Canadian Partnership for Quality Radiotherapy

Technical Quality Control Guidelines

for Safety Systems at Radiation Treatment Centres

A guidance document on behalf of:

Canadian Association of Radiation Oncology

Canadian Organization of Medical Physicists

Canadian Association of Medical Radiation Technologists

Canadian Partnership Against Cancer

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Introduction

The Canadian Partnership for Quality Radiotherapy (CPQR) is an alliance amongst the three key national professional organizations involved in the delivery of radiation treatment in Canada: the Canadian Association of Radiation Oncology (CARO), the Canadian Organization of Medical Physicists (COMP), and the Canadian Association of Medical Radiation Technologists (CAMRT). Financial and strategic backing is provided by the federal government through the Canadian Partnership Against Cancer (CPAC), a national resource for advancing cancer prevention and treatment. The mandate of the CPQR is to support the universal availability of high quality and safe radiotherapy for all Canadians through system performance improvement and the development of consensus-based guidelines and indicators to aid in radiation treatment program development and evaluation.

This document contains detailed performance objectives and safety criteria for *Safety Systems in Radiation Treatment Centres.* Please refer to the overarching document *Technical Quality Control Guidelines for Canadian Radiation Treatment Centres*[1] for a programmatic overview of technical quality control, and a description of how the performance objectives and criteria listed in this document should be interpreted.

System Description

The safe and secure use of radiation in a radiation treatment centre requires that various equipment and safety systems are in place to eliminate the possibility of unplanned and/or inappropriate irradiation of staff, patients, or public during the course of operation. These systems may also limit access to specific controlled areas so that only authorized qualified personnel can operate the radiation devices. In many situations, these systems are directly linked to the machine operation so that activation of a safety system alarm or interlock inhibits the machine from operating or producing radiation. In the context of this Technical Quality Control (TQC) guideline, “safety systems” are those systems that interface the radiation

equipment to the facility to mitigate the risk of unintended exposures of persons. As such, this guideline covers the safety systems and equipment associated with radiation treatment devices, research irradiators, and imaging systems such as computed tomography (CT) simulators used in a cancer centre as well as the systems and equipment installed to maintain security.

One motivation for addressing safety system technical quality control in an independent guideline is that these systems are often a primary focus of Canadian Nuclear Safety Commission (CNSC) staff when licencing and inspecting a radiation treatment facility. Additional tests to those described below may be required if they have been specified in CNSC licence applications.

The routine quality control objectives and criteria for safety and security systems[2] outlined below also apply to acceptance testing and commissioning. A qualified medical physicist, or their designate, must ensure that the safety systems satisfy the guidelines presented in this document prior to, or at the time of, the delivery of the first radiation beam or exposure of the source. All tests should be run under the conditions typical to those expected during routine operation. For example, acceptance tests of warning lights should be performed under full daylight conditions (especially if there are skylights) to ensure performance. This allows the commissioning measurements to determine the baseline behaviour expected in the subsequent quality control program. The results must be documented and form the basis of staff training for routine operation.

Furthermore, an appropriate subset of the tests should be performed after any repair or preventive maintenance interventions on the equipment, or after any upgrade to the safety and security equipment. The extent of testing required should be judged by a qualified medical physicist.

Daily tests of the safety systems associated with a treatment, research, or imaging unit should be scheduled prior to the delivery of the radiation beam or exposure of the source at that unit.

The frequency for various tests has been established through review of the literature[2-4] and by consultation with the community. A centre can adopt different frequencies based on an informed analysis of the test; as specified in the overarching document *Technical Quality Control Guidelines for Canadian Radiation Treatment Centres*.[1] However, the centre must document evidence supporting such variation. Also, if the frequency of a safety system test has been specified in a centre's CNSC licence, any change in frequency will require a licence amendment.

In the event that a safety or security system does not meet the stated performance objectives and criteria, the use of the radiation equipment should be suspended until the failure is repaired or equivalent measures to mitigate risk are implemented with the consent of the supervising medical physicist in conjunction with the radiation safety officer. Note that the use of equivalent measures to mitigate risk will need to be communicated to, and accepted by, the applicable regulatory bodies (e.g., the CNSC) before implementation. The supervising medical physicist, radiation safety officer, or designate shall document all safety system repairs in requisite service report logs.

Glossary

The following glossary of terms is included to clarify specialized terminology used in this guideline.

Door interlock: A safety system designed to return the equipment to a safe state if triggered. Door interlocks typically include additional features such as a last-person-out component.

> **Primary door interlocks** refer to the principle components of the safety system installed at the main access point to the bunker/treatment room (with or without a physical door). This includes door switches/entrance light beam/infrared sensors and light curtain, and last-person-out circuit at a minimum.
>
> **Secondary door interlocks** refer to safety systems installed in an enclosure within the facility such as modulator rooms and additional features installed to supplement the primary door interlock system such as additional motion sensors, light beam/infrared sensors and light curtains, and last-person-out timer features.

Emergency off circuit, actuator, or buttons, and motion stops: The emergency off circuit refers to the circuit connected to the equipment. The actuators are the buttons or other devices that break the circuit thereby returning the equipment to a safe state (e.g., beam off, source retracted). Emergency motion stops do not necessarily "kill" power to the equipment but always stop irradiation and suspend any motion, if applicable. Not all devices have an emergency off/motion stop circuit.

For the Gamma Knife, the emergency stop button moves the sources into the home position but does not close the shutter doors. The couch is retracted and the shutter doors are closed when the emergency stop button is disengaged. The purpose of this functionality is to allow for the removal of items (e.g., IV pole) which have fallen into the unit during treatment.

Irradiation state indicators/warning lights: A visual display indicating the presence of radiation.

> **Primary displays** are located near the main access point to the room.
>
> **Secondary indicators** refer to additional displays located inside enclosures within the room (e.g., modulator rooms) and additional displays other than primary display (e.g., in-room displays).

Independent area radiation monitor warning system: A radiation monitoring device that operates independently of the radiation treatment equipment. It is activated by direct detection of the presence of radiation in the room (e.g., using a Geiger counter).

Related Technical Quality Control Guidelines

This guideline is limited to the safety systems associated with radiation treatment equipment. The testing of collisional safety systems on radiation therapy units are not included in this TQC guideline. Readers should refer to CPQR's related TQC guidelines for specific treatment devices regarding testing of these systems (i.e., for linacs, Gamma Knife, or CyberKnife).[5-7]

Furthermore, to comprehensively assess equipment performance, additional tests, as outlined in related CPQR TQC guidelines must also be completed and documented, as applicable. Related TQC guidelines, available at cpqr.ca, include:

- Medical Linear Accelerators with Multi-leaf Collimators
- Accelerator Integrated Cone Beam Systems for Verification Imaging
- Brachytherapy Remote Afterloaders
- Kilovoltage Radiotherapy Machines
- CT Simulators
- Conventional Simulators
- Gamma Knife Radiosurgery
- Helical Tomotherapy
- Cyberknife Radiosurgery

Test Tables

The documents recording the quality assurance results should be detailed enough to verify the correct performance of the discrete components of the system. For example, testing the access control for a doorless bunker would require testing the light beam/infrared sensors, light curtains, and motion sensors as part of the door interlock test and the documentation of test results should be granular enough to verify that each component has passed its individual tests.

Table 1: Linear Accelerators (including robotic radiosurgery systems)

Designator	Test	Performance	
		Tolerance	**Action**
Daily			
AD1	Primary door interlock/last-person-out circuit	Functional	
AD2	Primary warning lights/irradiation state indicators	Functional	
AD3	Room audiovisual monitors/cameras and intercom systems	Functional	
AD4	Independent area radiation monitor warning system (if installed)	Functional	
Monthly			
AM1	Emergency off circuit	Functional	
Quarterly			
AQ1	Emergency off buttons/actuators	Functional	
AQ2	Secondary warning lights/irradiation state indicators	Functional	
AQ3	Secondary door interlock/last-person-out circuit (if present)	Functional	
AQ4	Emergency motion stop buttons or actuators	Functional	

Notes on Daily Tests

All daily tests should be performed on each day the radiation beam is to be delivered or the source is to be exposed at that unit, including weekend use and other days involving non-clinical use such as preventative maintenance.

AD1 Test should verify that:

- The time delay circuit prevents operation of the equipment if the entrance door is not closed within a pre-set time period following activation of the last-person-out time delay switch.
- If the last-person-out is not activated that the irradiation cannot be initiated.
- The door interlock terminates irradiation immediately if the door is opened and prevents the equipment from being used while the door is open.

- Reactivation of the last-person-out switch is required to restart irradiation following its termination by the door interlock.

Verification that irradiation cannot be initiated should be accomplished through a positive test (e.g., pushing "Beam On") at least once in the door interlock tests. Door interlock messages are acceptable for the remaining parts of the test.

In the case of doorless bunkers, this test should involve testing the components that provide access control equivalent to a primary door interlock such as optical trip lines; and should include confirmation of their beam-interrupt ability.

AD2 Primary irradiation state indicator displays should be tested by delivering a beam.

AD4 Test should also verify that battery backup systems keep the radiation warning system operational when disconnected from the main power supply. Area monitors connected to a hospital's emergency power supply is an acceptable alternative to a battery backup provided the emergency power system is tested periodically.

Notes on Monthly Tests

AM1 Test should verify that activating one of the emergency off buttons/actuators terminates the exposure. A test confirming interruption of power supply to device ("hard kill") should be performed at least once per quarter. Note that the emergency off circuit for some devices (e.g., Varian linacs) will initiate a hard kill only.

Test should verify that the equipment cannot be restarted from the control console without first resetting the safety interlock circuit. Test can be performed using any of the emergency stop actuators, provided that testing is rotated so that all emergency stops are tested at least once every quarter (See AQ1).

Notes on Quarterly Tests

AQ1 Termination of irradiation can be verified either directly using an external emergency stop such as the one in the control console area, or via a suitable surrogate indicator (e.g., demonstration that activating an emergency stop results in loss of main power, loss of high-voltage [HV] power at gantry). This test can be performed in conjunction with AM1; ensuring that each actuator is checked at least once per quarter.

AQ2 Test the illumination of the indicator when the radiation is on. The use of inexpensive digital cameras in "movie" mode can facilitate the testing of secondary displays within enclosures such as modulator rooms.

AQ3 Applicable to systems with the presence of a second entrance to the treatment room, that is not used routinely (e.g., servicing, etc.). Test procedures would follow the same steps as daily test AD1.

Table 2: Brachytherapy Remote Afterloaders

Designator	Test	Performance	
		Tolerance	**Action**
Daily			
BD1	Primary door interlock/last-person-out button	Functional	
BD2	Primary warning lights/irradiation state indicators	Functional	
BD3	Room audiovisual monitors/cameras and intercom systems	Functional	
BD4	Independent area radiation monitor warning system	Functional	
BD5	Remote monitoring station alarm (PDR systems only)	Functional	
BD6	Survey meter	Functional	
BD7	Emergency equipment (portable shielded safe, source manipulators, etc.)	Present	
Monthly			
BM1	Emergency off circuit	Functional	
Quarterly			
BQ1	Emergency off buttons/actuators	Functional	
BQ2	Secondary warning lights/irradiation state indicators	Functional	

Notes on Daily Tests

All daily tests should be performed on each day the source is to be exposed, including weekend use and other days involving non-clinical use such as preventative maintenance. For multiday pulsed dose rate (PDR) brachytherapy treatments, daily tests should be done on the day treatment is to commence; the tests need not be repeated the second day if treatment spans two days.

BD1 Test should verify that:

- The time delay circuit prevents operation of the equipment if the entrance door is not closed within a pre-set time period following activation of the last-person-out time delay switch.
- If the last-person-out is not activated that the irradiation cannot be initiated.
- The door interlock terminates irradiation immediately if the door is opened and prevents the equipment from being used while the door is open.
- Reactivation of the last-person-out switch is required to restart irradiation following its termination by the door interlock.

Verification that irradiation cannot be initiated should be accomplished through a positive test (e.g., pushing "beam on") at least once in the door interlock tests. Door interlock messages are acceptable for the remaining parts of the test.

In the case of doorless bunkers this test should involve testing the components that provide access control equivalent to a primary door interlock (see note for AD1).

BD2 Primary irradiation state indicator displays should be tested by exposing a source.

BD4 Test should also verify that battery backup systems keep the radiation warning system operational when disconnected from the main power supply. Area monitors connected to a hospital's emergency power supply is an acceptable alternative to a battery backup provided the emergency power system is tested periodically.

Notes on Monthly Tests

BM1 Test should verify that activating one of the emergency off buttons/actuators terminates the exposure and returns the source to its safe.

Test can be performed using any of the emergency stop actuators, provided that testing is rotated so that all emergency stops are tested at least once every quarter (See BQ1).

Notes on Quarterly Tests

BQ1 Termination of irradiation can be verified either directly using an external emergency stop such as the one in the control console area, or via a suitable surrogate indicator (e.g., demonstration that activating an emergency stop results in loss of main power, loss of HV power at gantry, etc.). This test can be performed in conjunction with BM1; ensuring that each actuator is checked at least once per quarter.

BQ2 Test the illumination of the indicator when the radiation is on. The use of inexpensive digital cameras in "movie" mode can facilitate the testing of secondary displays within enclosures such as modulator rooms.

BQ3 Applicable to systems with the presence of a second entrance to the treatment room, that is not used routinely (e.g., servicing). Procedures would follow the same steps as daily test BD1.

Table 3: Radioactive source teletherapy and research irradiator systems (single or multiple sources)

Designator	Test	Performance	
		Tolerance	Action
Daily			
TD1	Primary door interlock/last-person-out button	Functional	
TD2	Primary warning lights/irradiation state indicators	Functional	
TD3	Room audiovisual monitors/cameras and intercom systems	Functional	
TD4	Independent area radiation monitor warning system	Functional	
TD5	Survey meter	Functional	
TD6	Emergency equipment (e.g., push bar for stuck source, or ratchet handle for Gamma Knife)	Present	
Monthly			
TM1	Emergency off circuit	Functional	
Quarterly			
TQ1	Emergency off buttons/actuators	Functional	
TQ2	Secondary warning lights/irradiation state indicators	Functional	
TQ3	Audible irradiation state indicator (research irradiators only)	Functional	

Notes on Daily Tests

All daily tests should be performed on each day involving delivery of the radiation beam or exposure of the source at that unit including weekend use and other days involving non-clinical use such as preventative maintenance.

TD1 Test should verify that:

- The time delay circuit prevents operation of the equipment if the entrance door is not closed within a pre-set time period following activation of the last-person-out time delay switch.
- If the last-person-out is not activated that the irradiation cannot be initiated.
- The door interlock terminates irradiation immediately if the door is opened and prevents the equipment from being used while the door is open.
- Reactivation of the last-person-out switch is required to restart irradiation following its termination by the door interlock.

Verification that irradiation cannot be initiated should be accomplished through a positive test (e.g., pushing “Beam On”) at least once in the door interlock tests. Door interlock messages are acceptable for the remaining parts of the test.

In the case of door-less bunkers this test should involve testing the components that provide access control equivalent to a primary door interlock (see note for AD1).

TD2 Primary irradiation state indicator displays should be tested by delivering by exposing a source.

TD4 Test should also verify that battery backup systems keep the radiation warning system operational when disconnected from the main power supply. Area monitors connected to a hospital's emergency power supply is an acceptable alternative to a battery backup provided the emergency power system is tested periodically.

Notes on Monthly Tests

TM1 Test should verify that activating the one of the emergency off buttons/actuators off terminates the exposure and returns the source to its safe. A test confirming interruption of power supply to device ("hard kill") should be performed at least once per quarter.

Test can be performed using any of the emergency stop actuators, provided that testing is rotated so that all emergency stops are tested at least once every quarter (See TQ1).

Notes on Quarterly Tests

TQ1 Termination of irradiation can be verified either directly using an external emergency stop such as the one in the control console area, or via a suitable surrogate indicator (e.g., demonstration that activating an emergency stop results in loss of main power, loss of HV power at gantry). This test can be performed in conjunction with TM1; ensuring that each actuator is checked at least once per quarter.

TQ2 Testing the illumination of the indicator when the radiation is on. The use of inexpensive digital cameras in "movie" mode can facilitate the testing of secondary displays within enclosures such as modulator rooms.

TQ3 Applicable to systems with the presence of a second entrance to the treatment room, that is not used routinely (e.g., servicing). Procedures would follow the same steps as daily test TD1.

Table 4: Kilovoltage radiotherapy systems

Designator	Test	Performance	
		Tolerance	**Action**
Daily			
KD1	Primary door interlock/last-person-out button (if installed)	Functional	
KD2	Primary warning lights/irradiation state indicators	Functional	
KD3	Room audiovisual monitors/cameras and intercom systems	Functional	
KD4	Independent area radiation monitor warning system (if installed)	Functional	
Monthly			
KM1	Emergency off circuit	Functional	
Quarterly			
KQ1	Emergency off buttons/actuators	Functional	

See Notes on Table 1

Table 5: X ray and CT simulator safety system

Designator	Test	Performance	
		Tolerance	**Action**
Daily			
XD1	Primary door interlock (if present)/last-person-out circuit or control area staff monitor (if present)	Functional	
XD2	Primary warning lights/irradiation state indicators	Functional	
XD3	Room audiovisual monitors/cameras and intercom systems (if installed)	Functional	
Monthly			
XM1	Emergency off circuit	Functional	
Quarterly			
XQ1	Emergency off buttons/actuators	Functional	

See notes on Table 1

Table 6: Security system

Designator	Test	Performance	
		Tolerance	Action
Semi-annual			
SS1	Intrusion detection system (all components)	Functional	

Notes on Semi-annual Tests

SS1 All systems required to ensure the safety of nuclear substances should be tested including intrusion detection systems installed in source storage rooms. As the description of security systems consists of prescribed information to be communicated only to authorized personnel, documentation of testing protocols and detailed results of tests must be stored securely. The supervising medical physicist should work with the radiation safety officer and the hospital's security staff to ensure test protocols validate the operation of all components of the security system and that results are documented in sufficient detail consistent with the institution security plan. Some tests will involve security staff.

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