds after Faraday cup insertion, the dose rate in any area operated in UNSECURE is greater than 40 mrem/h, the tandem accelerator charging chains are stopped.

The RSS is designed with extensive redundancy. Area detectors are obviously not strictly redundant because they are at physically different locations in an area, but most system electronics and interlocks are fully redundant.

FAULT DETECTION

Since, as mentioned above, detectors and associated electrometers are not truly redundant, we came to realize that it is important to monitor the most likely causes of electrometer failure and cause-interlock actuation in the case of electrometer failure. Electronics were integrated into the RSS to monitor a signal from each of the 23 electrometers in the facility with provision to monitor up to nine future electrometers. A connector was added on each electrometer to monitor one of the internal DC power supplies. Loss of electrometer power results in a control room alarm and actuation of RSS beam stop interlocks. Operators may acknowledge the alarm, which removes the beam stop, but an area with a failed electrometer must be operated in the TOTAL SECURE mode.

As a further improvement, in conjunction with electrometer upgrades, discussed in a following section, electrometer fault detection was greatly improved from simply monitoring one internal power supply to monitoring all internal power supplies and monitoring each critical cable connection on the electrometer and associated detector. Critical cable connections are monitored either by sensing the presence of a jumper in the external connector or, in the case of the detector bias and signal coaxial cables, by detecting a continuous shield connection between the two related BNC chassis connectors: one BNC is isolated from the chassis and the other is grounded to the chassis. Since the detector is electrically ungrounded in its polyethylene shield, the isolated BNC connector has a path to ground only through the shield of the two cables and the body of the detector can. Electrometer circuitry detects loss of ground at the isolated BNC.

ELECTROMETER UPGRADE

All 23 RSS electrometers were upgraded. Electrometer circuitry, which had become obsolete and was based on electronic components, which were becoming increasingly difficult to obtain, was completely redesigned to use modern components. At the same time, electrometer fault detection was improved and a front panel fault circuit test button was added to decrease time required during quarterly RSS functional checks to test electrometer fault detection.

UPGRADES TO COMPLY WITH SAFETY ORDERS

A major system upgrade was motivated by pending implementation of DOE Order 5480.25 and related ORNL facility safety procedures. As it turns out, DOE Order 5480.25 is not explicitly required at our facility; however, it has been replaced with internal "Necessary and Sufficient Standards" that assure compliance with DOE orders. An extensive review of RSS compliance with new safety rules resulted in several required changes to the RSS, most of which were trivial, such as changing the color of 100 mrem/h warning beacons from magenta to red, providing redundant status indications of critical beam stop devices in the control room, placing detector cable runs in conduit or cable trays, and adding beam shutdown pushbuttons at exit doors. Other changes were more significant.

One subtle problem uncovered by the analysis concerned electric power to area beacons, horns, and warning light. It would be possible for a single-point fault to cause loss of power to the beacons, horns, and warning lights yet, since the beacons, horns, and warning lights are not normally on, the problem could remain undiscovered until the next quarterly check, or until the next time the area was placed into the SECURE mode and the absence of a warning horn and secure mode lights noted by an operator. Although at first it seemed that this could require a new system for detection, which could be expensive to implement in all nine areas, we found a simple change to wiring topology would alert the operator to the problem. Power was wired from the power source to each device in an area (usually a simple reconfiguration of wiring on a terminal strip) and finally to a duplex outlet. Area electrometers with their built-in loss-of-power fault indications were in turn powered by the outlet. Any loss of power thus causes a control room alarm and insertion of a beam stop. Area wiring is not redundant, but detection of a wiring fault is redundant, eliminating the need for redundant wiring.

The analysis also uncovered system faults that could be caused by loss of power to certain of the several electronic chassis in the system. In each case, appropriate alarms and interlocks were added to make the system fail-safe.

The analysis also uncovered instances where redundant signals were carried through a single connector. In cases where unplugging the connector would cause the system to fail without an alarm, separate connectors were installed for each set of redundant signals. The solution is not perfect: both connectors could be unplugged. But the system is always functionally checked after every maintenance; thus we only need guard against failure of a connector (for example, a connector not correctly secured which comes loose with vibration).

Probably the most expensive change to the system required by the rules was conceptually simple: most areas had only one 100mrem/h red beacon and associated evacuation horn and we were required by the new rules to implement redundant 100 mrem/h beacons and horns. Since radiation detectors are in different locations in the area, each detector must cause all redundant beacons and horns to come on, which required extensive changes from the original circuit.

DOCUMENTATION

Documentation was potentially a costly problem since original RSS drawings had been done on paper. The estimated cost of modifying the large, dense drawings was considerable. The solution was to hire a local firm that was able to convert drawings to AutoCAD at a reasonable price. Once in AutoCAD format, drawing modifications could be done by the design engineer directly.

ADMINISTRATIVE CHANGES

A complete functional test of the RSS is performed quarterly and had evolved into an elaborate ritual that could tie up the operations staff for days. At the time of the upgrade, test procedures were reviewed and streamlined with the result that functional tests can now be performed in one day. The old procedure called for a selected radiation detector/electrometer to be removed from the system periodically and sent to a calibration facility. With the calibrated detector as a reference standard, all detectors in the system were functionally tested with a ^{137}Cs source, which was placed at several distances from the detector, and several detectors were tested with an Am-Be neutron source. A review of several years of records was undertaken with the result that the neutron source measurements were discontinued. Because of the physical nature of the detectors (a single detector filled with boron-trifluoride surrounded by a polyethylene moderator) there is no credible way the neutron response could change without a corresponding change in the gamma response and, in fact, the records show just that. In addition, the neutron measurements resulted in personnel exposure not consistent with "as low as reasonably achievable."

Extensive measurements of gamma-ray source strength versus distance were used, together with a bracket to hold the source a measured distance from the detector to eliminate the need to send detectors to the calibration lab and to reduce the number of measurements at each detector in the course of functional testing.

The new "electrometer inoperative" test button saves time formerly spent disconnecting cables to perform the same function.

CONCLUSION

The HRIBF tandem accelerator radiation safety system, by permitting experimenters and operations staff controlled access to beam transport and experiment areas with accelerated beam present, has been extremely beneficial to the experimental program. Recent upgrades to modernize the system and to comply with safety orders have added to the safety and reliability of the system. Recent changes to quarterly functional tests, with no compromise in safety, have substantially reduced time required for tests.

ACKNOWLEDGEMENTS

Research at the Oak Ridge National Laboratory is supported by the U.S. Department of Energy under contract DE-AC05-96OR22464 with Lockheed Martin Energy Research Corp. The Joint Institute for Heavy Ion Research has member institutions the University of Tennessee, Vanderbilt University, and the Oak Ridge National Laboratory; it is supported by the members and by the Department of Energy through contract number DE-FG05-87ER40361 with the University of Tennessee.