Canada's Nuclear Regulator

Nuclear Substances in Canada: A Safety Performance Report for 2010

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Nuclear Substances in Canada: A Safety Performance Report for 2010

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NUCLEAR SUBSTANCES IN CANADA: A SAFETY PERFORMANCE REPORT FOR 2010

1.0 EXECUTIVE SUMMARY

This report elaborates on the safety performance of the nuclear sectors regulated by the Canadian Nuclear Safety Commission (CNSC) with respect to the use of nuclear substances in medical, industrial and commercial applications, as well as for academic and research purposes. This safety report covers the 2010 calendar year.

The safe use of nuclear substances requires compliance with the *Nuclear Safety and Control Act*, CNSC regulations and licence conditions, as well as the minimization of the consequences of incidents and occupational radiation doses. For this report, safety performance is measured in terms of licensees' regulatory compliance, reported incidents and occupational doses to workers. This report provides safety performance information on 2,622 CNSC licences in the following four CNSC-regulated sectors:

Medical sector
The medical sector uses nuclear substances and nuclear energy for diagnostic and therapeutic purposes in health care. This sector contained 593 CNSC licences as of December 31, 2010. The professions represented can be divided into nuclear medicine and radiation therapy.

Industrial sector
The industrial sector uses nuclear substances in civil engineering and in the delivery of services such as industrial radiography, oil well logging and industrial processes. This is the largest of the reported sectors, with 1,482 licences as of December 31, 2010.

Academic and research sector
The licensed activities in the academic and research sector focus primarily on biological and biomedical research that uses open-source radioisotopes, research particle accelerators and research irradiators. This sector contained 290 licences as of December 31, 2010.

Commercial sector
The commercial sector focuses primarily on the production and sale of nuclear substances and the third-party servicing of radiation devices and prescribed equipment. This sector contained 257 licences as of December 31, 2010.

The safety performance of CNSC licensees is measured in terms of the following performance metrics:

- doses to workers
- inspection ratings of operational procedures
- inspection ratings of radiation protection
- inspection ratings of sealed source tracking
- reported incidents and events
- enforcement activities – orders

Figures 1 to 6 compare the performance of the four sectors for each of these metrics, respectively.

1.1 Doses to Workers

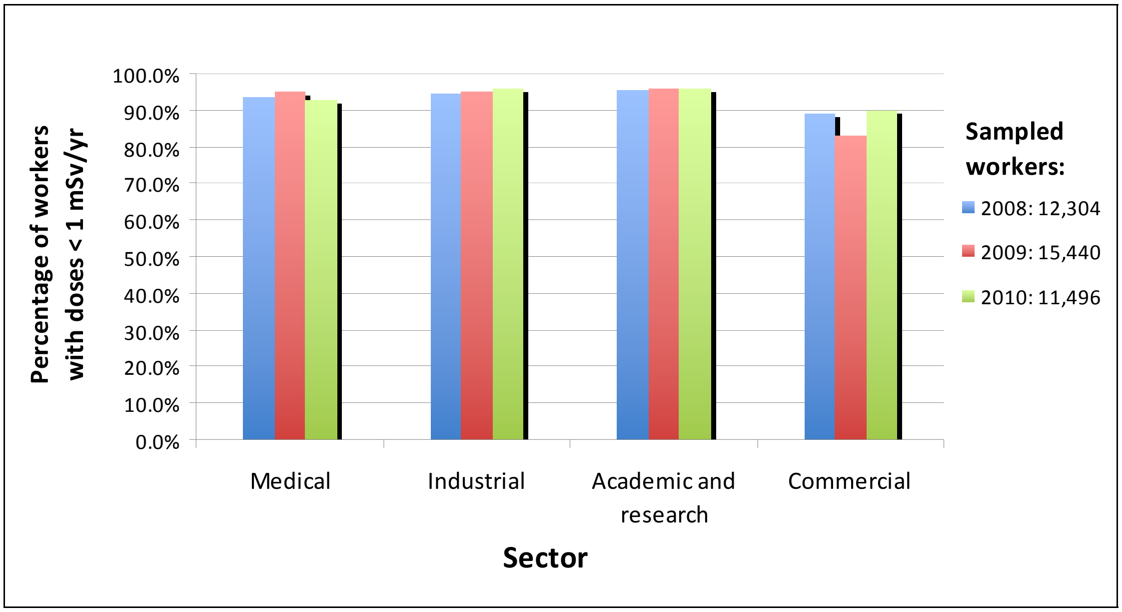

Figure 1: Sector-to-sector comparison – Percentage of workers who received whole body doses of less than 1 mSv per year.

In 2010, most sectors showed an improvement in occupational doses. The exception was a slight decrease in the medical sector, primarily due to doses received by workers in diagnostic and therapeutic nuclear medicine. The improvement is reflected by an increase in the percentage of workers who received less than the prescribed public dose limit of 1 mSv/year, as shown in Figure 1. Although this is not explicitly shown in Figure 1, nuclear energy workers in all nuclear sectors received doses significantly lower than the regulatory limits of 50 mSv/year and 100 mSv over a five-year period, since no nuclear energy worker exceeded 20 mSv in any given year during the reporting period.

1.2 Inspection Ratings of Operational Procedures

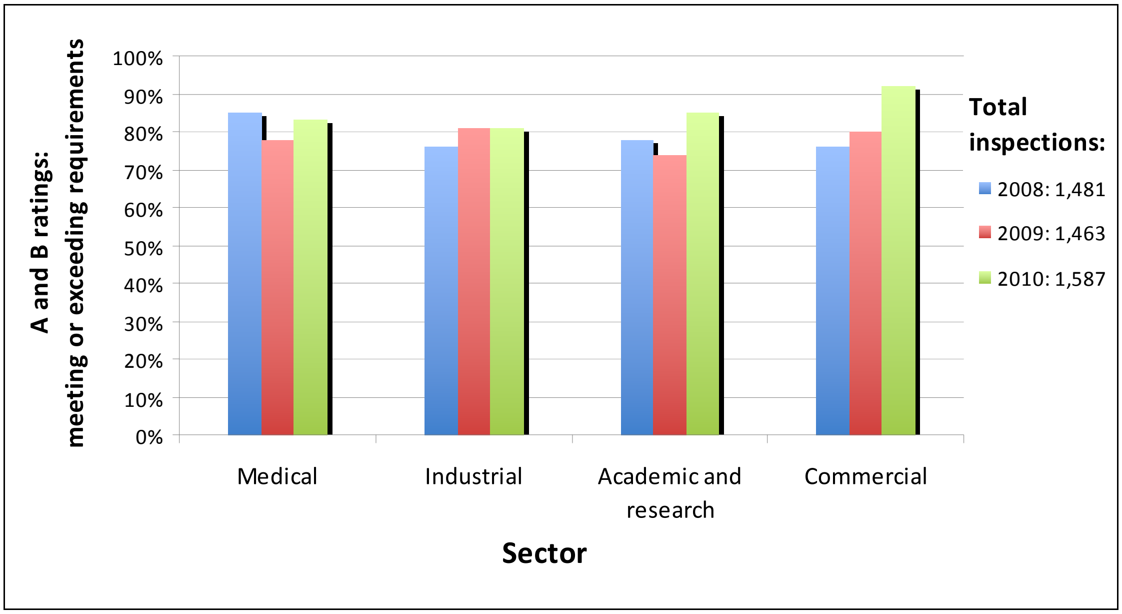

Figure 2: Sector-to-sector comparison – Inspection ratings of operational procedures.

As shown in Figure 2, licensees in most sectors showed improvement in their compliance levels for operational procedures during 2010, compared to 2009. The exception was the industrial sector, whose performance in this safety area for 2010 remained constant compared to the previous year. The commercial sector's compliance level improved significantly, from 80% in 2009 to 92% in 2010. This increase was primarily due to the servicing sub-sector, with 74% of its inspected licensees found to be compliant in 2009, compared to 95% in 2010. Overall, there were 1,587 inspections performed in 2010, encompassing a review of licensees' operational procedures. Only two of these inspections (both in the industrial sector) resulted in "E" ratings, which were followed by CNSC enforcement actions to have the licensees take appropriate corrective measures. In general, the trends were positive with respect to compliance within the safety area of operational procedures.

1.3 Inspection Ratings of Radiation Protection

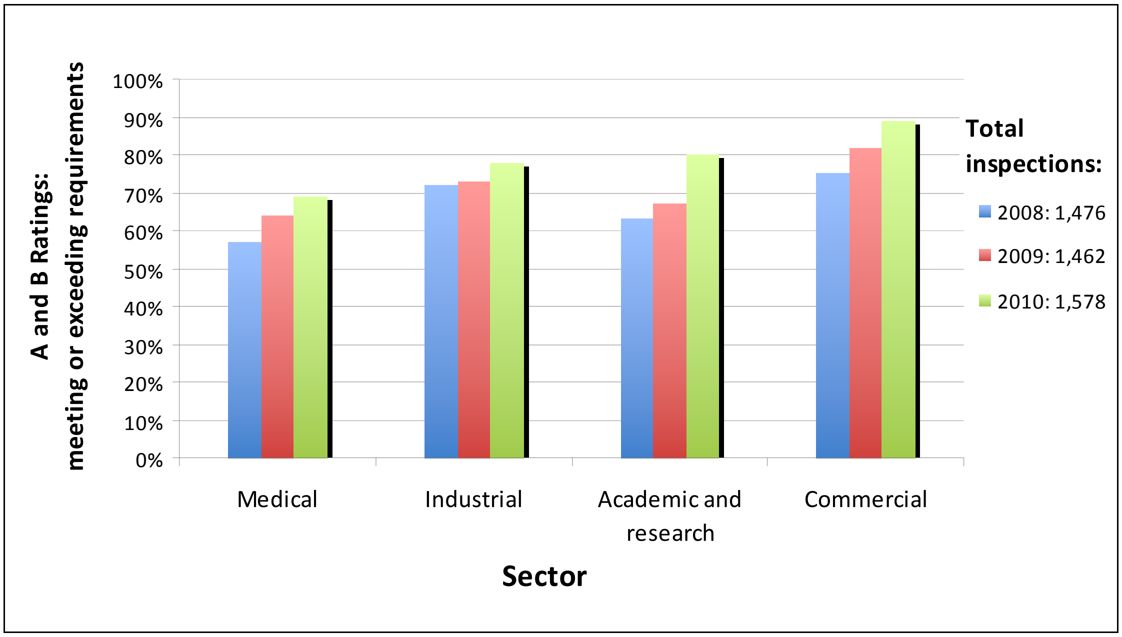

Figure 3: Sector-to-sector comparison – Inspection ratings of radiation protection.

All sectors improved their compliance levels for the radiation protection safety area, as shown in Figure 3. The most notable increase was seen in the academic and research sector, with 67% of its inspected licensees found to be compliant in 2009, compared to 80% in 2010. Although the medical sector showed improvement with an overall compliance level of 69% in 2010, it is still behind the other sectors. In 2010, the CNSC performed 1,578 inspections of the radiation protection safety area; of these, eight licensees (all in the industrial sector) received “E” ratings, which were followed by CNSC enforcement actions to have the licensees take corrective measures. Trends for this safety area were generally positive between 2008 and 2010.

1.4 Inspection Ratings of Sealed Source Tracking

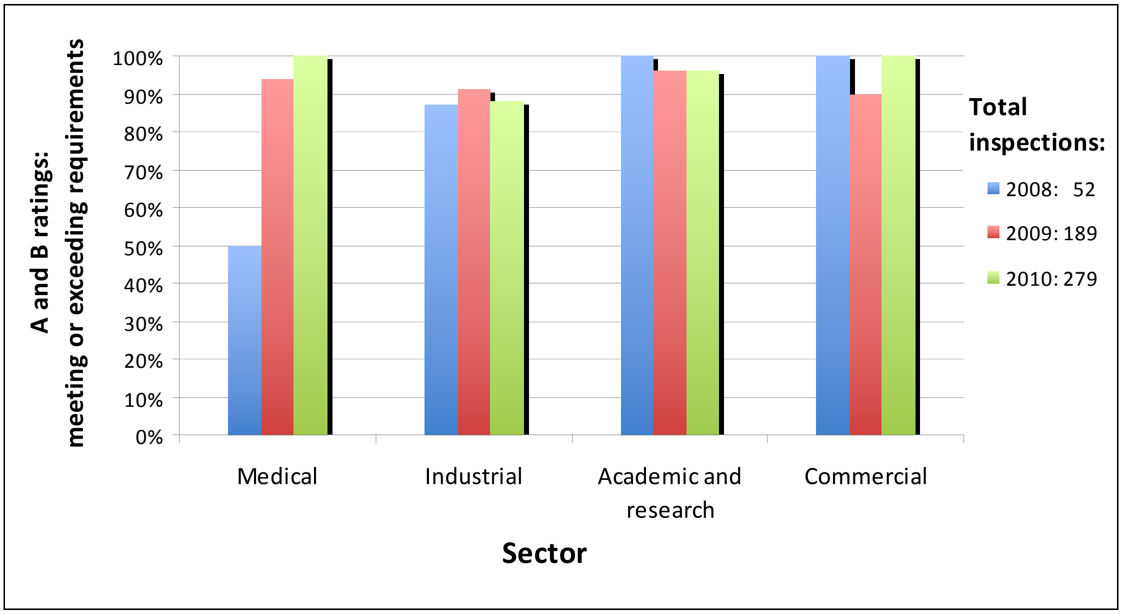

Figure 4: Sector-to-sector comparison – Inspection ratings of sealed source tracking.

As shown in Figure 4, all sectors showed strong compliance levels with respect to the sealed source tracking requirements. There were fewer inspections of this safety area, as not all licensees are subject to mandatory sealed source tracking. Only those licensees using high-risk sealed sources (Categories 1 and 2), must report source movements to the CNSC within a prescribed timeframe, as required under their licences. In general, compliance levels were consistent with previous years, or improving in the safety area of sealed source tracking.

1.5 Reported Incidents and Events

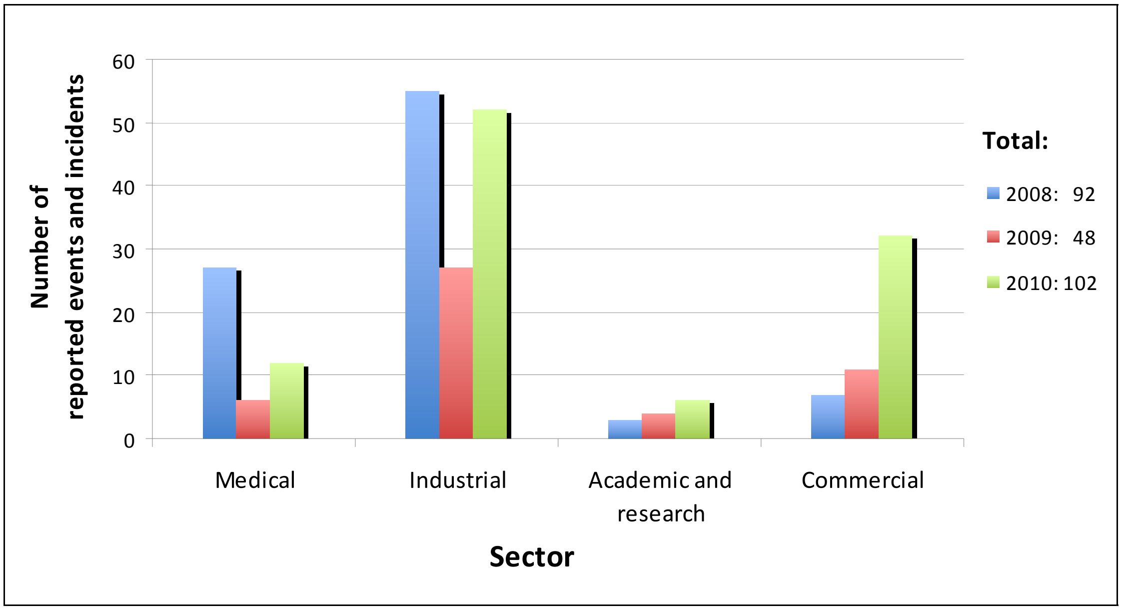

Figure 5: Sector-to-sector comparison – Reported events and incidents.

As shown in Figure 5, the number of reported events and incidents increased in 2010, as compared to 2009. In the industrial sector, there was a significant rise in the number of portable gauges that were hit or run over by vehicles, possibly due to an increased usage with Canada's healthy construction industry. In the commercial sector, there was a significant increase in the number of reported spills and contamination, mainly due to the CNSC request that licensees report all skin contamination incidents, regardless of the doses received. Finally, the slight increase in the medical sector was mostly due to spills and contamination incidents in the nuclear medicine area, where workers frequently handle nuclear substances in liquid form or work with patients who may inadvertently cause spills.

In 2010, there were 10 events related to missing nuclear substances, all in the industrial sector. Five of them involved nuclear substances that were subsequently recovered from various locations, including metal recycling facilities through the use of portal alarm monitors. This means that half of the events related to missing nuclear substances involved the recovery of previously lost or stolen substances. In two of the five remaining events, the nuclear substances were recovered shortly after they were reported lost or stolen. The three remaining events are under investigation and involve very low to low risk sources.

None of the events or incidents reported to the CNSC between 2008 and 2010 resulted in any person receiving a dose in excess of regulatory limits. In all cases, licensees implemented appropriate measures to mitigate event consequences and to limit radiation exposure to workers and the public.

1.6 Enforcement Activities – Orders

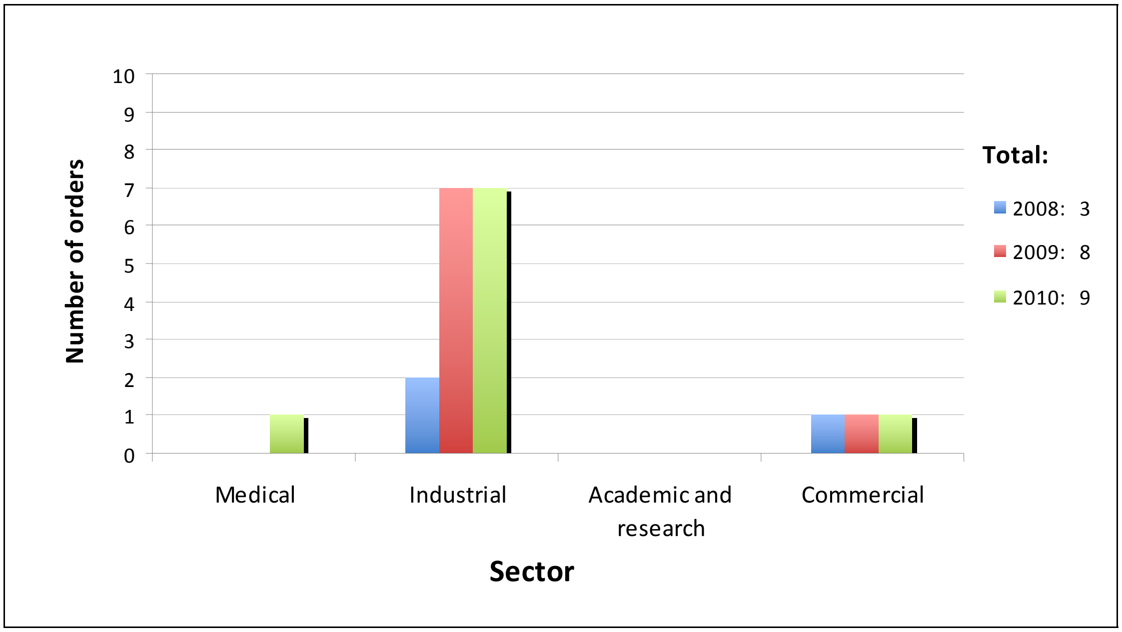

Figure 6: Sector-to-sector comparison – CNSC orders to licensees.

As shown in Figure 6, the number of CNSC orders issued to licensees remained stable in 2010, compared to 2009. There was one order in the medical sector as a result of a medical facility operating an uncertified accelerator, which coincided with an order to a third-party servicing licensee in the commercial sector. Of the seven orders issued to the industrial sector, the majority were related to either portable gauge or industrial radiography licensees. No orders were issued to licensees in the academic and research sector between 2008 and 2010.

2.0 PURPOSE

This document reports on the safety performance of certain sectors regulated by the CNSC.

3.0 SCOPE

This report focuses on the use of nuclear substances and prescribed equipment in medical, industrial and commercial applications, as well as for academic and research purposes. This safety performance report covers the 2010 calendar year, and also includes data from 2008 and 2009, in order to identify trends. It does not address Class I nuclear facilities, such as nuclear power plants, nuclear research reactors, uranium mines and mills, waste facilities, dosimetry services, or import and export activities. It does, however, include large particle accelerators, known as Class IB research particle accelerators.

4.0 INTRODUCTION

The CNSC's mission is to regulate the use of nuclear energy and nuclear substances and prescribed equipment to protect the health, safety and security of Canadians and the environment; and to implement Canada's international commitments on the peaceful use of nuclear energy. Under the *Nuclear Safety and Control Act*[1] (NSCA), the CNSC's mandate involves four major areas:

- regulate the development, production and use of nuclear energy in Canada to protect health, safety and the environment
- regulate the production, possession, use and transport of nuclear substances, and the production, possession and use of prescribed equipment and prescribed information
- implement measures respecting international control of the development, production, transport and use of nuclear energy and substances, including measures respecting the non-proliferation of nuclear weapons and nuclear explosive devices
- disseminate objective scientific, technical and regulatory information concerning the activities of the CNSC and the effects on the environment and on the health and safety of persons, of the development, production, possession, transport and use of nuclear substances

This report provides objective information and data that licensees may use for their own performance improvement initiatives. For a comprehensive overview of the CNSC, readers are invited to consult the CNSC's *2010–11 Annual Report*[2].

[1] Available online at laws-lois.justice.gc.ca/eng/acts/N-28.3/index.html
[2] Available online at nuclearsafety.gc.ca/pubs_catalogue/uploads/CNSC-2010-2011-Annual-Report_e.pdf

This report provides safety performance information for the following CNSC-regulated sectors for the 2010 calendar year:

- medical
- industrial
- academic and research
- commercial

Safety performance results from 2008 and 2009 are also included in this report, for trending purposes.

Nuclear substances within radiation devices are used in a wide range of applications in Canada. Many day-to-day commodities are produced with the aid of nuclear substances licensed by the CNSC. Common uses of radiation devices include static eliminators used in the production of plastics to remove static electricity, fixed nuclear gauges that control the fluid levels of factory-filled beverage bottles, and portable nuclear gauges that measure moisture and density in soil and the thickness of asphalt in new road construction.

Nuclear substances are also found in devices that protect the health and safety of Canadians; these devices include smoke detectors, emergency exit signs and emergency lighting on airplanes. They do not require a licence for possession by the end-user; however, their manufacture and initial distribution in Canada are licensed by the CNSC.

Medical applications using radiopharmaceuticals are designed to target and treat specific tissues and organs, allowing for the delivery of a nuclear substance to specific areas of the body. Radiopharmaceuticals are widely used in the diagnosis and treatment of diseases such as cancer.

Examples of nuclear substances found in academic areas include those in irradiators to irradiate cells or samples in research laboratories. Particle accelerators are used in research in the fields of subatomic physics, materials, and biomedicine. They can also be used to generate some of the nuclear substances used in medical and research facilities. Nuclear substances are also used for teaching and in research laboratories for diverse activities, including the elucidation of biological activities and growth in cells, sequencing of nucleic acid, and demonstration of the properties of radiation.

Commercial uses of nuclear substances fall mainly into the servicing of fixed and portable gauges, and exposure devices. Servicing licences often include the installation, repair and non-routine maintenance of radiation devices or prescribed equipment.

APPENDIX A provides a brief overview of the CNSC's approach for regulating the nuclear substances used in the aforementioned sectors. The CNSC verifies compliance through desktop evaluations and routine onsite inspections, in order to determine licensee conformance with the NSCA, regulations and licence conditions, many of which include references to relevant national and international standards. Both licensing and compliance verification processes focus on key safety and control areas (SCAs) pertaining to licensee programs.

This report centres on ratings obtained from the CNSC's onsite compliance inspections of three key SCAs: operational procedures, radiation protection, and international obligations. The CNSC deems these to be the most relevant indicators of safety performance and the most representative of the regulated sectors covered in this report. The following provides additional information on the assessment of inspection ratings related to these three SCAs:

- Operational procedures: This SCA is part of the management function. Assessment of inspection ratings for this SCA provides insight into the unique processes and procedures that apply to day-to-day operations.
- Radiation protection: This SCA is one of the core control processes. Assessment of inspection ratings for this SCA provides insight into the overall functionality of the radiation safety program at a licensee's facility.
- International obligations (sealed source tracking): This SCA is a core control process and covers licensee programs required for the successful implementation of international obligations. For the nuclear sectors in this report, these obligations relate to the required tracking of high-risk sealed sources in Canada. These obligations stem from Canada's commitment to the International Atomic Energy Agency *Code of Conduct on the Safety and Security of Radioactive Sources*. The National Sealed Source Registry (NSSR) is a CNSC-managed national database that maintains inventory information on sealed sources in Canada. The movement of high-risk sources (Categories 1 and 2) is tracked through the Sealed Source Tracking System (SSTS), the use of which is mandatory only for licensees using these high-risk sources. For more information on the SSTS, readers are invited to consult the National Sealed Source Registry and Sealed Source Tracking System annual reports[3]. The CNSC requires licensee compliance with the tracking of sealed sources in order to guarantee adequate traceability and accountability of these sources.

Two additional performance measures used in this report include:

- occupational doses (also referred to as "dose to workers"), which provide an objective measure of a sector's safety performance
- the change in incident frequency from year to year (which is of greater interest than the higher numbers of incidents and events that some sectors have shown, due to the nature of their licensed activities)

In summary, the safety performance of each sector is evaluated using inspection ratings of operational procedures, radiation protection and high-risk sealed source tracking, as well as doses to workers, and reported incidents and events. These are all excellent indicators of safety performance.

For greater clarity, some sectors have been broken down into smaller sub-sectors based on similarities in licensed activities.

Although the CNSC assesses all licence applications before issuing or renewing licences, not all licensees require the same level of regulatory oversight and compliance verification. A high-risk licensed activity may undergo more detailed oversight and inspections, and also necessitate the submission of an annual compliance report (ACR) by the licensee. A low-risk licensed activity may only require the submission of an ACR. APPENDIX A provides more information on the CNSC's risk-informed approach for regulating the nuclear sectors in this report.

[3] Available online at nuclearsafety.gc.ca/eng/readingroom/reports/ssts/index.cfm

The components of the CNSC's risk-informed regulatory approach include assessment and compliance verification activities.

The CNSC's assessment process for licensing is usually a desktop review of the licensee's operations, and may include reviews of a licence application (new application or renewal of an existing licence) or a licensee program (such as the radiation protection program).

Compliance verification activities consist of field inspections, as well as reviews and assessments of ACRs. The CNSC has adopted a risk-informed regulatory program and as such may not inspect all licensees every year. For example, it is possible that inspectors will see numerous sealed-source licensees with SSTS requirements during one year, and very few in subsequent years. Furthermore, inspectors may not see every licensee during each calendar year, except for those involved with activities designated as high-risk. This approach guides the CNSC in applying increasingly restrictive levels of enforcement, including orders, to promote licensee compliance. In addition to orders, licensees may choose to voluntarily restrict their operations until they implement measures to restore their compliance with the NSCA, regulations and licence conditions. The CNSC may also utilize other measures to promote and enforce compliance, such as increasing the frequency of its compliance verification activities.

There are 2,622 licences that fall into the medical, industrial, academic and research, and commercial sectors covered in this report. CNSC inspectors planned and performed more than 1,500 compliance inspections in 2010. APPENDIX B provides a detailed comparison of safety performance measures among sectors. It includes a summary of the number of licences by sector, as well as an overall comparison of dose to workers, SCA inspection rating results, and the number of reported events and incidents for each of the four sectors.

5.0 SAFETY PERFORMANCE MEASURES

5.1 Compliance Ratings

Compliance ratings are based on a licensee's compliance with the NSCA, regulations and licence conditions. When needed, the CNSC enforces compliance using a graduated approach, whereby enforcement actions taken are commensurate with the risk presented by the infraction. This can be in the form of a simple written notification to the licensee for low-risk infractions, or more extensive regulatory oversight following medium-risk infractions. The CNSC may issue an order for an infraction that presents immediate risks to the environment or to the health or safety of the persons, or for repeated infractions that may indicate significant degradation in licensee programs.

The CNSC follows up on all enforcement actions, to ensure that licensees have taken all necessary corrective actions to restore compliance with CNSC requirements. This section contains definitions of the performance measures used to produce this report, and Section 5.2 defines the rating system.

5.1.1 Doses to Workers

This information represents the dose records of persons who may be subjected to occupational exposures to radiation associated with CNSC-licensed activities. The dose data is extracted from dose reports provided by licensees in their ACRs for 2010. For the purpose of this performance measure, CNSC staff analyzed a representative sample of worker dose records from randomly selected ACRs from licensees in each sector.

Performance Objective:

> Dose to workers is below the regulatory limit and as low as reasonably achievable (ALARA)[4].

The prescribed whole body dose limit for members of the public is 1 mSv/year; whereas the limits for a nuclear energy worker (NEW) are a maximum of 50 mSv in a one-year dosimetry period and 100 mSv in a five-year dosimetry period.

5.1.2 Operational Procedures

Operational procedures relate to the licensee's ability to perform licensed activities in accordance with the NSCA, its Regulations, and CNSC licence conditions. The licensee is expected to demonstrate that operational and safety requirements are met, that appropriate procedures concerning the use and maintenance of equipment are given to and followed by workers, and that appropriate documentation that demonstrates compliance is maintained. To verify these program elements, CNSC staff review documents and perform field inspections of operational practices.

Performance Objective:

> Licensee operations are safe, with adequate regard for health, safety, security, environmental protection, and conform to Canada's international obligations.

5.1.3 Radiation Protection

Radiation protection relates to the program that a licensee puts in place to protect persons from unnecessary exposure to ionizing radiation. The licensee is expected to demonstrate that adequate provisions are in place to maintain doses below regulatory limits and that are ALARA. This objective can be met through the monitoring of worker doses, posting of radiation warning signs, appropriate planning for radiological emergencies, management oversight of operational activities, and effective workplace practices emphasizing time, distance and shielding and the use of appropriate protective equipment.

Performance Objective:

> Licensees ensure that there is adequate protection in place for the health and safety of persons with respect to ionizing radiation.

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[4] Refer to G-129, Rev.1, *Keeping Radiation Exposures and Doses "As Low as Reasonably Achievable (ALARA)"* available online at nuclearsafety.gc.ca.

5.1.4 Sealed Source Tracking

The CNSC's Sealed Source Tracking System (SSTS) was created to establish a greater degree of regulatory oversight for radioactive sealed sources in Canada and to comply with the International Atomic Energy Agency *Code of Conduct on the Safety and Security of Radioactive Sources*. Licensees are required to report the movement of high-risk radioactive sealed sources to the CNSC, using the SSTS as appropriate. Records are maintained to demonstrate compliance.

Performance Objective:

> Licensees have adequate measures in place to track and report the movement of high-risk radioactive sealed sources to the CNSC in a timely and accurate manner, via the SSTS, and to implement appropriate safeguard measures where applicable.

5.1.5 Reported Incidents and Events

Licensees are required under the NSCA and its Regulations or through specific licence conditions to immediately report to the CNSC any incidents or events related to their licensed activities. Within 21 days following the initial report, licensees are required to submit a more detailed final report to the CNSC on the incident or event. This final report is to include a root-cause analysis and measures taken or proposed by the licensee to prevent recurrence. Together, the initial and final reports allow the CNSC to ensure that adequate corrective actions are taken by the licensee.

Performance Objective:

> Licensees have adequate measures in place to report incidents and events and to demonstrate an effective root-cause analysis of reportable events. This analysis ensures that licensee programs continually improve, and remain relevant and effective.

5.2 Compliance Rating System

The CNSC has adopted a graduated grading scheme for the regulated sectors covered by this report, to indicate the level of licensee compliance with regulatory requirements within specific SCAs. The grading system allows the CNSC to assign one of five possible grades ("A" to "E") to a regulatory requirement within each SCA. The grades are as follows:

A – Exceeds requirements

Assessment topics or programs meet and consistently exceed applicable CNSC requirements and performance expectations. Performance is stable or improving. Any problems or issues that arise are promptly addressed, such that they do not pose an unreasonable risk to the maintenance of health, safety, security, environmental protection, or conformance with international obligations to which Canada has agreed.

B – Meets requirements

Assessment topics or programs meet the intent or objectives of CNSC requirements and performance expectations. Licensees are generally compliant; at most, there are only minor deviation from requirements or the expectations for the design and execution of the programs, but these deviations do not represent an unreasonable risk to the maintenance of health, safety, security, environmental protection, or conformance with international obligations to which Canada has agreed.

C – Below requirements

Performance has deteriorated and falls below expectations, or assessment topics or programs deviate from the intent or objectives of CNSC requirements to the extent that there is a moderate risk that the programs will ultimately fail to achieve expectations for the maintenance of health, safety, security, environmental protection, or conformance with international obligations to which Canada has agreed. Although the risk of failing to meet regulatory requirements in the short term remains low, improvements in performance or programs are required to address identified weaknesses. The licensee has taken or is taking appropriate action. Examples of C-rated non-compliances include: the CNSC licence was not posted at the site of the licensed activity; the list of qualified workers was incomplete; the radiation warning sign was not posted appropriately; or the transfer of a high-risk sealed source was not performed in the Sealed Source Tracking System (SSTS) within the prescribed reporting timeframe.

D – Significantly below requirements

Assessment topics or programs are significantly below requirements, or there is evidence of continued poor performance, to the extent that whole programs are undermined. This area is compromised. Without corrective action, there is a high probability that the deficiencies will lead to an unreasonable risk to the maintenance of health, safety, security, environmental protection, or conformance with international obligations to which Canada has agreed. Issues are not being addressed effectively by the licensee or applicant. The licensee has neither taken appropriate compensating measures, nor provided an alternative plan of action. Examples of D-rated non-compliances include: the list of nuclear energy workers was not available; copies of leak tests were not being provided when transferring sealed sources; exceeded action levels related to dose to workers were not reported to the CNSC or investigated; or the transfer of multiple high-risk sealed sources was not performed within the prescribed reporting timeframe.

E – Unacceptable

There is evidence of an absence, total inadequacy, breakdown, or loss of control of an assessment topic or a program. There is a very high probability of an unreasonable risk to the maintenance of health, safety, security, environmental protection, or conformance with international obligations to which Canada has agreed. An appropriate regulatory response – such as an order or restrictive licensing action – has been or is being implemented to rectify the situation. Examples of E-rated non-compliances include: exposure devices used without the appropriate maintenance being performed; absence of management control over work practices; exposure device operators not wearing their dosimetry equipment, or working without radiation survey meters; radiation doses not being ascertained for the workers; or the transfer of sealed sources to unauthorized recipients.

6.0 SAFETY PERFORMANCE OF LICENSEES

6.1 Medical Sector

6.1.1 Description

Medical-sector licensees use nuclear substances or produce nuclear substances through the activation of target materials by megavoltage X-rays. Collectively, this sector accounted for 593 CNSC licences as of December 31, 2010. Licensed activities occur at hospitals and medical clinics for diagnostic imaging and therapeutic purposes.

Figure 7: Gamma camera. Source: CNSC.

Nuclear medicine studies demonstrate the metabolic activity of various organs. Radioisotopes such as Technetium 99m, Carbon 11 and Fluorine 18 are used as part of radiopharmaceuticals that are administered to patients. The relevant rates of radiopharmaceutical uptake within an organ, demonstrated as “hot spots” in a nuclear imaging study, provide valuable information about the function of the tissues within. These images are captured by licensed equipment, such as a positron emission tomography (PET) scanner or a gamma camera, as shown in Figure 7.

Examples of common nuclear medicine diagnostic procedures include myocardial perfusion scans to visualize heart blood flow and function, bone scans to evaluate bones for integrity, infection or tumour, and renal perfusion scintiscans to create an image of the kidney.

Figure 8: Medical linear accelerator. Source: CNSC.

Medical linear accelerators, as shown in Figure 8, are the most commonly used tool to deliver radiation therapy. The technology used in these devices has advanced rapidly over the last 15 years. Modern linear accelerators can deliver treatments faster and more accurately than before and have evolved into hybrid treatment and imaging devices, some of which can generate computed tomography (CT) images in addition to delivering the radiation treatment.

Radioisotopes are also used in many therapeutic procedures. For example, Iodine 131 is used to treat diseases of the thyroid, Phosphorus 32 is used to treat certain blood disorders, and other isotopes are used in conjunction with antibodies for site-specific treatment of certain cancers.

For the purpose of this report, only certain sub-sectors were identified within the medical sector: diagnostic and therapeutic nuclear medicine, medical linear accelerator, afterloader, and stereotactic teletherapy device sub-sectors. Together, these sub-sectors account for 76% or 452 licences of the 593 licences in the medical sector.

6.1.2 Safety Performance

6.1.2.1 Doses to Workers

The data in this section represents the dose records of persons who may be subjected to occupational exposures to radiation associated with CNSC-licensed activities. The dose data is extracted from dose reports provided by licensees in their annual compliance reports (ACRs) for the 2008 to 2010 reporting period. For the purpose of this performance measure, CNSC staff analyzed a representative sample of worker dose records from randomly selected ACRs from licensees in each sector.

The term "sampled workers" in this section's figures represents the number of workers whose dose data was analyzed. There were 4,826 workers sampled in 2010. The majority of medical-sector employees received low occupational doses, consistent with previous years. As shown in Figure 9, nearly 90% of all medical-sector employees received less than 0.5 mSv in 2010. For comparison, the average Canadian receives a dose of 2 mSv/year from natural background radiation.

There were 771 nuclear energy workers (NEWs) sampled in the area of diagnostic and therapeutic nuclear medicine. As shown in Figure 10, 98% of them received less than 5 mSv in 2010. The number of workers in the lowest dose ranges shifted notably to higher dose ranges. This most prominent shift occurred in workers that moved from the 0 – 0.5 mSv range to the 0.5 – 1.0 mSv range. Although this shift was important, more than half of the sampled NEWs still received doses lower than the 1 mSv/yr public dose limit; and they all received doses under 20 mSv/yr (well under their regulatory limit of 50 mSv/yr).

As shown in Figure 11, more than 99% of the other workers received doses lower than their regulatory limit, with one of them slightly exceeding the dose limit for members of the public. This was identified in the licensee' ACR in 2010 and CNSC staff worked with the licensee to ensure appropriate corrective measures were implemented.

As shown in Figure 12 and Figure 13, occupational dose data provided by licensees indicates that radiation therapy workers continued to receive very low doses, as in past years, with 99% of workers receiving less than 0.5 mSv/year during the 2008–10 reporting period. This is lower than the 1 mSv/year limit for the public and much lower than the limit for NEWs.

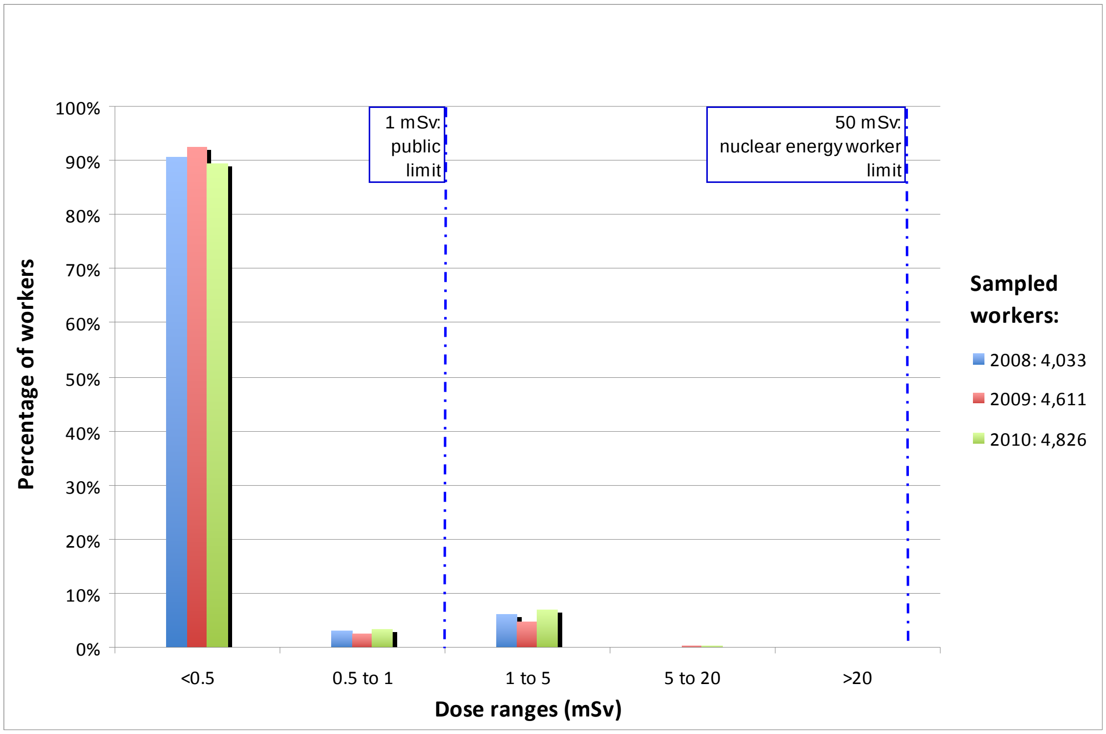

Figure 9: Medical sector – Annual whole body doses to nuclear energy workers and other workers.

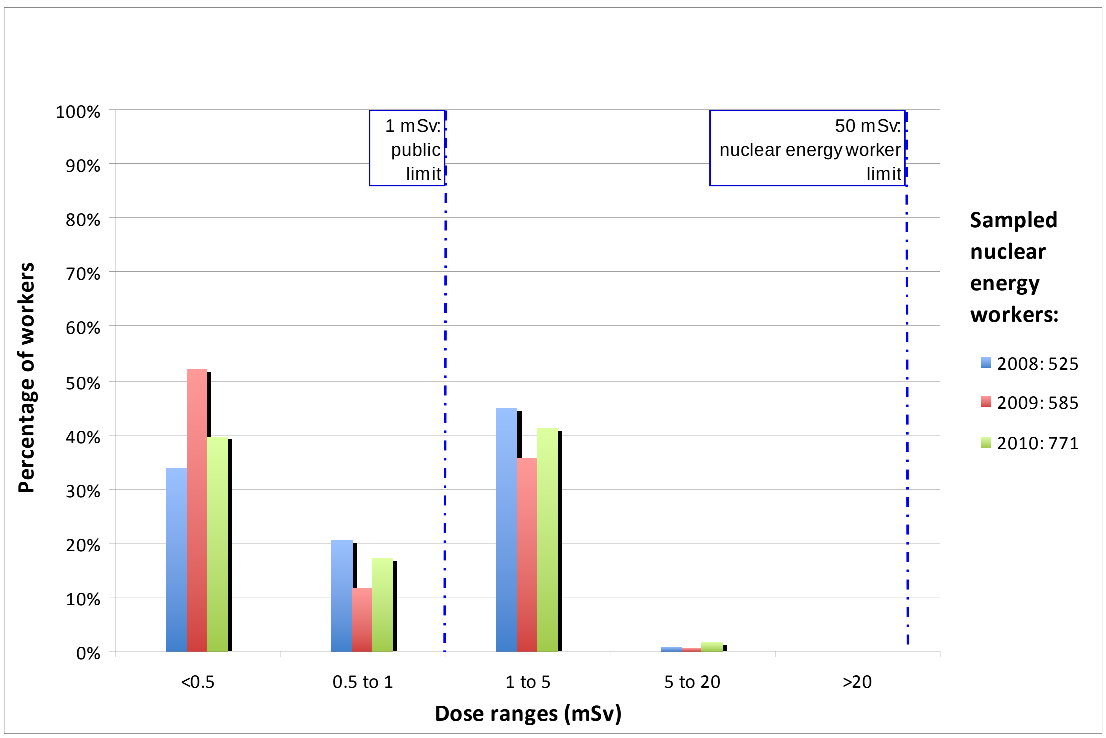

Figure 10: Diagnostic and therapeutic nuclear medicine – Annual whole-body doses to nuclear energy workers.

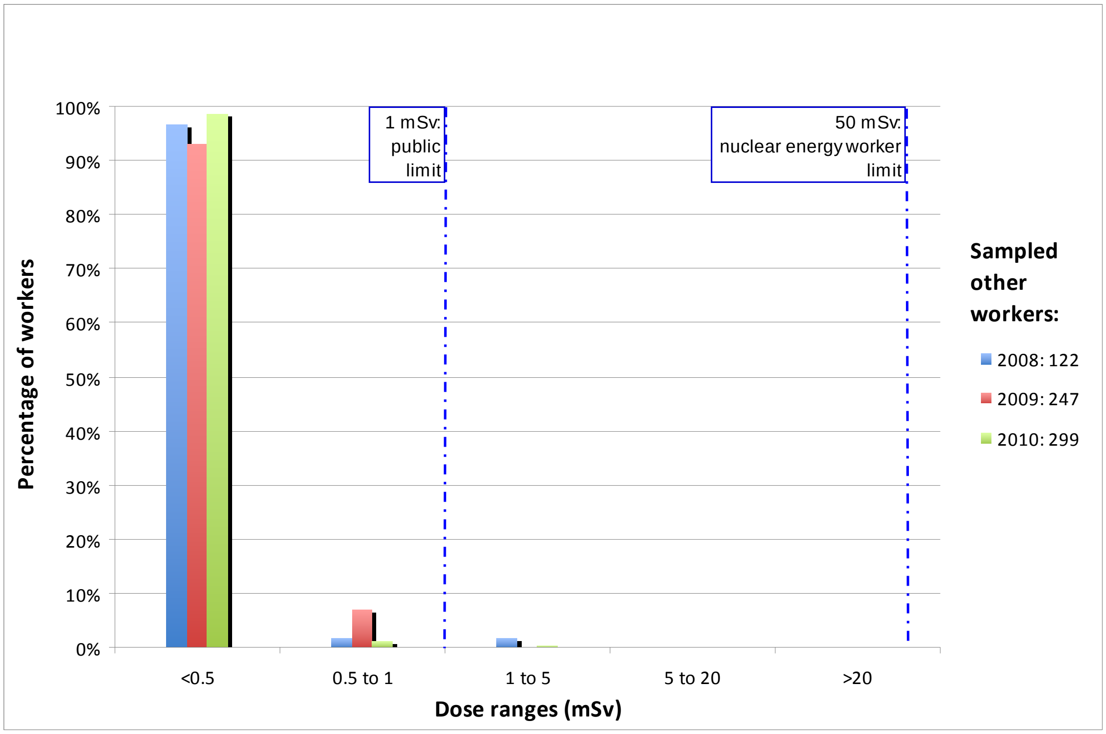

Figure 11: Diagnostic and therapeutic nuclear medicine – Annual whole body doses to other workers.

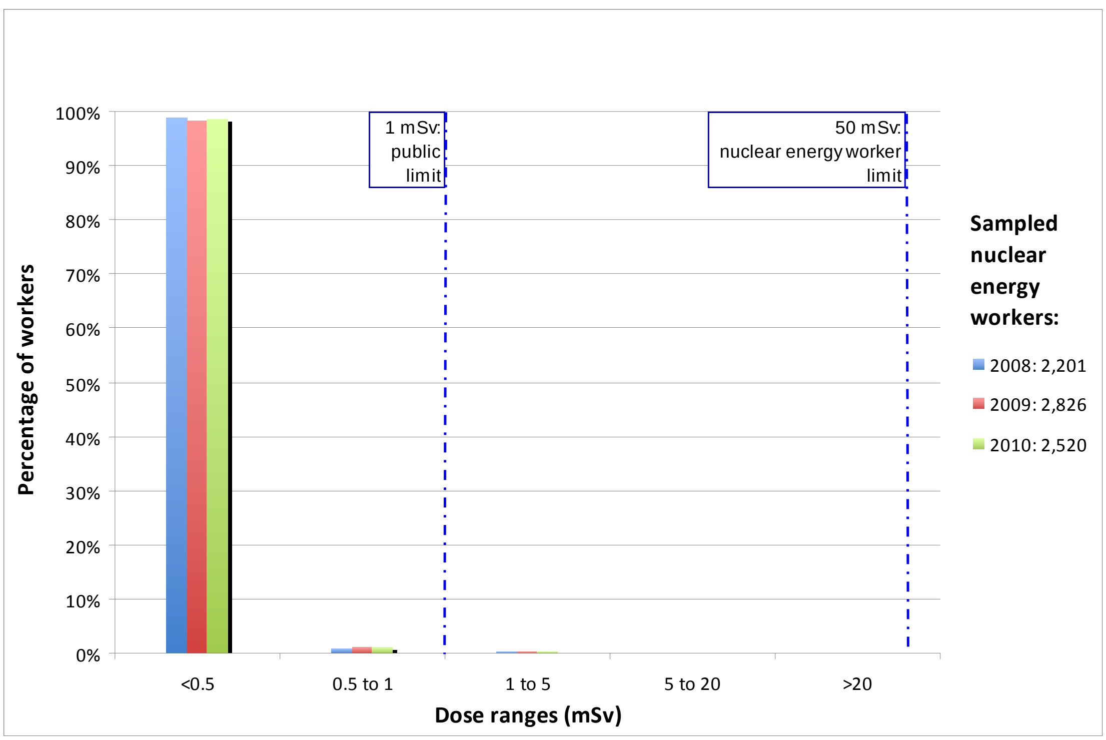

Figure 12: Radiation therapy – Annual whole body doses to nuclear energy workers.

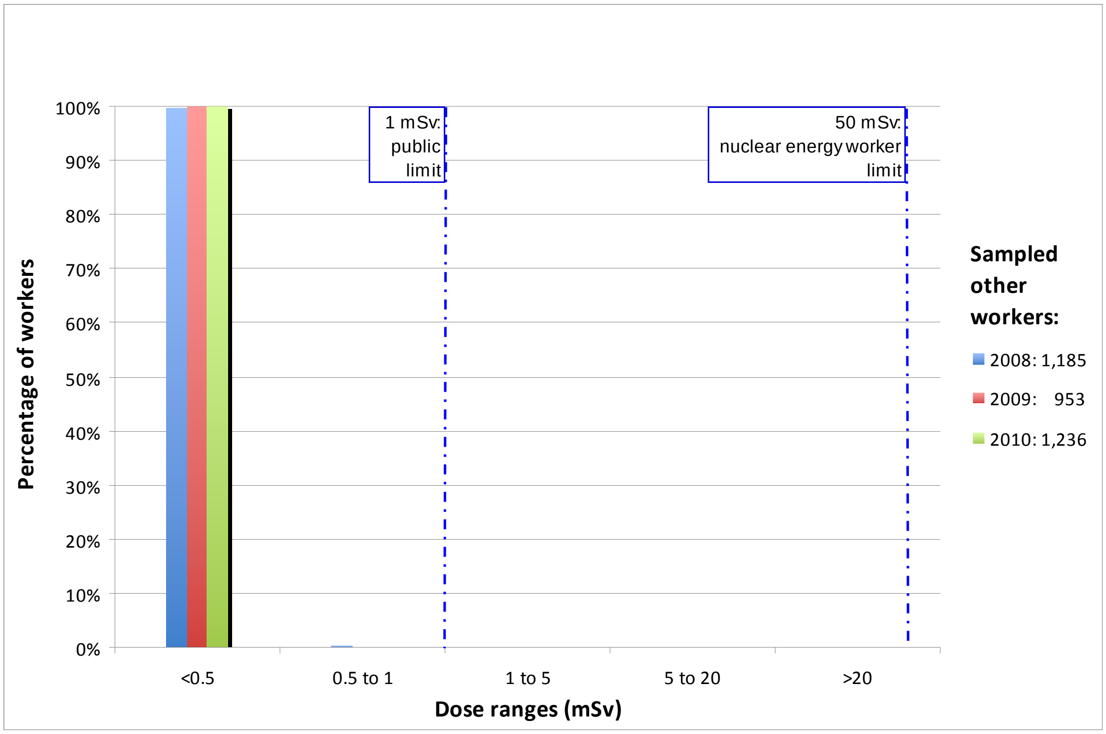

Figure 13: Radiation therapy – Annual whole body doses to other workers.

6.1.2.2 Inspection Ratings of Operational Procedures

As shown in Figure 14, the medical sector demonstrated good compliance based on ratings of operational procedures, with 83% of the inspected licensees found to be compliant in 2010, up from 78% in 2009. Of the inspected licensees found to be non-compliant, 14% had “C”-rated non-compliances that did not significantly affect safety, and 3% had “D”-rated non-compliances. A “D” rating is significantly below requirements, with deficiencies that could lead to an unreasonable risk to the health and safety of workers, the public or the environment if left uncorrected.

Typical non-compliances in this sector include failure to adhere to the licensee’s own policies and procedures, and inadequate or improper quality assurance methods. The CNSC used various enforcement actions to ensure that licensees regain compliance, such as written action notices and communication with senior management. It should be noted that no “E” ratings were assigned to the area of operational procedures, during inspections performed in 2010. For detailed results of inspection ratings, refer to Appendix B.4 and B.7.

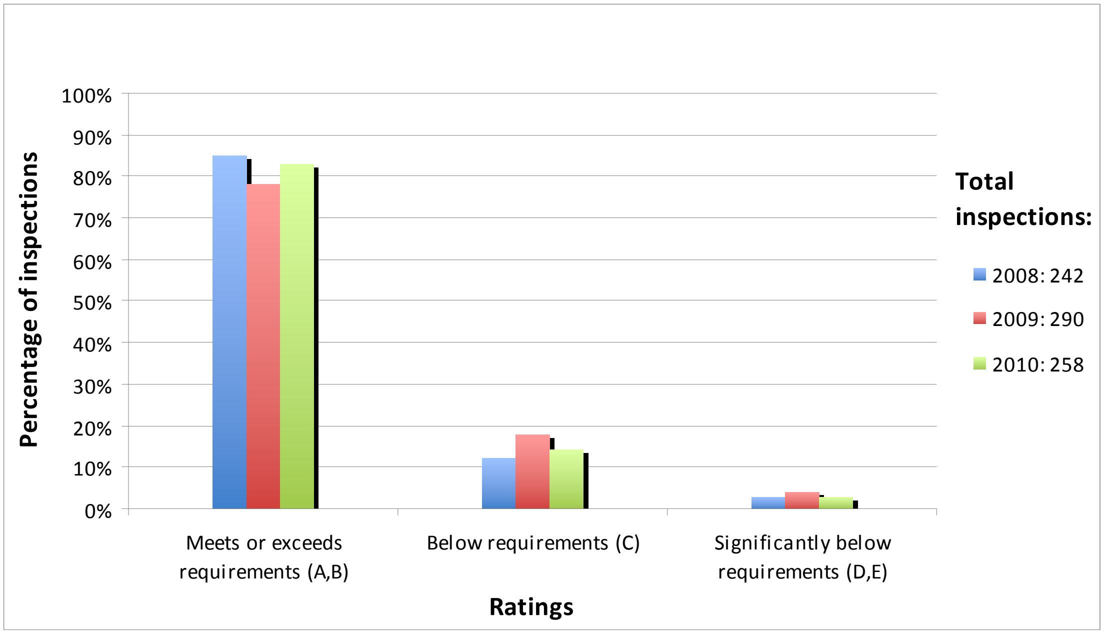

Figure 14: Medical sector – Inspection ratings of operational procedures.

6.1.2.3 Inspection Ratings of Radiation Protection

The radiation protection program represents the management of radiation safety at a given centre and includes related management practices and training, as well as the minimization and measurement of occupational doses.

Figure 15 shows continued improvement in radiation protection inspection ratings in 2010. A decline in the number of “D”-rated non-compliances was noted compared to the previous two years, from 19% in 2008 and 2009 to 8% in 2010. Typical non-compliances in this sector include failure to maintain an up-to-date list of nuclear energy workers and failure to ascertain doses to workers. The CNSC’s enforcement actions to address these types of non-compliance include asking licensees to provide regular progress reports in resolving the non-compliances, or increasing the frequency of inspections. It should be noted that no “E” ratings were assigned to the area of radiation protection, during inspections performed in 2010. For detailed results of inspection ratings, refer to Appendix B.5 and B.8.

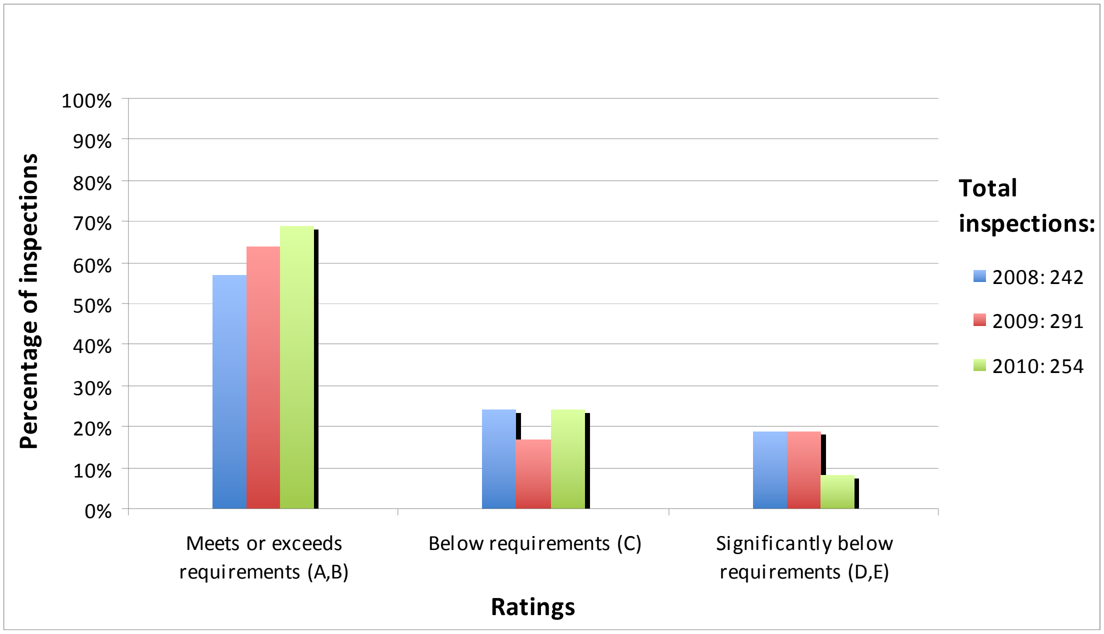

Figure 15: Medical sector – Inspection ratings of radiation protection.

6.1.2.4 Inspection Ratings of Sealed Source Tracking System (SSTS)

As shown in Figure 16, SSTS inspection ratings indicate that medical sector licensees met requirements in all seven CNSC inspections performed in 2010. For detailed results of inspection ratings, refer to Appendix B.6 and B.9. For more information on the SSTS, readers are invited to consult the National Sealed Source Registry and Sealed Source Tracking System annual reports, available on the CNSC Web site[5].

[5] Available online at nuclearsafety.gc.ca/eng/readingroom/reports/ssts/index.cfm

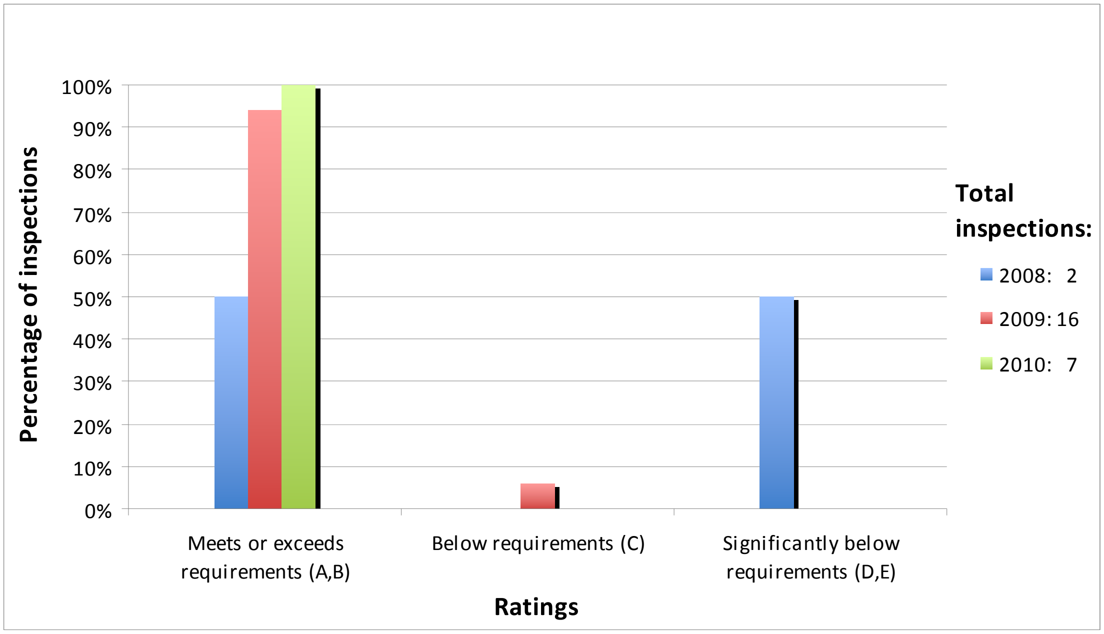

Figure 16: Medical sector – Inspection ratings of Sealed Source Tracking System.

6.1.2.5 Reported Events and Incidents

As shown in Figure 17, medical-sector licensees reported 12 events in 2010.

Two of these events involved electrical malfunctions of radiation devices, with no radiological consequences or exposures.

Nine incidents involved spills or contamination in nuclear medicine facilities; these incidents can be attributed to the fact that the nuclear substances being handled are typically in liquid form. These spills resulted mainly from technologists who dropped vials or spilled liquid while drawing it from vials. Other incidents of spills or contamination occurred during the administration of a nuclear substance to a patient, usually when an intravenous line was disconnected. Contamination can also occur when a patient vomits. Typical isotopes used in the medical sector have half-lives that are measured in hours or a few days, so spills can be addressed by the licensee with minimal impact on clinical operations.

The slight increase in these types of reported incidents may be due to CNSC outreach activities that reminded licensees of their obligation to report all skin contamination incidents, regardless of the resultant doses. In all cases, licensees implemented incident response procedures to mitigate their consequences.

In one instance, the CNSC received a report of the cremation of a person who had been implanted with 120 Iodine 125 seeds. Although Iodine 125 has a half-life of 60 days, cremation is not recommended for two years following implantation. The person was cremated eight months following the implantation of the seeds. However, it has been demonstrated in scientific literature that public exposure from cremation is not a concern[6]. Following this report, the crematorium, equipment and ashes were surveyed, and 40 intact seeds were retrieved from the ashes. The remaining seeds had been partially or completely destroyed in the cremation process, and only a trace amount of residual radiation was found in the ashes. There was a very small amount of radiation detected in the crematorium chamber, likely from the naturally occurring radioactivity in the refractory bricks. No contamination was found in the surrounding area. This incident did not result in any radiological consequences or exposure to members of the public.

In the medical sector, no nuclear substances were reported missing, and there were no reported transportation-related incidents or breaches of security reported in 2010.

No events reported by medical-sector licensees resulted in a radiation dose to any member of the public in excess of regulatory public dose limits. In all cases, licensees implemented responses to mitigate event consequences and to limit radiation exposure to workers and the public.

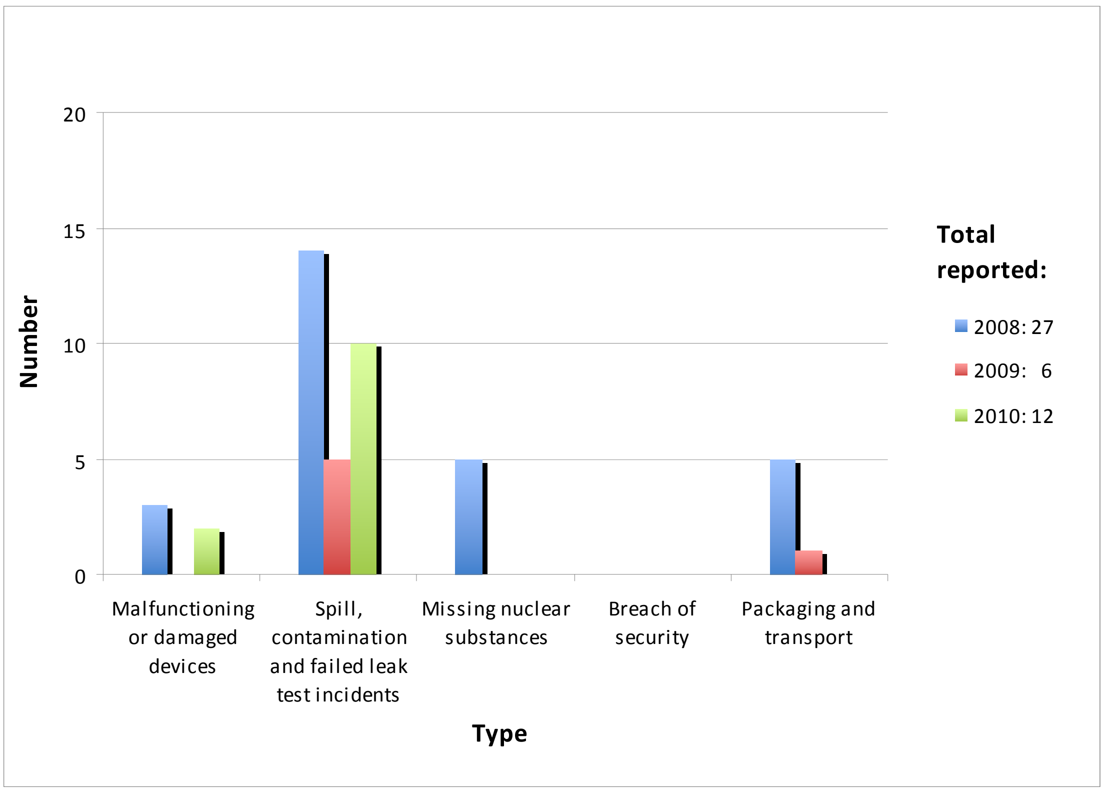

Figure 17: Medical sector – Reported events and incidents.

[6] "Radiation Safety Issues Regarding the Cremation of the Body of an I-125 Prostate Implant Patient", published in the *Journal of Applied Clinical Medical Physics*, Volume 2, No. 3, Summer 2001.

6.1.2.6 Enforcement Activities – Orders and Measures to be taken by the Licensees

In 2010, one order was issued under the NSCA to a medical-sector licensee who was found operating a linear medical accelerator that had not been certified by the CNSC. Details of the order issued by a CNSC inspector are shown in Table 1. This order coincided with an order to the vendor of the particular medical accelerator, discussed in the commercial sector. An inspection was immediately conducted following the issuance of the order and confirmed that the licensee was operating safely. Given the otherwise acceptable performance of the licensee and in accordance with the *Directive to the CNSC Regarding the Health of Canadians*[7], the licensee was permitted to continue operating the accelerator. There were no orders issued in the previous two years to licensees in this sector.

Licensee	Location	Date order was issued	Measures to be taken by the licensee	Date order was closed
Southlake Regional Health (Linear medical accelerator operation)	Newmarket, ON	June 1, 2010	Submission of a licence application to the CNSC for accelerator and demonstration that its operation does not pose additional risk to workers and patients	June 9, 2010

Table 1: Enforcement activities in 2010 – Order and measures to be taken by the licensee.

6.2 Medical Sub-sectors

6.2.1 Diagnostic and Therapeutic Nuclear Medicine Sub-sector

In diagnostic nuclear medicine, unsealed nuclear substances are administered to humans in order to diagnose medical problems. In therapeutic nuclear medicine, unsealed nuclear substances are administered to humans for therapeutic purposes related to their health care. In this sub-sector, there were 352 CNSC licences as of December 31, 2010, constituting 59% of CNSC medical-sector licences.

Diagnostic nuclear medicine procedures are unique, in that they are used to determine both organ structure and function, whereas other imaging modalities – such as CT and diagnostic X-rays – are generally limited to providing information on organ structure only. There are almost 100 different diagnostic procedures available, and every major organ system can be imaged using these techniques. In North America, cardiac imaging is the most common single procedure used in nuclear medicine.

Diagnostic procedures require the administration of a drug labelled with a nuclear substance, known as a radiopharmaceutical, to the patient. The most common of these are Iodine 131, Technetium 99m, Thallium 201 and Gallium 67. Activities range from quantities of a few kilobecquerels to several gigabecquerels. Images resulting from a

[7] Available online at laws.justice.gc.ca/eng/regulations/SOR-2007-282/index.html

nuclear medicine bone scan are shown in Figure 18. Depending on the body's metabolism for that chemical, radiopharmaceuticals are selectively concentrated within the body's organs, where they emit characteristic gamma radiation. This radiation is then detected externally using specialized detectors. Many different nuclear substances are used in nuclear medicine procedures.

Figure 18: Nuclear medicine bone scan. Source: Wikipedia.org / Creative Commons Attribution 3.0. Retrieved June 24, 2010.

Therapeutic nuclear medicine requires the administration of significant amounts of nuclear substances to a patient, in the treatment of both malignant and benign conditions. The most common type of treatment involves administering a drink or capsule containing Iodine 131 to treat thyroid dysfunction or malignancy. Because a large percentage of the nuclear substance is excreted from the patient's body, patients and caregivers must take special precautions to avoid the spread of radioactive contamination or unnecessary radiation doses. Figure 19 compares inspection ratings of operational procedures in the diagnostic and therapeutic nuclear medicine sub-sector to those of the medical sector, from 2008 to 2010. The figure shows the percentage of inspections meeting or exceeding requirements ("A" and "B" ratings). Figure 20 compares radiation protection inspection ratings for the diagnostic and therapeutic nuclear medicine sub-sector to those of the medical sector, during the same reporting period (2008 to 2010). Both Figures 19 and 20 show an increase in the number of licensees that were found to be compliant in 2010.

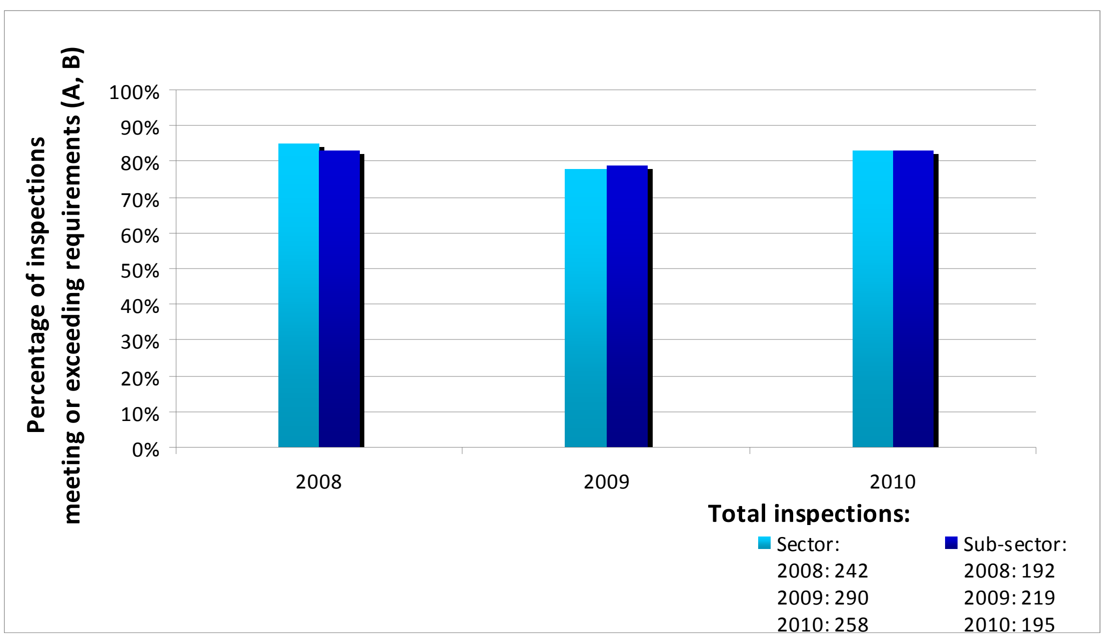

Figure 19: Medical sector vs. diagnostic and therapeutic nuclear medicine sub-sector – Comparison of inspection ratings of operational procedures.

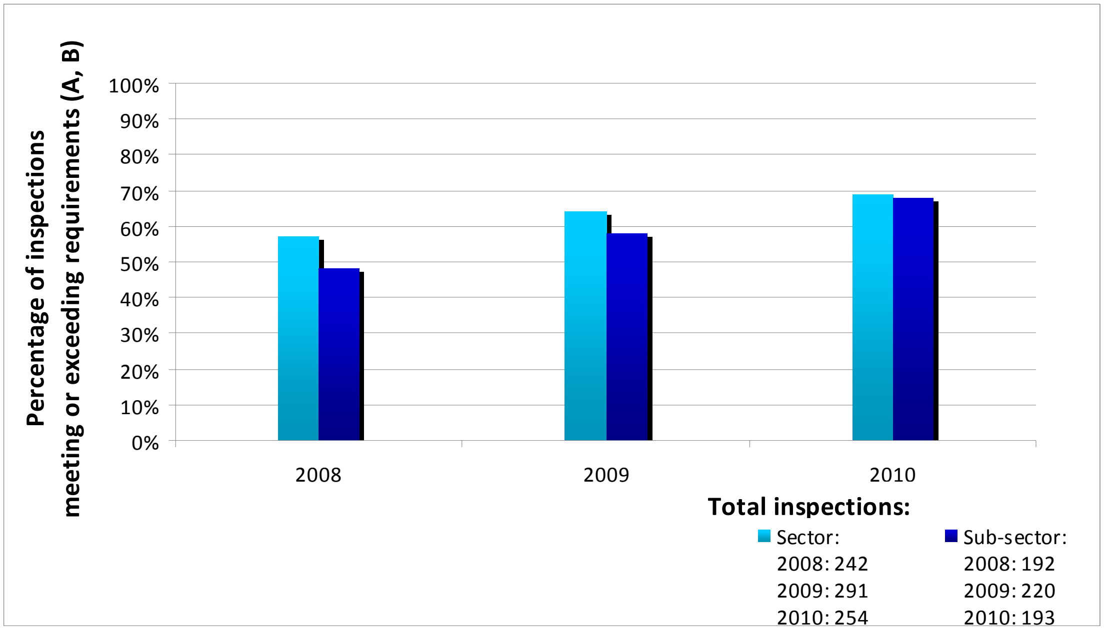

Figure 20: Medical sector vs. diagnostic and therapeutic nuclear medicine sub-sector – Comparison of inspection ratings of radiation protection.

6.2.2 Medical Linear Accelerator Sub-sector

Medical linear accelerators are used by radiation oncologists to treat cancer. A medical linear accelerator is shown in Figure 21. At the end of 2010, there were over 190 medical accelerators installed in Canada.

Figure 21: Medical linear accelerator. Source: CNSC.

Medical linear accelerators operate in the mega electron voltage range and are capable of inducing low-level radioactivity in some materials; therefore, they are subject to the NSCA. Linear accelerators are primarily used to deliver high doses of focused radiation to cancerous tissue, while avoiding surrounding healthy tissue. This treatment is commonly used for breast, prostate, head and neck, and lung cancers. Medical accelerators operating below a beam energy of 10 mega electron volt (MeV) are beyond the scope of this report because in 2010 the CNSC did not exercise its regulatory authority over these prescribed equipments. In October 2011, the Canadian Nuclear Safety Commission (CNSC) changed its policy concerning the regulation of particle accelerators and began to exercise its regulatory authority with respect to all particle accelerators operating at a beam energy of 1 (one) MeV or greater. The 2011 safety report will include information regarding low-energy accelerators to reflect the CNSC's change in policy regarding regulation of this category of device. It is expected that all affected particle accelerators will be brought under the regulatory purview of the CNSC by December 2013.

All centres where these devices are installed use multiple technologies and perform several CNSC-licensed activities.

Operational procedures are specific to the licensed activities and include quality control procedures, security, and emergency preparedness. As shown in Figure 22, this sub-sector's performance in the operational procedures safety area was essentially on par with that of the sector as a whole.

As shown in Figure 23, the linear accelerator sub-sector's performance decreased relative to that of the previous two years. It should be noted, however, that this drop can be attributed to the performance of two particular licensees in 2010. Corrective actions have been implemented and the CNSC is following up on them.

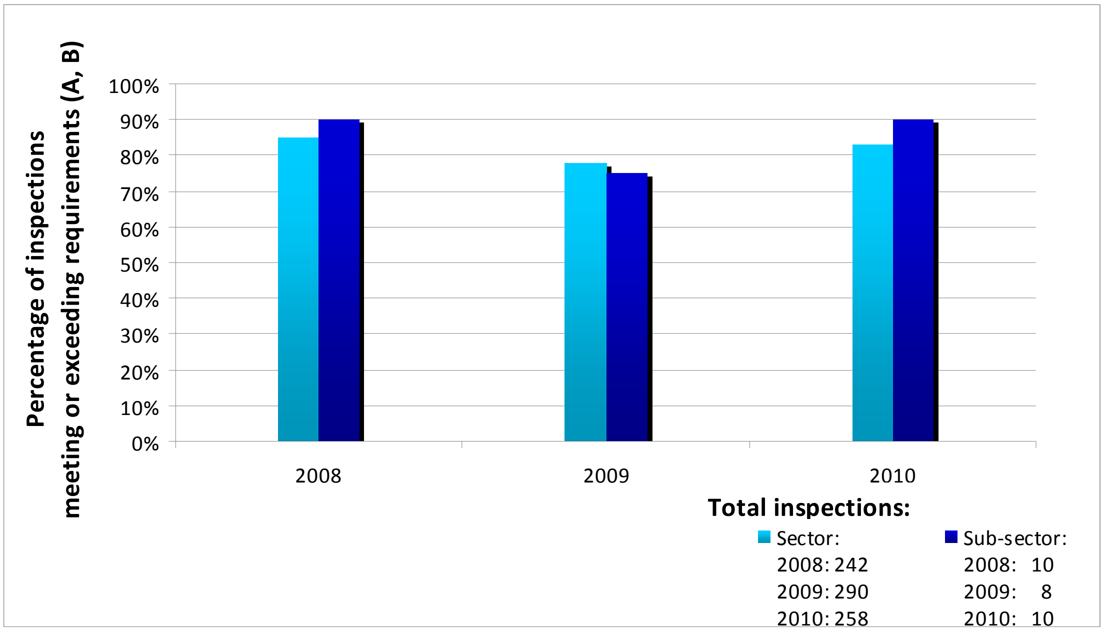

Figure 22: Medical sector vs. medical linear accelerator sub-sector – Comparison of inspection ratings of operational procedures.

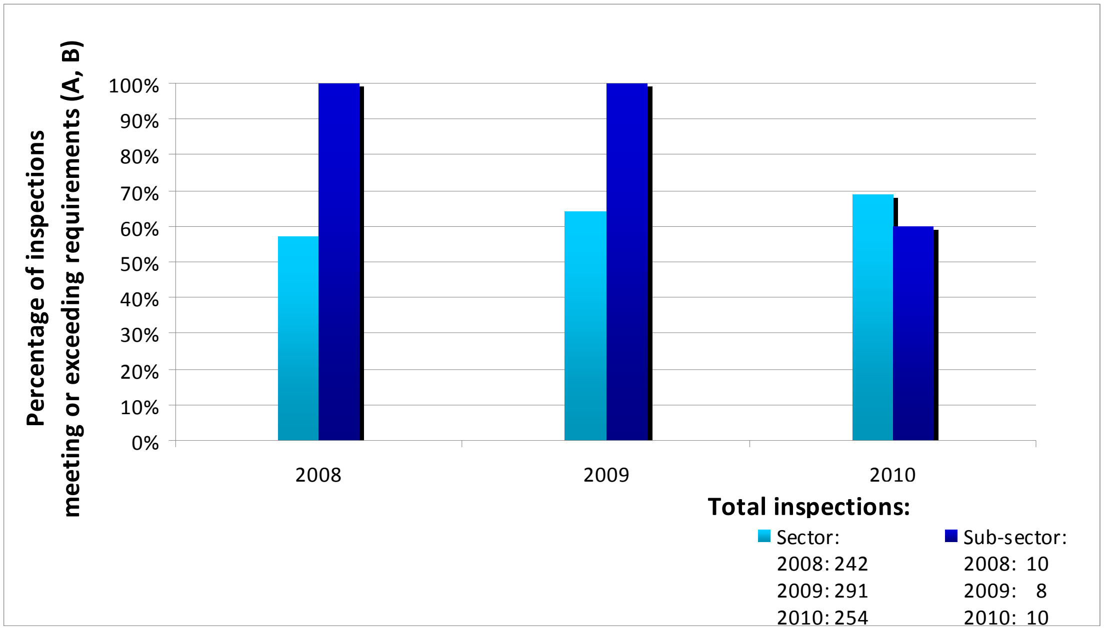

Figure 23: Medical sector vs. medical linear accelerator sub-sector – Comparison of inspection ratings of radiation protection.

6.2.3 Afterloader Sub-sector

Like linear accelerators, remote-controlled afterloader devices are used to treat cancer by positioning a radioactive source in body cavities, interstitially or near the skin.

This sub-sector includes licensees that use devices that contain a single medium- or high-activity Iridium 192 source; these devices are called "pulse-dose-rate" (PDR) or "high-dose-rate" (HDR) afterloaders, respectively. An HDR afterloader is shown in Figure 24. At the end of 2010, there were a total of 37 HDR and PDR afterloaders in Canada, an increase of 15% compared to the previous year.

Figure 24: High dose rate afterloader. Source: CNSC.

Figure 25 compares operational procedure inspection ratings of the afterloader sub-sector with those of the medical sector; a similar comparison of radiation protection inspection ratings is shown in Figure 26. Figures 25 and 26 show the percentage of inspections that found licensees met or exceeded requirements ("A" and "B" ratings). The operational procedure ratings for afterloaders improved in 2010, reversing a trend observed in 2009. As would be expected, the afterloader sub-sector's radiation protection inspection ratings were nearly identical to those of the medical linear accelerator sub-sector, since all licensees that operate afterloaders also operate medical accelerators (although the reverse is not true).

The CNSC used various enforcement actions to address non-compliances in this sub-sector, such as asking licensees to provide regular progress reports towards the resolution of the non-compliances, or increasing the frequency of inspections.

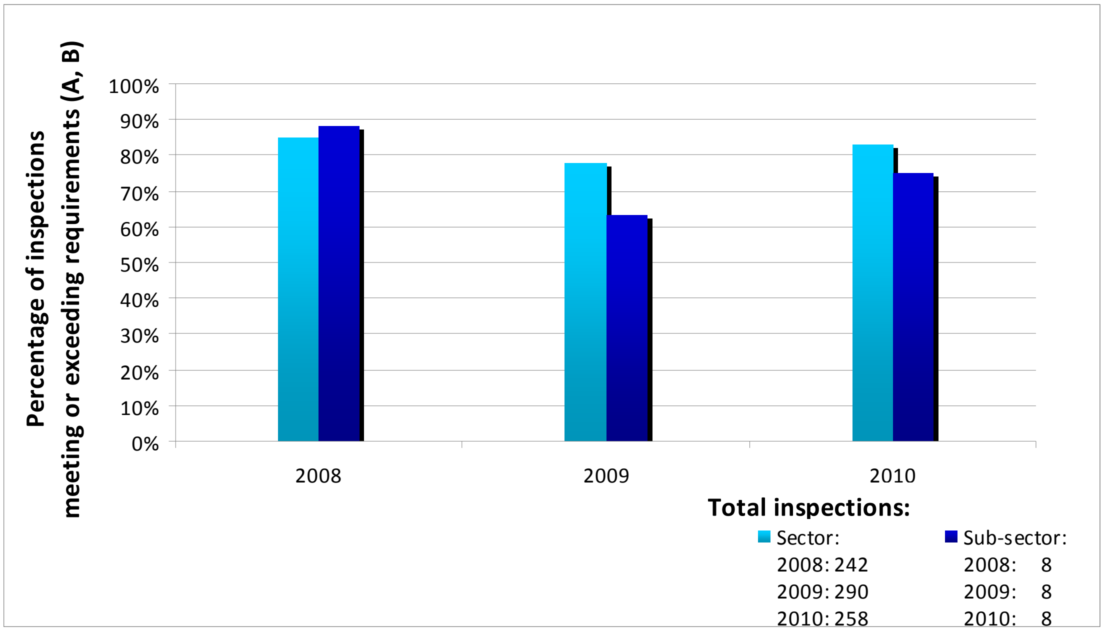

Figure 25: Medical sector vs. afterloader sub-sector – Comparison of inspection ratings of operational procedures.

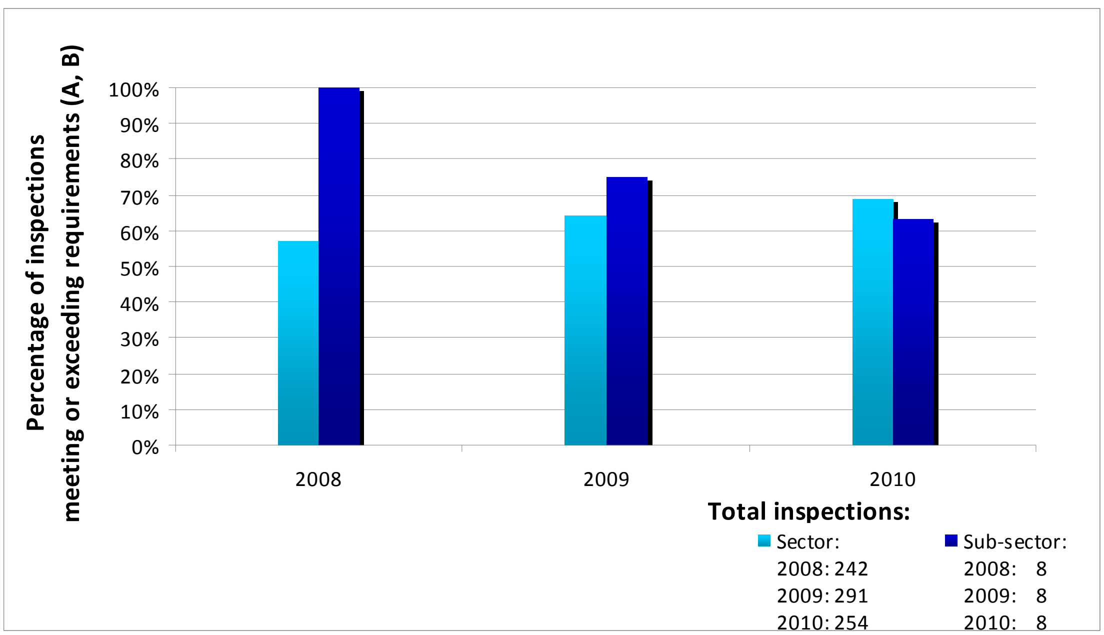

Figure 26: Medical sector vs. afterloader sub-sector – Comparison of inspection ratings of radiation protection

6.2.4 Stereotactic Teletherapy Device Sub-sector

Stereotactic teletherapy devices, as shown in Figure 27, are specialized devices designed to deliver highly focused radiotherapy and radiosurgical treatments to intracranial targets for the treatment of tumours and non-cancerous disorders.

Figure 27: Stereotactic teletherapy device. Source: CNSC.

As of 2010, there were four of these devices operated by three licensees in Canada.

In 2010, there was one inspection of a stereotactic teletherapy device, and the licensee was found to meet all inspection criteria.

6.3 Medical Sector – Summary Statement

In general, the medical sector was found to be compliant. Occupational doses to workers were relatively low, and doses to radiation therapy workers were particularly low.

The accelerator and afterloader sub-sectors showed a decline in their radiation protection program ratings, which can be attributed to the poor performance of two licensees holding multiple licences. These two licensees also demonstrated poorer performance with respect to operational procedure ratings involving multiple licences, thereby affecting the overall accelerator and afterloader sub-sector ratings. The non-compliances identified during CNSC inspections did not represent an immediate safety concern. They were addressed through the use of various enforcement actions, such as requests for the licensees to provide regular progress reports towards resolving the non-compliances, or more frequent inspections.

The number of events and incidents increased relative to 2009, due primarily to an increase in the number of reported spills in nuclear medicine laboratories. The number of events in this sector will be monitored to determine if there is an increasing trend or if the number of reported events in 2009 was abnormally low.

6.4 Industrial Sector

6.4.1 Description

Industrial-sector licensees use nuclear substances and radiation devices to perform diagnostic, quality-control and characterization tasks. These licensees accounted for 1,482 licences as of December 31, 2010. Licensed industrial-sector activities are typically conducted in industrial production facilities or as fieldwork and in construction.

The industrial applications of nuclear substances are as varied as the processes to which they are applied. Radioisotopes are chosen based on the properties of the radiation they emit, and the intended application. For example, the penetration ability of Cobalt 60 varies greatly from that of Iridium 192, and Californium 252 is used for its neutron-emitting properties. Typical industrial-sector applications include measurement of physical parameters (for example, density, moisture content and geological composition, as well as level and flow rate in industrial processes), in fields such as oil and gas exploration, manufacturing, and civil engineering.

For the purpose of this report, only certain sub-sectors were identified within the industrial sector: portable gauge, fixed gauge, industrial radiography, as well as sterilization and research sub-sectors. Together, these sub-sectors account for 69% or 1,027 of the 1,482 licences in the industrial sector.

6.4.2 Safety Performance

6.4.2.1 Doses to Workers

Industrial-sector licensees who use nuclear substances and radiation devices have the potential of working with high-activity sources, depending on their usage. Based on the specific use of the nuclear substance, workers may not necessarily need to work in close proximity to the nuclear substance; this keeps doses to workers in the industrial sector generally at the same level as those to workers in the medical and commercial sectors.

The data in this section represents the dose records of persons who may be subjected to occupational exposure to radiation associated with CNSC-licensed activities. The dose data is extracted from dose reports provided by licensees in their annual compliance reports (ACRs) for the 2008 to 2010 period. For the purpose of this performance measure, CNSC staff analyzed a representative sample of worker dose records from randomly selected ACRs from licensees in each sector.

The term "sampled workers" in the figures represents the number of workers whose dose data was analysed, of which there were 3,752 in 2010. As shown in Figure 28, the average doses to workers in the industrial sector were at approximately the level for each of the three years covered by this report. In 2010, more than 98% of industrial-sector workers (excluding portable gauge users) received radiation doses below the public limit of 1 mSv/year. Figure 28 does not include information on doses received by workers using portable gauges. These were reported using slightly different dose ranges and are shown separately in Figure 32. When including portable-gauge licensees, 95.9% of workers in this sector received doses lower than the public dose limit.

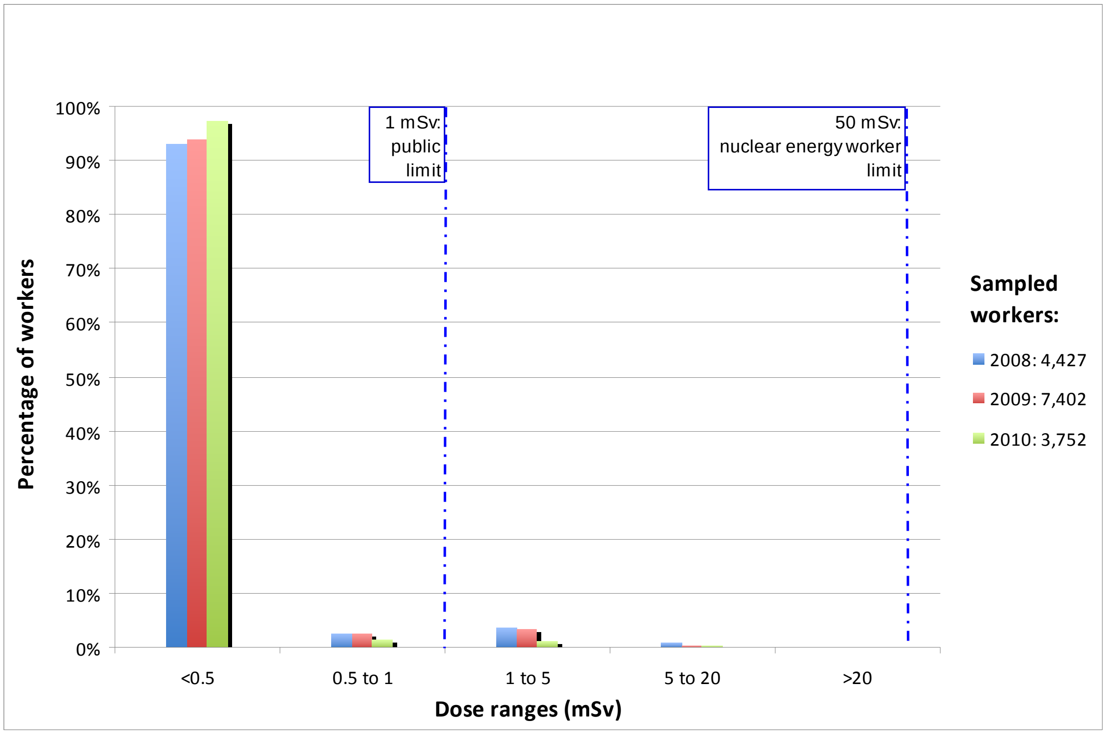

Figure 28: Industrial sector – Annual whole body doses to nuclear energy workers and other workers, excluding users of portable gauges.

Doses to workers in the industrial radiography sub-sector are historically among the highest received by industrial-sector licensees. Workers in this sub-sector operate in close proximity to radiation devices that contain strong, penetrating radiation sources for non-destructive testing purposes.

In 2010, 59% of nuclear energy workers (NEWs) in the industrial radiography sub-sector received doses below the public dose limit. Less than 1% of workers were subjected to dose levels greater than 20 mSv, but all received less than the maximum annual dose limit of 50 mSv for NEWs. This information is shown in Figure 29.

The ranges of worker doses for 2010 in the industrial radiography sub-sector were relatively consistent with those from 2009; the exception to this was the number of workers in the 5 – 20 mSv range, who experienced a notable decline from 2009 numbers, down to 2008 levels.

It is important to note that radiation doses to exposure device operators may depend on individual workloads. Industrial radiography work often involves testing new components to be installed in an industrial environment. Greater amounts of construction work performed during periods of economic expansion may generate more radiography work, resulting in higher worker doses.

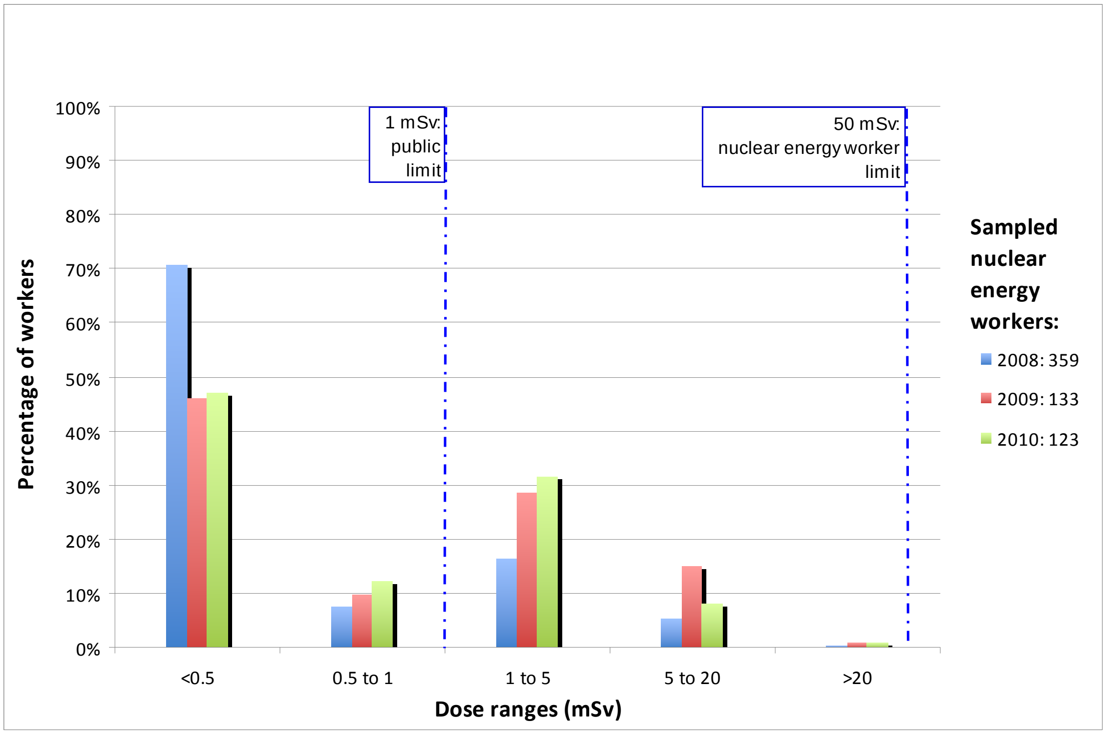

Figure 29: Industrial radiography – Annual whole body doses to nuclear energy workers.

In all other industrial-sector applications, excluding industrial radiography and portable gauge use, dose levels to both NEWs and other workers remained constant or decreased from 2008 to 2010. As shown in Figure 30, more than 99% of NEWs received doses lower than the public dose limit of 1 mSv/year, based on results from 2010. As shown in Figure 31, approximately 99% of doses to other workers were lower than 0.5 mSv, or half of the public dose limit. These other workers, also referred to as “non-NEWs”, consistently received this dose level between 2008 and 2010.

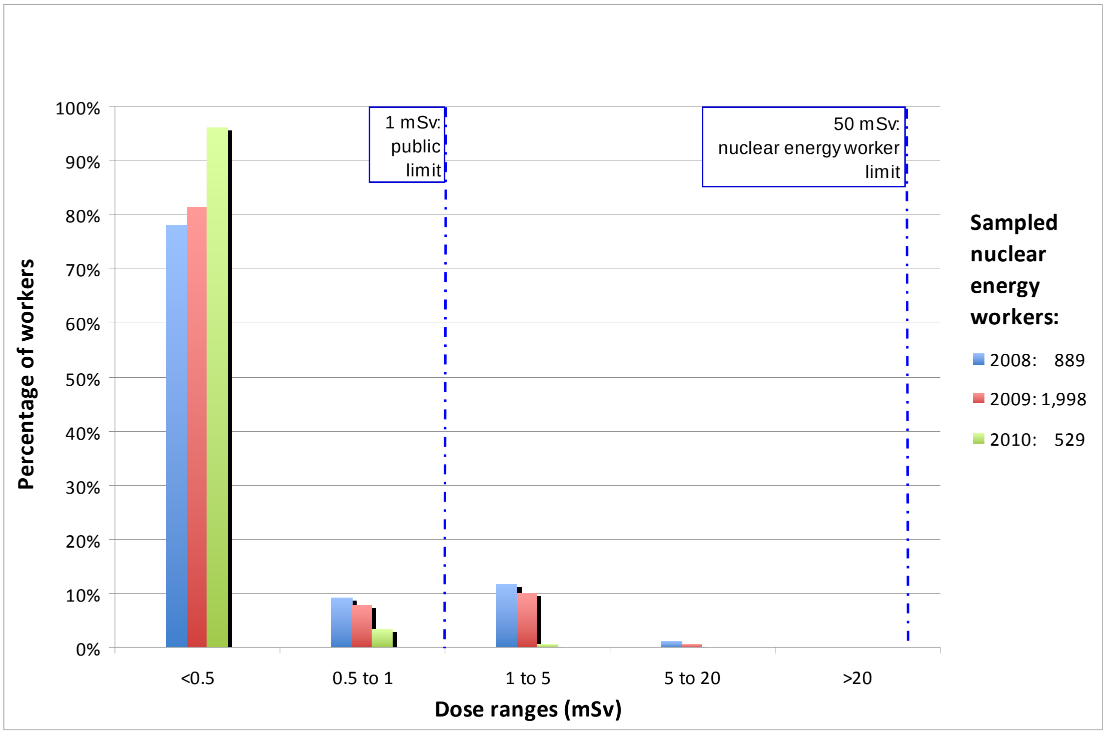

Figure 30: All other industrial applications – Annual whole body doses to nuclear energy workers.

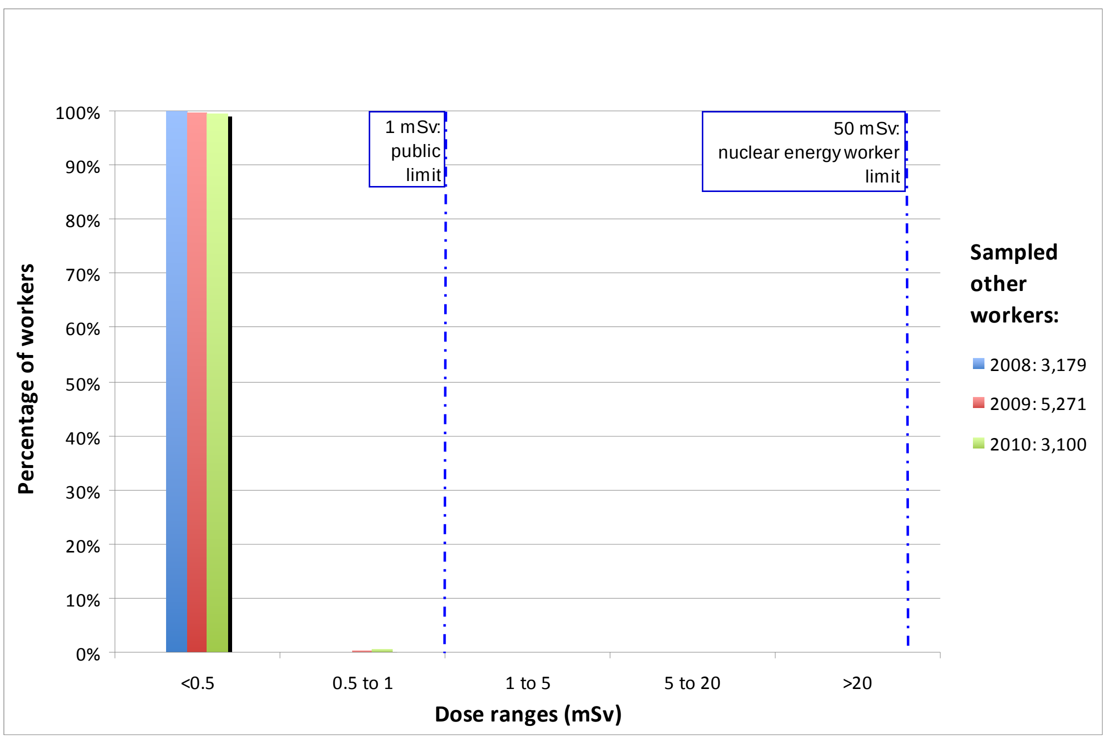

Figure 31: All other industrial applications – Annual whole body doses to other workers.

Doses to NEWs using portable gauges have been increasing slightly from 2008 to 2010. The number of NEWs receiving doses of less than 1 mSv per year has been decreasing linearly, from 91% in 2008 to 80% in 2010. At the same time, the number of NEWs receiving doses between 1 and 5 mSv has increased linearly, from 8% in 2008 to 19% in 2010. This may have been due to an increase in the use of portable gauges on construction sites, coinciding with more infrastructure work across Canada. Throughout the 2008–10 reporting period, no NEWs exceeded the annual dose limit of 50 mSv. This sub-sector's doses are shown in Figure 32.

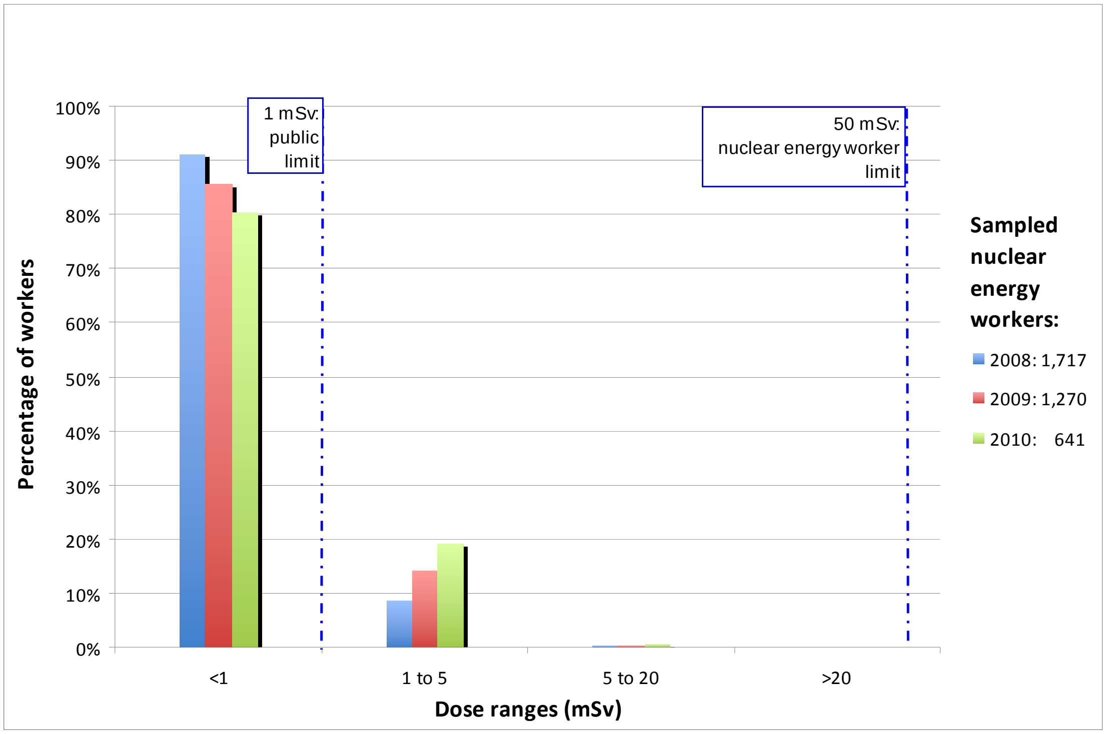

Figure 32: Portable gauges – Annual whole body doses to nuclear energy workers (NEWs).

6.4.2.2 Inspection Ratings of Operational Procedures

Figure 33 shows inspection ratings of operational procedures for the industrial sector. In 2010, 81% of inspected licensees were found to be compliant in this safety area. Of the inspected licensees that were found to be non-compliant, 15% had "C"-rated non-compliances that did not significantly affect safety, while 4% were found to have "D"- or "E"-rated non-compliances. A "D" rating is significantly below requirements, with deficiencies that could lead to an unreasonable risk to the health and safety of workers, the public or the environment, if left uncorrected. In 2010, two inspections of industrial-sector licensees indicated unacceptable compliance levels presenting an unreasonable risk within this safety area, resulting in "E" ratings. In both cases, the inspector issued an order as an immediate enforcement action to protect the health and safety of the public, the workers and the environment. Details of these enforcement actions are discussed in Section 6.4.2.6, Enforcement Activities, and readers are invited to consult the *Regulatory Action* page on the CNSC Web site for additional information[8].

Typical non-compliances in this safety area included failure by workers to follow licensee procedures, failure of licensees to keep appropriate training records, or failure to perform leak testing of devices at prescribed frequencies.

The CNSC employs a graduated enforcement approach when addressing non-compliances that do not pose an immediate risk to the health and safety of workers, the public or the environment. The measures used by the CNSC to ensure that licensees regain compliance included written action notices, correspondence and meetings with the licensee's senior management, and acceptance of licensee plans to voluntarily shut down until operations are ready to be in compliance.

During the 2008–10 reporting period, compliance of inspected licensees varied by 5% or less annually, and licensees maintained their compliance with the operational procedures safety area. The number of non-compliant licensees remained approximately the same over this time frame, and trending indicates that compliance with this safety area's regulatory requirements remained constant and at a relatively high level. For detailed results of inspection ratings, refer to Appendix B.4 and B.7.

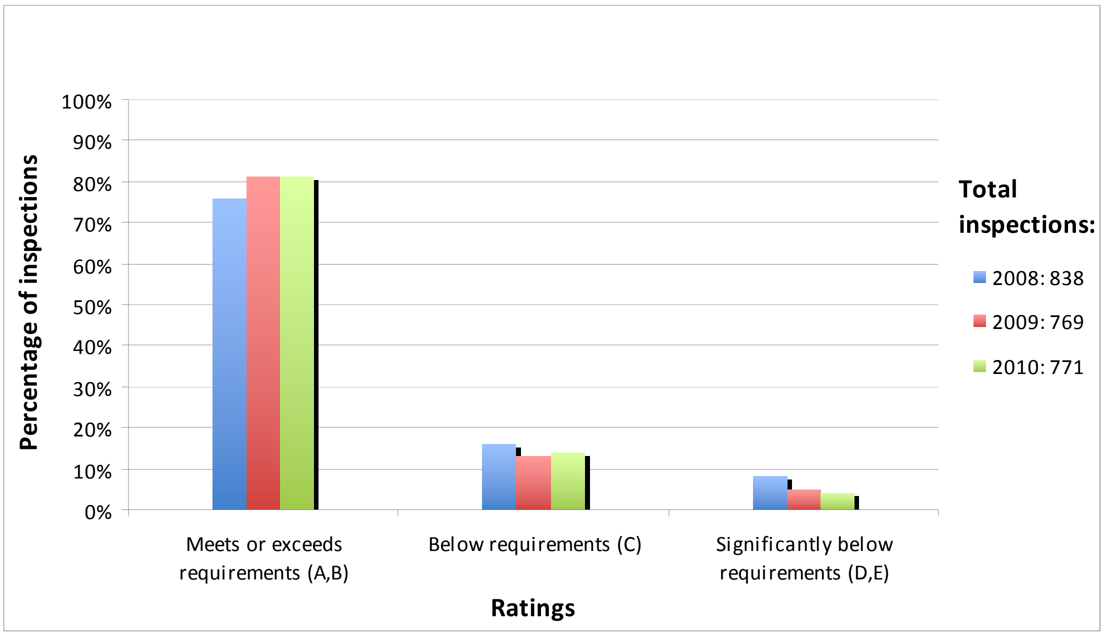

Figure 33: Industrial sector – Inspection ratings of operational procedures.

Based on these results, compliance in the safety area of operational procedures was maintained at a generally constant level over the reporting period from 2008 to 2010. The number of inspected licensees demonstrating a rating of "significantly below requirements" decreased slightly.

[8] Available online at nuclearsafety.gc.ca/eng/lawsregs/regulatoryaction/index.cfm

6.4.2.3 Inspection Ratings of Radiation Protection

Figure 34 shows inspection ratings of radiation protection for the industrial sector. In 2010, 78% of inspected licensees were found to be compliant in this safety area. Of the inspected licensees found to be non-compliant, 15% had “C”-rated non-compliances that did not significantly affect safety, while 7% were found to have “D”- or “E”-rated non-compliances. In 2010, eight inspections of industrial-sector licensees indicated unacceptable compliance levels presenting an unreasonable risk within this safety area, resulting in “E” ratings. During six of these inspections, a CNSC inspector issued an order as an immediate enforcement action to protect the health and safety of the public, the workers and the environment. In the other two cases, the licensees took immediate corrective actions on their own to address the non-compliances observed by the inspector. One licensee immediately moved portable gauges away from an occupied area, and conducted an investigation, including the identification and correction of possible causes, to prevent a recurrence. The other licensee voluntarily ceased all operations with radiation devices until all persons responsible for the management of the radiation safety program and workers received appropriate training. Details of the enforcement actions involving orders are discussed in Section 6.4.2.6, Enforcement Activities. Readers are also invited to consult the *Regulatory Action* page on the CNSC Web site for additional information[9].

Typical non-compliances in this safety area included inadequately labelled devices, failure to report to the CNSC that an action level was exceeded, or inability of a licensee to demonstrate that doses are ALARA (As Low As Reasonably Achievable).

The CNSC employs a graduated enforcement approach when addressing non-compliances that do not pose an immediate risk to the health and safety of workers, the public or the environment. The measures used by the CNSC to ensure licensees regain compliance included written action notices, correspondence and meetings with the licensee’s senior management, and acceptance of licensee plans to voluntarily shut down until operations are in compliance.

When examining compliance in this safety area over the 2008–10 reporting period, the compliance rate of inspected licensees appears to have improved slightly over time. In 2008, 72% of the inspected licensees were found to be compliant with requirements; that number rose to 78% in 2010. A more significant compliance increase was noted in the number of inspected licensees who had been initially deemed as “significantly below requirements”; in 2008, 14% of inspected licensees were found to be significantly below requirements, and that number improved to 7% in 2010. This could indicate an overall improvement in this safety area.

[9] Available online at nuclearsafety.gc.ca/eng/lawsregs/regulatoryaction/index.cfm

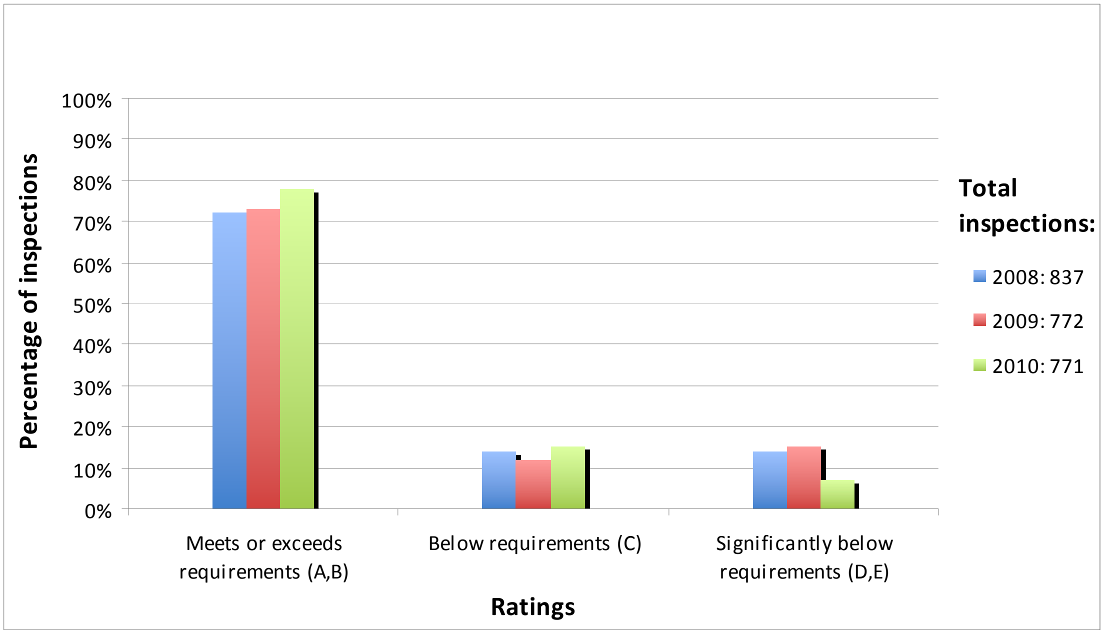

Figure 34: Industrial sector – Inspection ratings of radiation protection.

Based on these results, licensee compliance in radiation protection appears to have improved slightly from 2008 to 2010. The number of inspected licensees that demonstrated compliance in 2010 increased from 2008; the number of inspected licensees in 2010 that were significantly below requirements decreased from that of 2008 and 2009. For detailed results of inspection ratings, refer to Appendix B.5 and B.8.

6.4.2.4 Inspection Ratings of Sealed Source Tracking System (SSTS)

SSTS inspection ratings for the industrial sector are shown in Figure 35. In 2010, 208 inspections verified compliance against SSTS requirements. During these inspections, 88% of inspected licensees were found to be compliant. The distribution of inspection results for licensees remained relatively constant over the 2008–10 reporting period. For detailed results of inspection ratings, refer to Appendix B.6 and B.9.

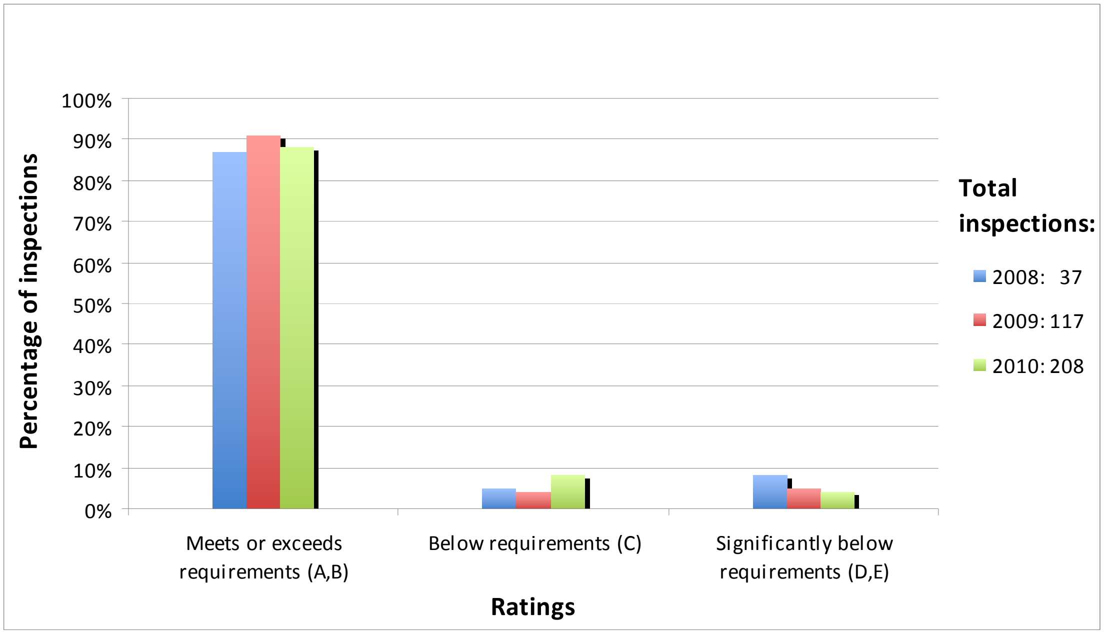

Figure 35: Industrial sector – Inspection ratings of Sealed Source Tracking System.

6.4.2.5 Reported Events and Incidents

The number of reported events in the industrial sector was relatively high when compared to the other sectors, but this is typical of this sector's 1,482 licensees. As shown in Figure 36, 52 events were reported in 2010.

The majority of incidents reported for this sector involved malfunctioning or damaged devices, many of which involved portable gauges that were hit or run over by vehicles at construction sites, as well as problems with stuck or disconnected sources in exposure devices. These incidents were most likely due to increased use of portable gauges on construction sites, coinciding with more infrastructure work being performed across Canada. The licensees involved implemented response procedures that the CNSC found satisfactory to mitigate the event consequences and to limit radiation exposure to workers and the public. As a result of the significant number of incidents involving portable gauges, the CNSC published a special edition of the *Directorate of Nuclear Substance Regulation Newsletter*[10], which detailed important steps to prevent and address portable-gauge incidents. CNSC inspectors conduct frequent field inspections of portable-gauge operations to verify on site that workers are using these devices safely.

The industrial sector also reported five incidents of missing nuclear substances. In two of these incidents, the substances were recovered the next day. Of the other three, one involved an analyzer reported missing following an inventory check, and two involved portable gauges stolen from construction sites or vehicles. These latter three incidents involve very low to low risk sources and are under investigation by the licensee and local authorities. The CNSC has also published the information on its Web site, and notified

[10] Available online at nuclearsafety.gc.ca/eng/licenseesapplicants/substancesdevices/substancesdevices/newsletter.cfm

the appropriate provincial and international authorities, such as the International Atomic Energy Agency and United States Nuclear Regulatory Commission. There were also five reports of found nuclear substances: in three instances, substances were found in metal recycling facilities, and two instances involved substances discovered by members of the public. For more information on these particular types of events, readers are invited to consult the *Lost or Stolen Sealed Sources and Radiation Devices Report*[11], available on the CNSC Web site.

There were four breaches of security events reported in 2010. In three of these incidents, a person who was not a nuclear energy worker entered a restricted area that had been established prior to the use of an exposure device; fortunately, in each case, the person did not receive any significant radiation dose from the device. Any doses received would be well below the regulated limit for a member of the public. The fourth reported incident involved a worker who did not return a portable gauge to a secured location at the end of his workday. Although these incidents were categorized as breaches of security, they resulted from a lack of control in the workplace.

In the area of packaging and transport, most reports were of accidents involving vehicles transporting nuclear substances. In all of these cases, there was no damage to any of the packages.

None of the events reported by industrial-sector licensees resulted in a radiation dose to a worker or a member of the public in excess of the regulatory limits.

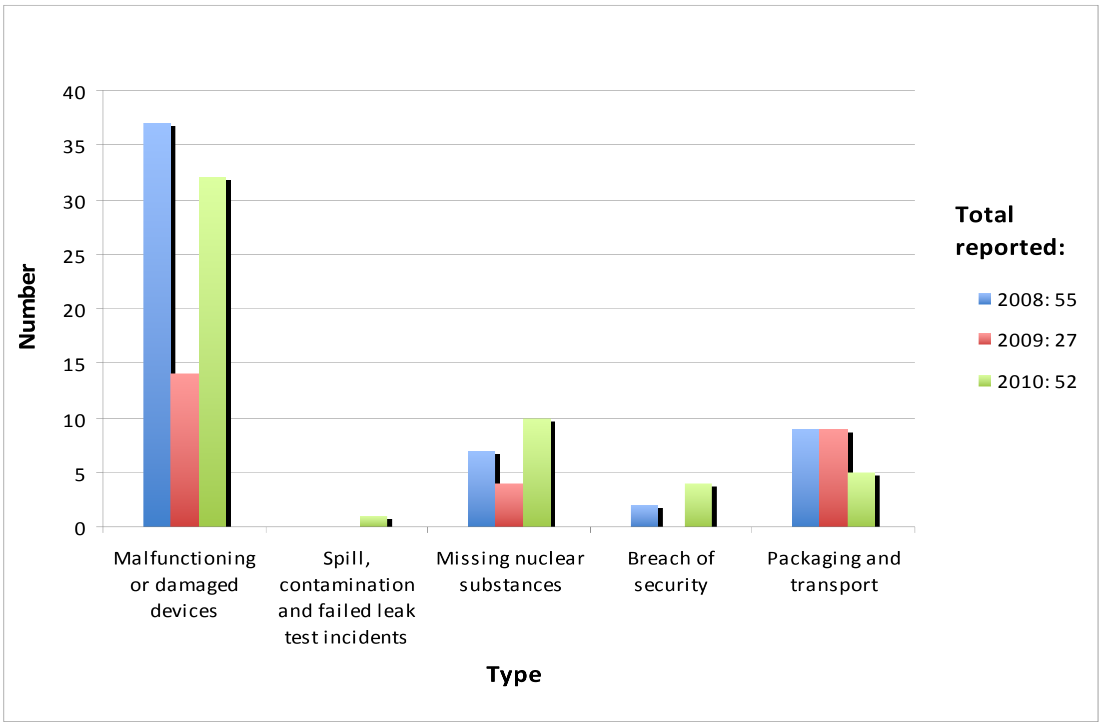

Figure 36: Industrial sector – Reported events and incidents.

[11] Available online at nuclearsafety.gc.ca/eng/readingroom/reports/lost_stolen_ss_rd/index.cfm

6.4.2.6 Enforcement Activities

6.4.2.6.1 Orders and Measures to be taken by the Licensees

In 2010, CNSC inspectors issued seven orders to licensees in the industrial sector. The orders are listed in Table 2.

Licensee	Location	Date order was issued	Measures to be taken by the licensees	Date order was closed
Acuren Group Inc. (Industrial radiography)	Fort McMurray, AB	January 13, 2010	Removal of workers from licensed activities	April 28, 2010
Nomad Inspection Services Ltd. (Industrial radiography)	Dawson Creek, BC	January 29, 2010	Removal of a worker from licensed activities	April 27, 2010
SPL Consultants Limited (Portable gauges)	Vaughan, ON	May 10, 2010	Placement of nuclear substances into storage and provision of worker training	June 7, 2010
Canada Engineering Services (Portable gauges)	Toronto, ON	May 27, 2010	Placement of nuclear substances into storage and provision of worker training	June 21, 2010
C.T. Soils & Materials Testing Inc. (Portable gauges)	Windsor, ON	June 10, 2010	Placement of nuclear substances into storage, establishment of management control over work practices, and provision of worker training	July 26, 2010
Harold Sutherland Construction Ltd. (Portable gauges)	Kemble, ON	September 30, 2010	Placement of nuclear substances into storage and provision of worker training	October 22, 2010
Core Laboratories Canada Ltd. (Geological subsurface zone location)	Red Deer, AB	December 21, 2010	Placement of nuclear substances into storage and decontamination or disposal of contaminated objects	January 6, 2011

Table 2: Enforcement activities in 2010 – Orders and measures to be taken by the licensees.

It should be noted that although more CNSC orders were issued in 2010 and 2009 (seven in each of these years) than in 2008 (two), this does not necessarily indicate an increase in overall non-compliance by licensees. For more information on the orders issued in 2008 and 2009, readers are invited to consult the previous edition of *Nuclear Substances in Canada: A Safety Performance Report*[12]. The CNSC has adopted a risk-informed regulatory program, whereby the frequency of inspection for a given licensee is based on the level of risk posed by the licensed activity. The frequency of compliance verification varies among licensees, according to the risk of the conducted activities. In the industrial sector, it varies from one year (for high-risk licensees) up to five years (for medium-risk licensees) and as required for low-risk licensees. The low-risk licensee inspections could be triggered due to an event, or a compliance issue observed in their annual compliance report. Therefore, the CNSC may not inspect all industrial-sector licensees each year, but all licensees must submit an annual compliance report to the CNSC for evaluation once per year. It is therefore possible that inspectors may see many licensees requiring the issuance of an order in one year, and very few in subsequent years. Moreover, the CNSC has been issuing orders more frequently for significant health and safety issues as opposed to using alternate, less severe compliance measures.

A summary of the orders that were issued to the industrial sector over the 2008–10 reporting period, by type of licensed activity, is shown in Figure 37.

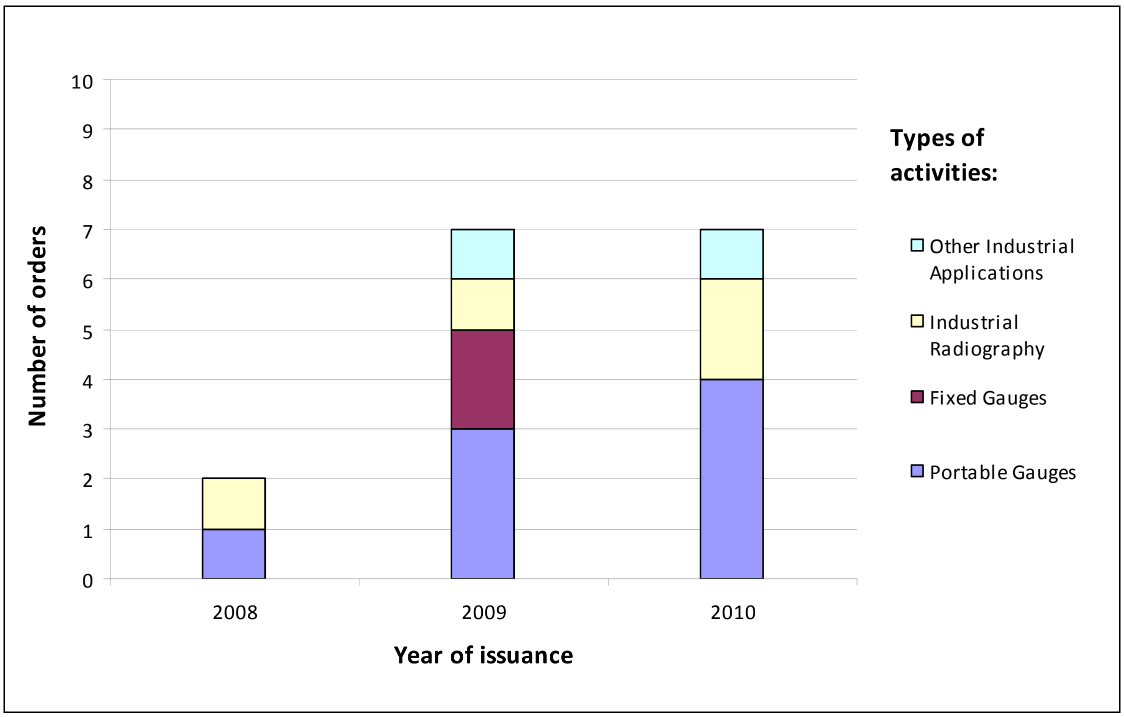

Figure 37: Industrial sector – Summary of orders by type of licensed activity.

[12] Available online at nuclearsafety.gc.ca/eng/readingroom/reports/use-of-nuclear-substances/index.cfm

6.4.2.6.2 Decertification of Exposure Device Operators

Workers who operate radiography exposure devices in Canada need to be certified by the CNSC, as required under the *Nuclear Safety and Control Act*. The CNSC also has the authority to decertify these persons as required, and will do so when it has reason to believe that the certified exposure device operator has endangered the health and safety of workers, the public or the environment.

There were two cases in 2010 where an exposure device operator was decertified, as shown in Table 3. Since it was not included in the previous edition of this report, the 2008 and 2009 information related to the decertification of exposure device operators is included here. There were no exposure device operators decertified in 2008 and one was decertified in 2009, as shown in Table 4.

Decertified Exposure Device Operator	Location	Date of decertification	Basis for CNSC decision
Mr. Cody Hankinson	Corner Brook, NL	May 4, 2010	Failure to verify the radiation source was in shielded position after completing work, making a false statement to CNSC inspector, and failure to post barriers and warning signs
Mr. Jimmy St-Laurent	Vanier, QC	June 1, 2010	Failure to wear proper dosimeters and to verify the radiation source was in the shielded position after completing work

Table 3: Decertification of Exposure Device Operators in 2010

Decertified Exposure Device Operator	Location	Date of decertification	Basis for CNSC decision
Mr. Clay Anderson	Edson, AB	September 4, 2009	Non-functional alarming dosimeter, and failure to verify the radiation source in shielded position after completing work

Table 4: Decertification of Exposure Device Operators in 2009

6.5 Industrial Sub-sectors

6.5.1 Portable Gauge Sub-sector

Portable gauges are radiation devices used to determine compaction, density or moisture content in the soil. An example of a portable moisture density gauge is shown in Figure 38. Some of these devices contain an americium-beryllium source that emits neutrons and allows for moisture content calculations; others may contain a Cesium 137 source, which emits gamma radiation and allows the operator to determine compaction or density; and some devices may contain both radioactive sources.

Figure 38: Portable moisture density gauge. Source: CNSC.

Figure 39: A CNSC inspector performs an inspection of a portable gauge at a construction site. Source: CNSC.

Portable gauges are typically transported for temporary use at construction job sites; users require training in radiation safety and transportation of dangerous goods. Inspections can be performed onsite, as shown in Figure 39.

Figure 40 compares the portable gauge sub-sector's ratings with those of the industrial sector, for operational procedures, and Figure 41 compares inspection ratings of radiation protection. Both figures illustrate the percentage of inspections where licensees met or exceeded requirements ("A" and "B" ratings). The portable gauge sub-sector was consistently found to have compliance levels similar to those of the industrial sector, in the operational procedures safety area between 2008 and 2010.

Between 2008 and 2010, the portable gauge sub-sector's compliance rate in radiation protection was slightly lower than that of the industrial sector. However, it was not significantly below the compliance rate of the industrial sector, and was within a 4% range over the 2008–10 reporting period.

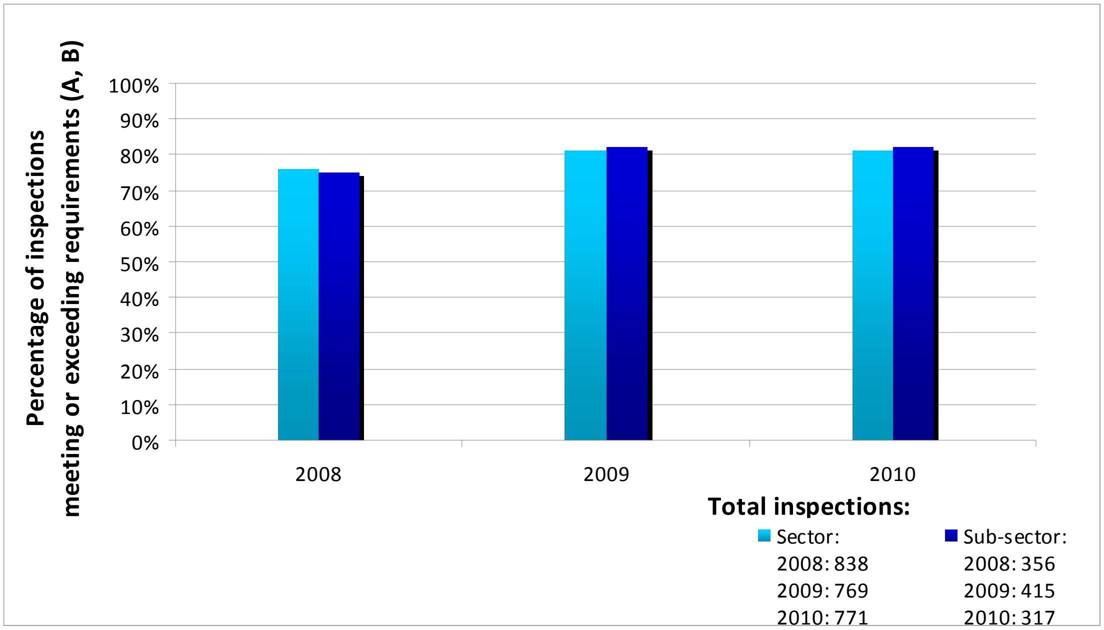

Figure 40: Industrial sector vs. portable-gauge sub-sector – Comparison of inspection ratings of operational procedures.

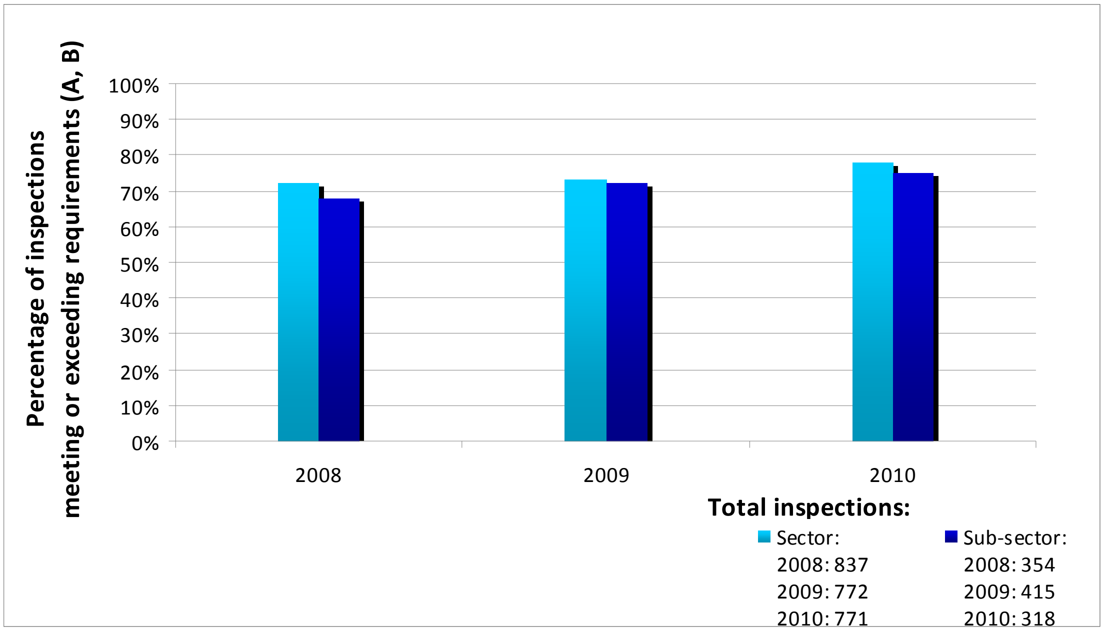

Figure 41: Industrial sector vs. portable-gauge sub-sector – Comparison of inspection ratings of radiation protection.

6.5.2 Fixed Gauge Sub-sector

Fixed gauges are radiation devices commonly used to determine operational parameters of an industrial process. Common parameters may include density, level and thickness. Fixed gauges contain nuclear substances with properties chosen for its specific application and vary widely from Americium 241 to Cesium 137 to Cobalt 60. Radiation is measured using a detector, typically on the opposite side of the source inside the gauge, which supplies feedback to a control system to adjust the process if necessary. Fixed gauges are typically mounted onto frames in an industrial facility, although vehicle-mounted mobile fixed gauges are found in the oil and gas industry. An example of a fixed gauge source holder is shown in Figure 42.

Figure 42: Fixed gauge source holder.
Source: CNSC.

Figure 43 compares the fixed gauge sub-sector's inspection ratings with those of the industrial sector, for operational procedures. A comparison of radiation protection inspection ratings is shown in Figure 44. Both figures show the percentage of inspections that found licensees met or exceeded requirements ("A" and "B" ratings). From 2008 to 2010, the fixed gauge sub-sector demonstrated compliance with the operational procedures safety area at about the same level as that as the overall industrial sector.

From 2008 to 2010, this sub-sector demonstrated better compliance in the radiation protection safety area than the industrial sector.

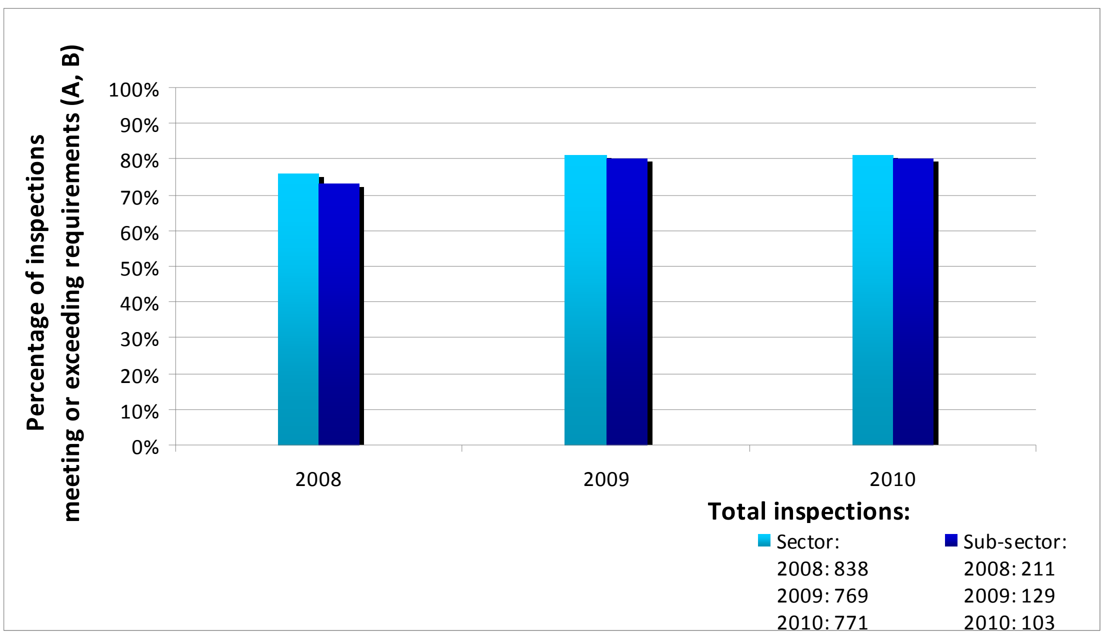

Figure 43: Industrial sector vs. fixed-gauge sub-sector – Comparison of inspection ratings of operational procedures.

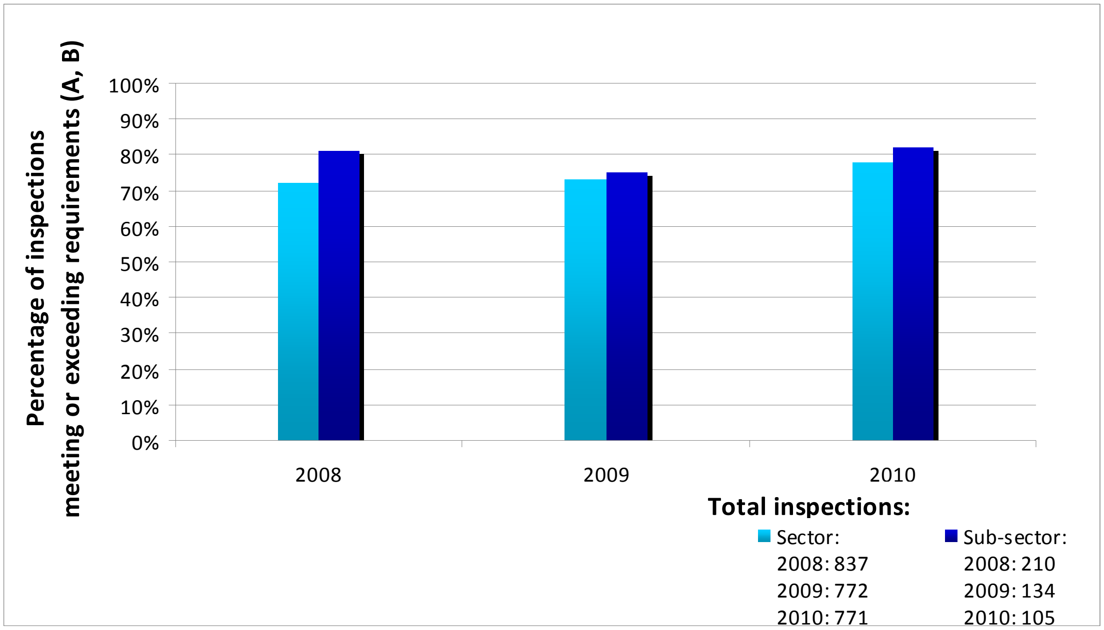

Figure 44: Industrial sector vs. fixed-gauge sub-sector – Comparison of inspection ratings of radiation protection.

6.5.3 Industrial Radiography Sub-sector

In industrial radiography, nuclear substances are used for the non-destructive examination of materials. Sealed radioactive sources are stored in devices (referred to as exposure devices) until they are required to be used. Exposure devices are engineered with multiple safety barriers, to prevent accidental exposure of the source, and are built using dense material – such as depleted uranium – for shielding properties. An example of an exposure device is shown in Figure 45, and a typical industrial radiography set-up is shown in Figure 46.

Figure 45: Exposure device with a survey meter. Source: CNSC.

Figure 46: A typical industrial radiography set-up. Source: CNSC.

The CNSC certifies exposure device operators, along with exposure devices themselves. Persons wishing to become certified exposure device operators must attend an industrial radiography course, perform an apprenticeship as a trainee, and pass a certification exam.

The CNSC also has the regulatory authority to decertify a certified exposure device operator; it will consider this enforcement action when it believes the operator's actions have caused an unreasonable risk to the health and safety of workers, the public or the environment. More information on this enforcement option, including a list of decertified persons, can be found in Section 6.4.2.6.2.

The activity of the nuclear substances in an exposure device is typically in the order of terabecquerels, and can be 1,000 times over the activity of a portable gauge. Nuclear substances are chosen based on the material being examined; denser and thicker materials typically require a nuclear substance with a high-energy gamma ray to allow the radiation to penetrate the material. Nuclear substances usually used in exposure devices include Iridium 192, Cobalt 60 and Selenium 75. Radiation from the nuclear substances passes through the material and allows defects in welds or composition to be recorded on photographic film or a digital imager placed on the opposite side of the object.

Figure 47 compares the industrial radiography sub-sector's ratings for operational procedures with those of the industrial sector ratings, and Figure 48 compares inspection ratings for radiation protection. These figures show the percentage of inspections that found licensees met or exceeded requirements ("A" and "B" ratings). From 2008 to 2010, this sub-sector demonstrated better compliance in the safety areas of radiation protection and operational procedures than other licensees in the industrial sector. This was partly due to the efforts of the joint CNSC–industry working group on industrial radiography. The CNSC has also that several licensees in this sub-sector are demonstrating considerable effort to be compliant. For more information, readers are invited to consult the CNSC's *Industrial Radiography Working Group* page on the CNSC Web site[13].

[13] Available online at nuclearsafety.gc.ca/eng/licenseesapplicants/substancesdevices/substancesdevices/industrial_radiography_working_group.cfm

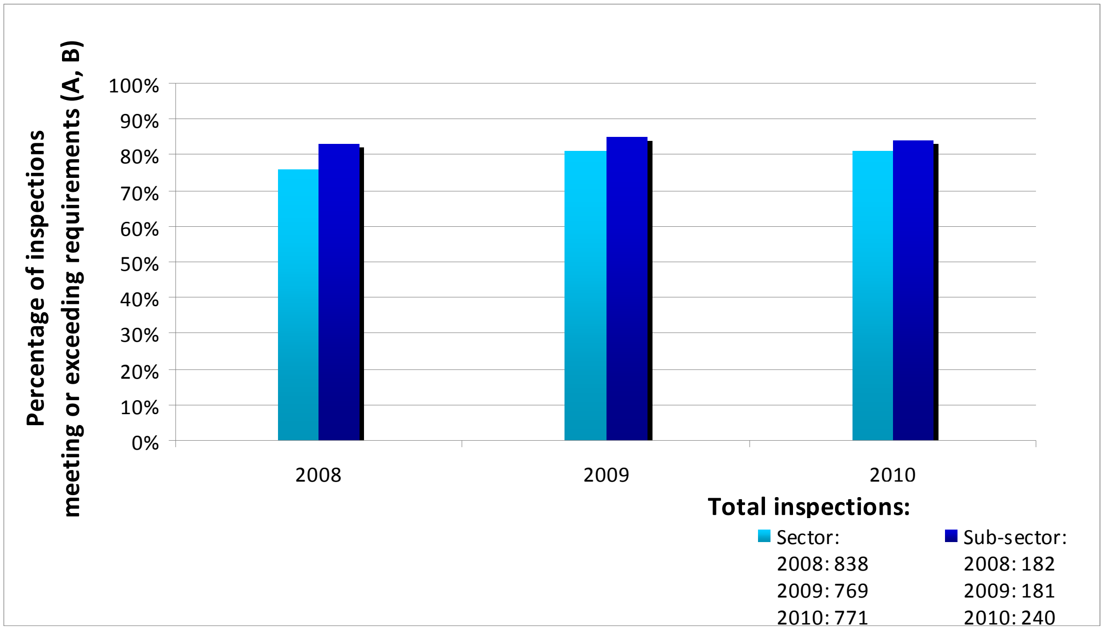

Figure 47: Industrial sector vs. industrial-radiography sub-sector – Comparison of inspection ratings of operational procedures.

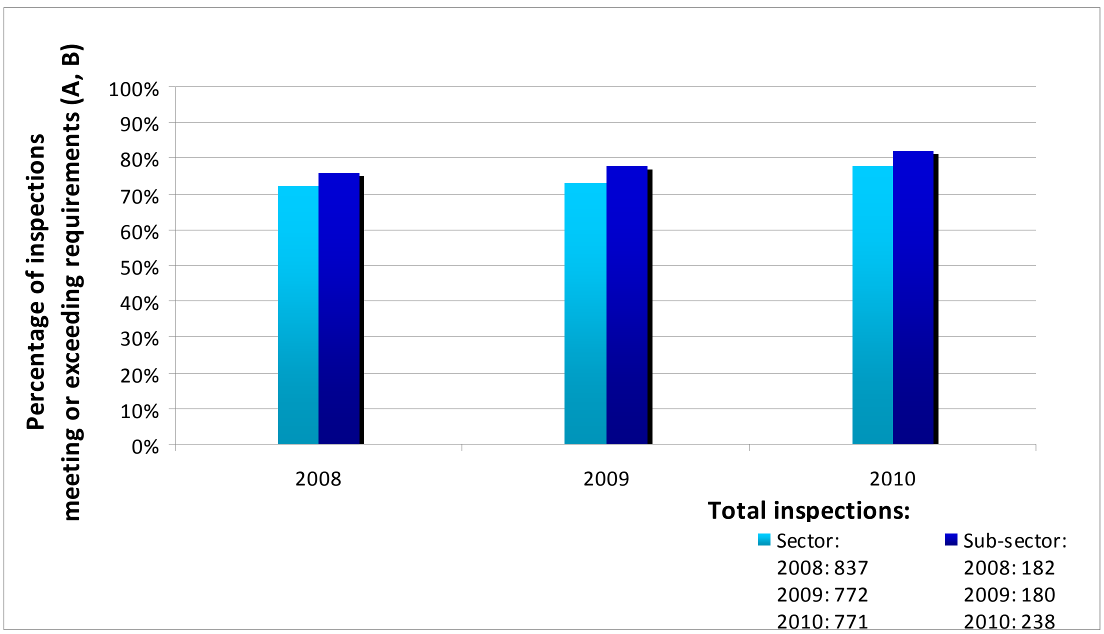

Figure 48: Industrial sector vs. industrial-radiography sub-sector – Comparison of inspection ratings of radiation protection.

6.5.4 Sterilization and Research Sub-sector

Pool-type irradiator facilities are used for the sterilization of medical, cosmetic and some spices. A small amount of research also investigates the effects of irradiation on polymers, parasites, bacteria, fungus, gemstones, etc. These industrial facilities are designed such that the products to be irradiated are passed by exposed racks loaded with sealed sources. Research facilities use a combination of sealed sources, exposed in a controlled environment to irradiate pallets turning in front of the sealed sources. When not in use, the radiation from the sealed sources is shielded by lowering the rack into a pool of water. Figure 49 shows the rack lowered into the pool and a close-up of the sealed sources in the rack.

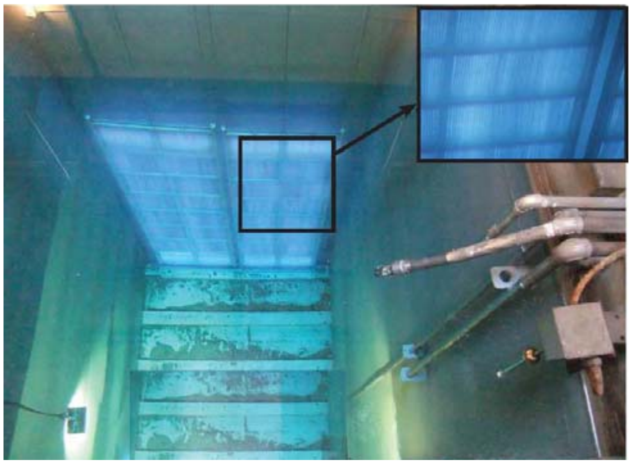

Figure 49: A typical pool-type irradiator. Source: CNSC.

There are three pool-type irradiators installed in Ontario and Quebec, the same number as in 2009.

The CNSC inspected one of these pool-type irradiators in 2010, and found that the operator was meeting all regulatory requirements.

6.6 Industrial Sector – Summary Statement

Between 2009 and 2010, the number of licences issued in the industrial sector fell by approximately 4%. This sector's licensees remained relatively compliant, with the compliance rate in the operational procedures safety area similar to that of the academic and research sector. Compliance in the radiation protection safety area remained approximately the same as in the academic and research sector, and better than in the medical sector.

Of all sectors, the industrial sector continued to have the highest number of reported incidents and events: its number of reportable events increased in 2010 from 2009 values, returning to approximately the same number as reported in 2008. Additionally, the number of CNSC orders issued to industrial-sector licensees was higher than for all other sectors. However, it should be noted that the industrial sector includes more than half of all licences covered in this report; therefore, more events and compliance issues are expected.

Doses to workers in the industrial sector were, on average, about the same as those of other regulated sectors. Between 2008 and 2010, worker doses – excluding those in the portable gauge and industrial radiography sub-sectors – remained relatively constant and did not appear to be trending up or down. In 2010, more than 98% of workers in this sector (excluding portable gauge users) received doses that were lower than the public dose limit of 1 mSv. When including portable-gauge licensees, 95.9% of workers in the industrial sector received doses lower than the public dose limit. Doses to workers in the sub-sectors of industrial radiography and portable gauges were slightly higher than those received by workers in other industrial applications, but the majority of worker doses were under 5 mSv.

The industrial radiography sub-sector continued to perform better than the overall industrial sector in the safety areas of radiation protection and operational procedures, showing about 4% higher compliance in 2010. Industrial-sector licensees continued to consistently show very good compliance with Sealed Source Tracking System (SSTS) requirements in 2010.

6.7 Academic and Research Sector

6.7.1 Description

Figure 50: Radioisotopes are powerful tools in biological and environmental research. Source: CNSC.

In 2010, the academic and research sector comprised 290 licences for nuclear substance and radiation devices, as well as Class II facility and equipment. This highly visible sector of the nuclear industry is found in universities, colleges and research labs, both private and public. Open and sealed sources, radiation devices and linear accelerators are used primarily for teaching, as well as pure and applied research. A laboratory environment where open sources could be used is shown in Figure 50.

Open-source nuclear substances are used in research on biological systems. Using nuclear substances tagged to various compounds, researchers can trace the metabolic fate of these compounds within living systems. Although the use of open source nuclear substances has declined over the past decade and is being replaced by non-radioactive procedures, it still remains a powerful research tool.

The sub-sectors of laboratory studies and consolidated use of nuclear substances, along with Class IB research particle accelerators constitute 200 licences, or 69% of the licences in the academic and research sector. The remaining licences include research and teaching using sealed sources and scintillation counters. An example of the latter licences is the use of sensitive instruments containing a radioactive source, such as a gas chromatograph, to analyse environmental samples. Figure 51 shows a scientist collecting these types of samples, and Figure 52 shows a gas chromatograph used to analyze them. High-energy physics research is another field within the academic and research sector that uses nuclear energy, predominantly via particle accelerators.

Figure 51: Sample collection, for future analysis using a gas chromatograph. Source: CNSC.

Figure 52: Gas chromatograph. Source: Wikipedia.org / Wikimedia Commons. Retrieved May 3, 2010.

6.7.2 Safety Performance

6.7.2.1 Dose to Workers

The data in this section represents the dose records of persons who may be subjected to occupational exposures to radiation associated with CNSC-licensed activities. For most sub-sectors, the dose data is extracted from dose reports provided by licensees in their annual compliance reports (ACRs), for the 2008 to 2010 reporting period. For the purpose of this performance measure, CNSC staff analyzed a representative sample of worker dose records from randomly selected ACRs from licensees in each sector. For the two Class IB research particle accelerators, occupational dose data was retrieved from the National Dose Registry. This data is consolidated at the sector level. Note that worker dose data for 2008 and 2009 has been modified from previous years' reports to include doses to workers at Class IB research particle accelerators.

The term "sampled workers" in some of the figures represents the number of workers whose dose data was analyzed when sampling was used to generate the data. According to the data, the whole body doses of sampled licensees in the academic and research sector was among the lowest reported, as shown in Figure 53. In 2010, more than 94% of the workers (Nuclear Energy Workers – or NEWs, and other workers) in this sector received doses of under 0.5 mSv, which is well below the prescribed limit for the public. Furthermore, no member of this group received a dose above 20 mSv between 2008 and 2010; this is well below the prescribed limit for NEWs. The dose results for workers involved in laboratory studies and consolidated use of nuclear substances are shown in Figure 54 and Figure 55 for NEWs and other workers, respectively. In 2010, both groups of workers received doses of less than 1 mSv/year. Data for Class IB research particle accelerators is shown in Figure 56, and will be discussed further in Section 6.8.2 of this report.

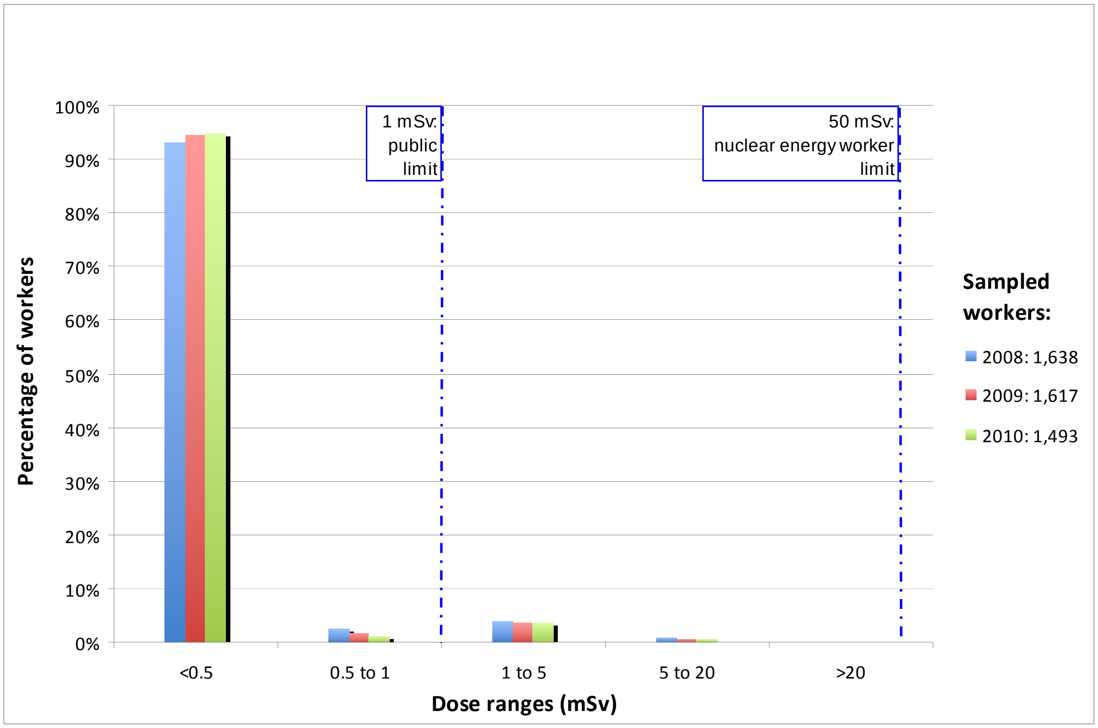

Figure 53: Academic and research sector – Annual whole body doses to nuclear energy workers and other workers.

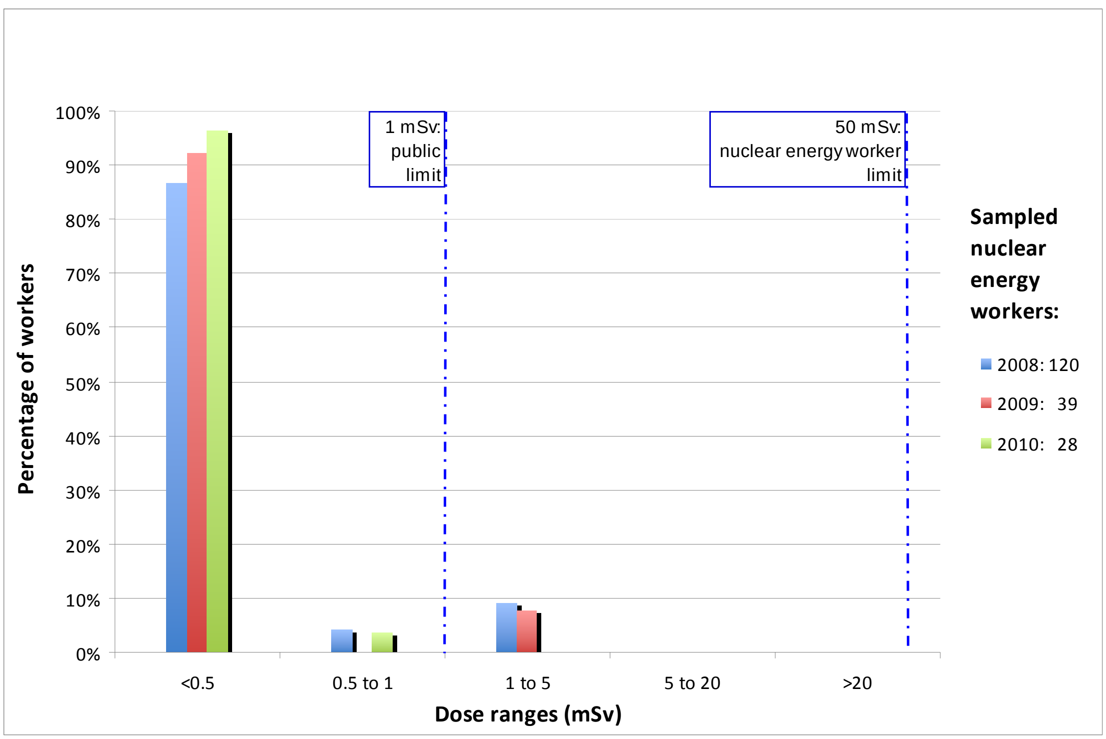

Figure 54: Laboratory studies and consolidated use of nuclear substances – Annual whole body doses to nuclear energy workers.

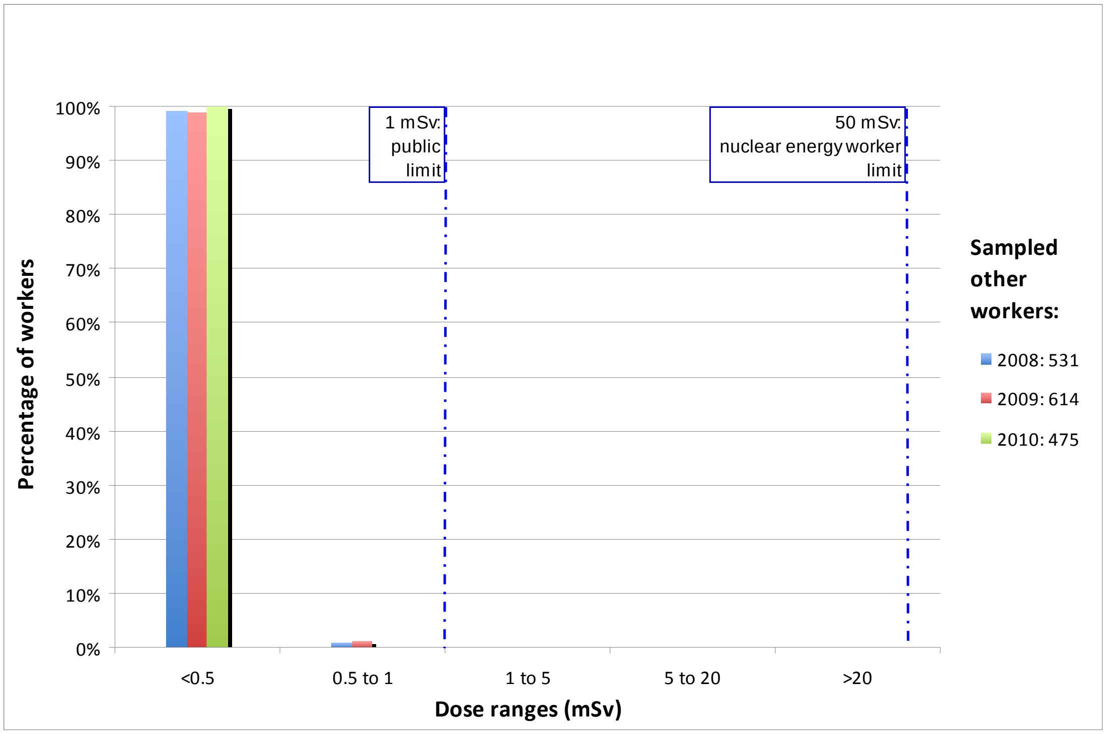

Figure 55: Laboratory studies and consolidated use of nuclear substances – Annual whole body doses to other workers.

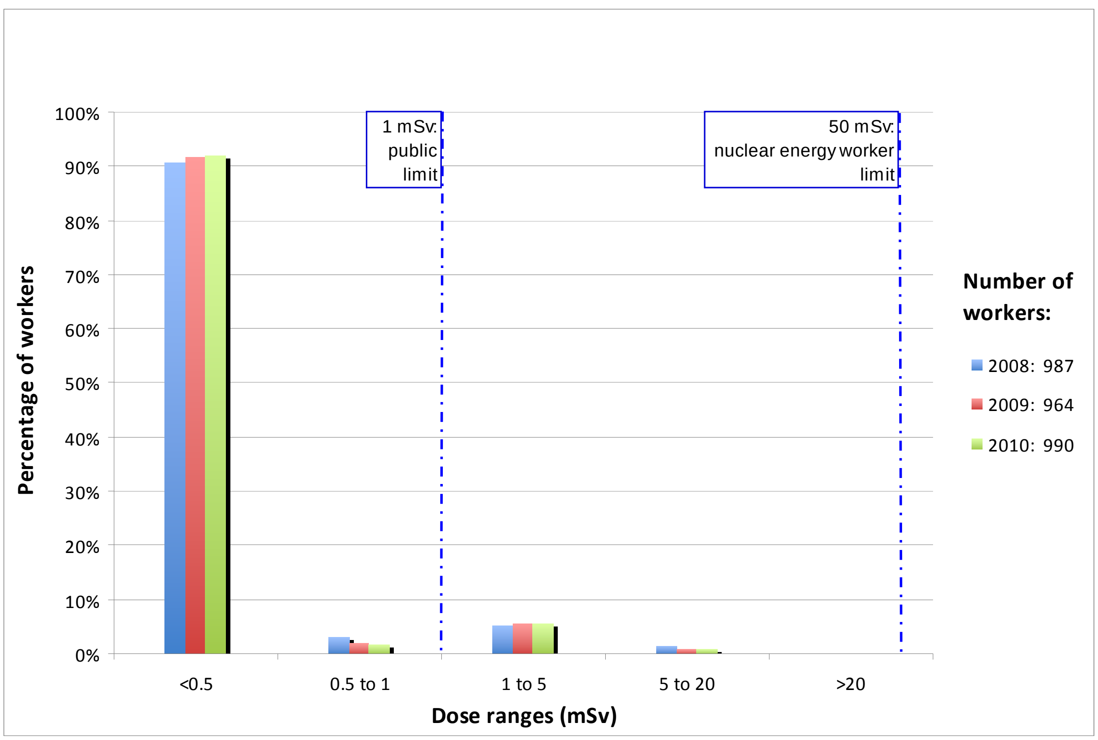

Figure 56: Class IB research particle accelerators – Annual whole body doses to nuclear energy workers and other workers.

6.7.2.2 Inspection Ratings of Operational Procedures

Inspection ratings of operational procedures for the academic and research sector are shown in Figure 57. In 2010, 85% of the inspected licensees in this sector were found to be compliant, up from 74% in 2009. Of the inspected licensees found to be non-compliant, 14% had “C”-rated non-compliances that did not significantly affect safety, and only 1% had “D”-rated non-compliances. A “D” rating is significantly below requirements, with deficiencies that could lead to an unreasonable risk to the health and safety of workers, the public or the environment if left uncorrected. It should be noted that no “E” ratings were assigned to the area of operational procedures during inspections in 2010.

Typical non-compliances in this safety area included failure to maintain adequate training records and failure to provide current work instructions to staff. The CNSC used various enforcement measures to request licensees to address these non-compliances.

In 2010, the inspection rate for the academic and research sector was 100%, as shown in Table B.2 (APPENDIX B). As these licensees are considered high-risk due to the nature of the activities authorized by their licences, an inspection is typically scheduled on an annual basis. At least one licensed location for each licensee was inspected in 2010. For detailed results of inspection ratings, refer to Appendix B.4 and B.7.

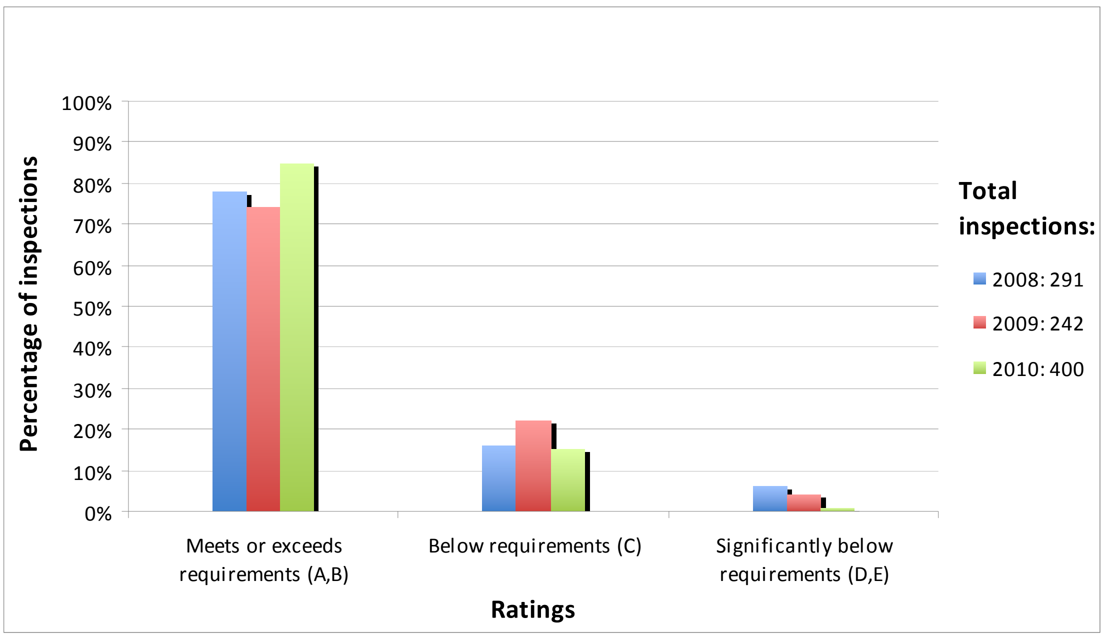

Figure 57: Academic and research sector – Inspection ratings of operational procedures.

6.7.2.3 Inspection Ratings of Radiation Protection

Radiation protection inspection ratings for the academic and research sector are shown in Figure 58. In 2010, 80% of inspected licensees were found to be compliant, a significant increase from the 2009 value (67%). Of the inspected licensees found to be non-compliant, 19% had “C”-rated non-compliances that did not significantly affect safety, and 1% had "D"-rated non-compliances. It should be noted that no "E" ratings were assigned to the area of radiation protection in 2010.

Typical non-compliances in this sector included failure to notify NEWs in writing of their doses, frivolous posting of radiation warning signage, and failure to label containers that had nuclear substances in them. The CNSC used various enforcement measures, such as written action notices, requests for licensees to revise their procedures and communication with senior management to resolve the issues. For detailed results of inspection ratings, refer to Appendix B.5 and B.8.

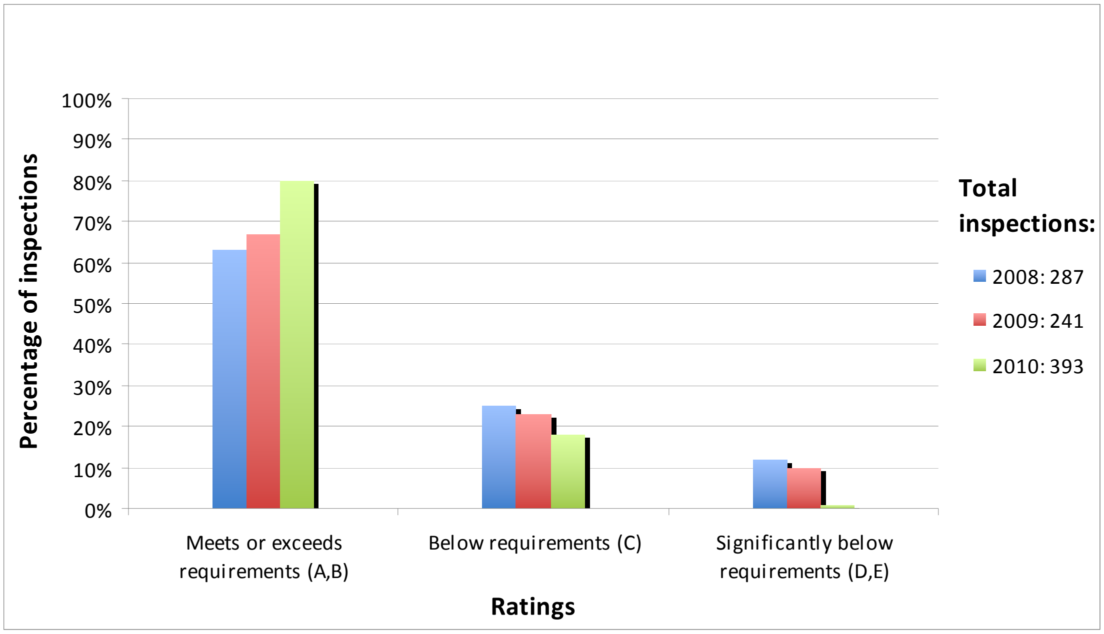

Figure 58: Academic and research sector –Inspection ratings of radiation protection.

6.7.2.4 Inspection Ratings of Sealed Source Tracking System (SSTS)

SSTS inspection ratings for the academic and research sector are shown in Figure 59. Results show that this sector met requirements 96% of the time in 2010. Of the 4% of licensees who were non-compliant, none of the non-compliances were significantly below requirements. No "E" ratings were assigned during SSTS inspections. For more information on the SSTS, readers are invited to consult the National Sealed Source Registry and Sealed Source Tracking System annual reports, which are posted on the CNSC Web site[14]. For detailed results of inspection ratings, refer to Appendix B.6 and B.9.

[14] Available online at nuclearsafety.gc.ca/eng/readingroom/reports/ssts/index.cfm

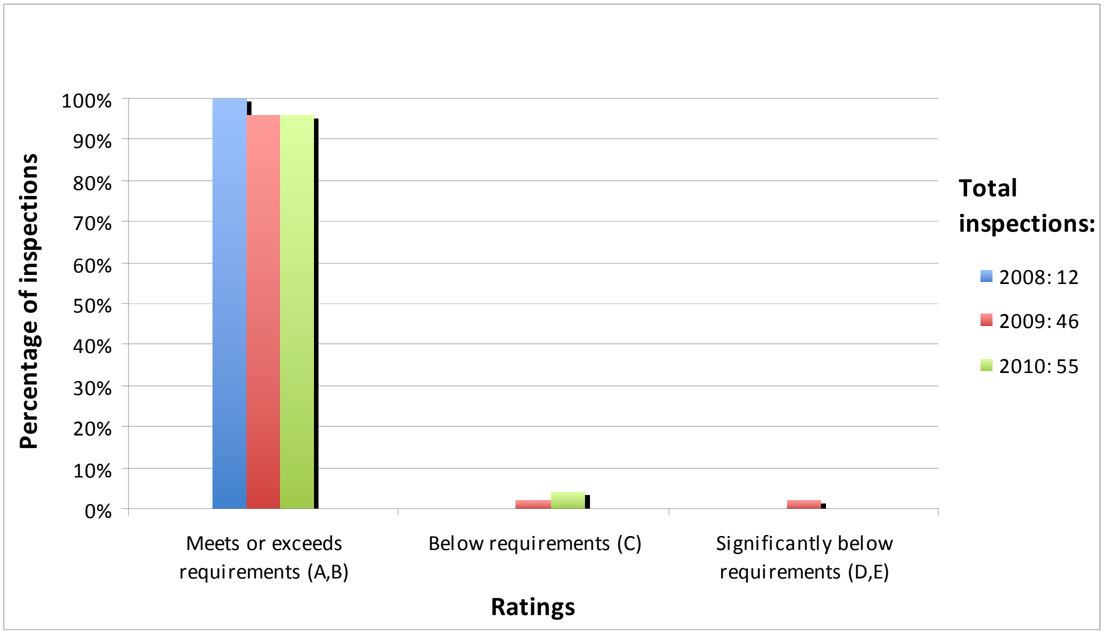

Figure 59: Academic and research sector – Inspection ratings of Sealed Source Tracking System.

6.7.2.5 Reported Events and Incidents

As shown in Figure 60, there were very few events in the academic and research sector, with only six reported in 2010.

Three of these events involved spills or contamination. Contamination incidents mainly resulted from technicians handling nuclear substances. In all cases, licensees implemented incident response procedures to mitigate consequences.

The other three events reported were for devices that malfunctioned or were damaged, without any radiological consequence or exposure.

None of these events resulted in any person receiving a dose in excess of the regulatory limit.

In 2010, there were no reports of lost, stolen or found nuclear substances, transportation incidents, or breaches of security in the academic and research sector.

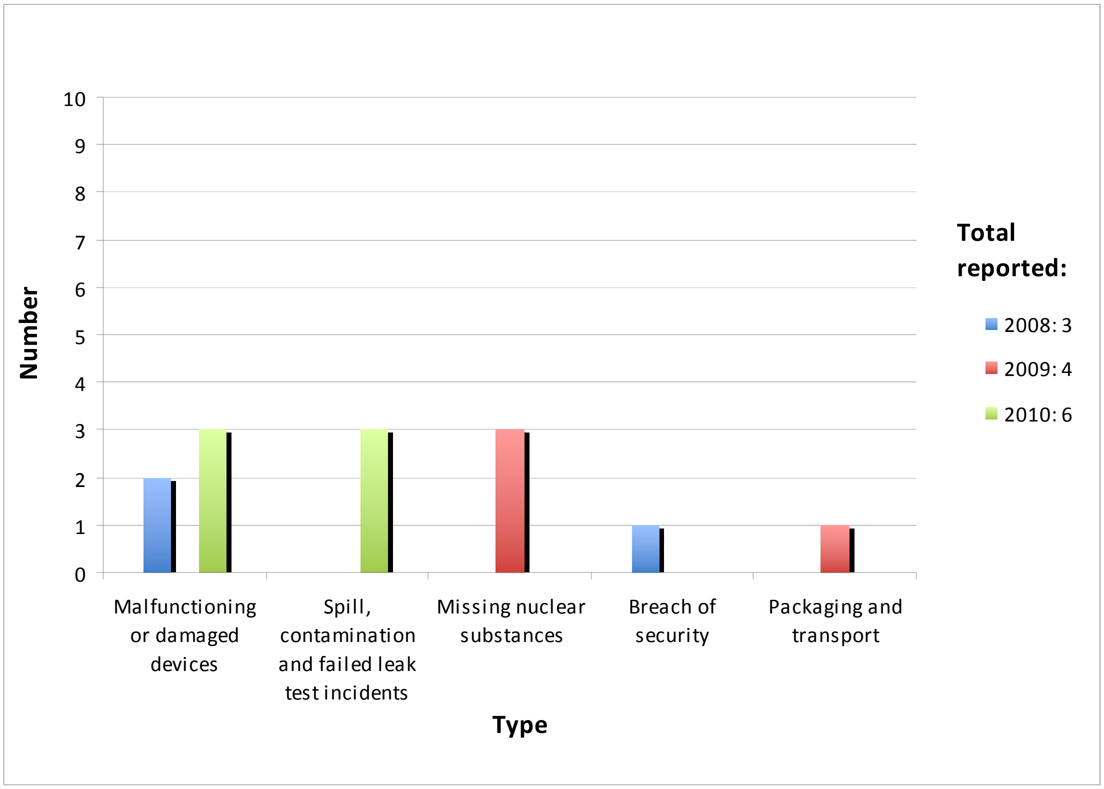

Figure 60: Academic and research sector – Reported events and incidents.

6.7.2.6 Enforcement Activities – Orders and Measures to be taken by the Licensees

The CNSC issued no orders to licensees in the academic and research sector over the 2008–10 reporting period.

6.8 Academic and Research Sub-sector

6.8.1 Laboratory Studies and Consolidated Use of Nuclear Substances Sub-sector

Within the academic and research sector, the most visible licensees are those based at universities, colleges and government laboratories. Typically, these areas involve licences for laboratory studies and for the consolidated use of nuclear substances, and account for 68% or 198 of the 290 licences in the academic and research sector. Activities for both laboratory studies and the consolidated use of nuclear substances are similar in scope, using open and sealed sources. The consolidated use of nuclear substances involves activities that permit greater use of nuclear gauges and other prescribed equipment, as it is characterized by a structured management committee that oversees the policies for authorization and use. The academic and research community generally has a well-structured radiation safety program.

Pure and applied research is dominant in laboratory studies and in the consolidated use of nuclear substances, in the fields of physics, biology and biomedicine; however, teaching is also a permitted use. An example of a potential application of a radiation device is shown in Figure 61.

Figure 61: A laboratory worker using a liquid scintillation counter (radiation device). Source: CNSC.

Laboratory studies use unsealed sources for research and diagnosis. Most often, licensees are hospitals, private medical laboratories, universities or private research establishments. Work typically involves the use of nuclear substances as tracers in labelling studies. Common isotopes used are Carbon 14, Cobalt 57, Hydrogen 3, Iodine 125, Phosphorus 32 and Sulphur 35. Radiation activity levels range from kilobecquerel (kBq) quantities to gigabecquerel (GBq) quantities and more. Laboratory studies are similar to consolidated use, but more restrictive in scope with the use of open and sealed sources.

Consolidated licences ensure that all nuclear substances, radiation devices and activities come under the control of a single administrative body, usually a radiation safety or radiation control committee. This licensed activity may occur on many sites and involve numerous workers using radiation devices and a variety of nuclear substances in open or sealed form.

A consolidated licence may include a variety of devices and extensive possession limits for open and sealed source nuclear substances, including scintillation counters and other radiation devices, such as portable gauges. All locations must be under the control of a radiation safety or radiation control committee that issues permits to individuals or groups of researchers in the same way that the CNSC issues licences. A permit system authorizes specific individuals to be responsible for activities within their departments. The CNSC also requires licensees to submit annual reports. The CNSC does not issue consolidated licences for radiography, human research, production and distribution, or tracer studies.

Figure 62 compares the sub-sector of laboratory studies and the consolidated use of nuclear substances with the academic and research sector, for inspection ratings of operational procedures. Figure 63 provides a similar comparison for radiation protection inspection ratings. These figures show the percentage of inspections that found licensees met or exceeded requirements (“A” and “B” ratings). In 2010, this sub-sector (laboratory studies and the consolidated use of nuclear substances) demonstrated a compliance record similar to that of the overall academic and research sector, in the areas of radiation protection and operational procedures.

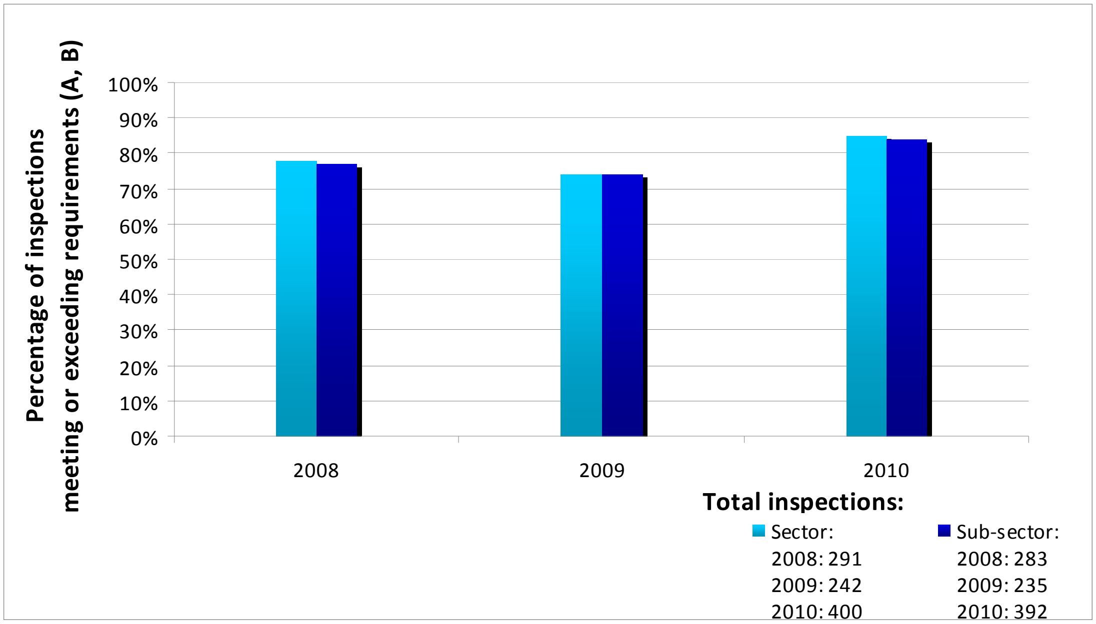

Figure 62: Academic and research sector vs. laboratory studies and consolidated use of nuclear substances sub-sector – Comparison of inspection ratings of operational procedures.

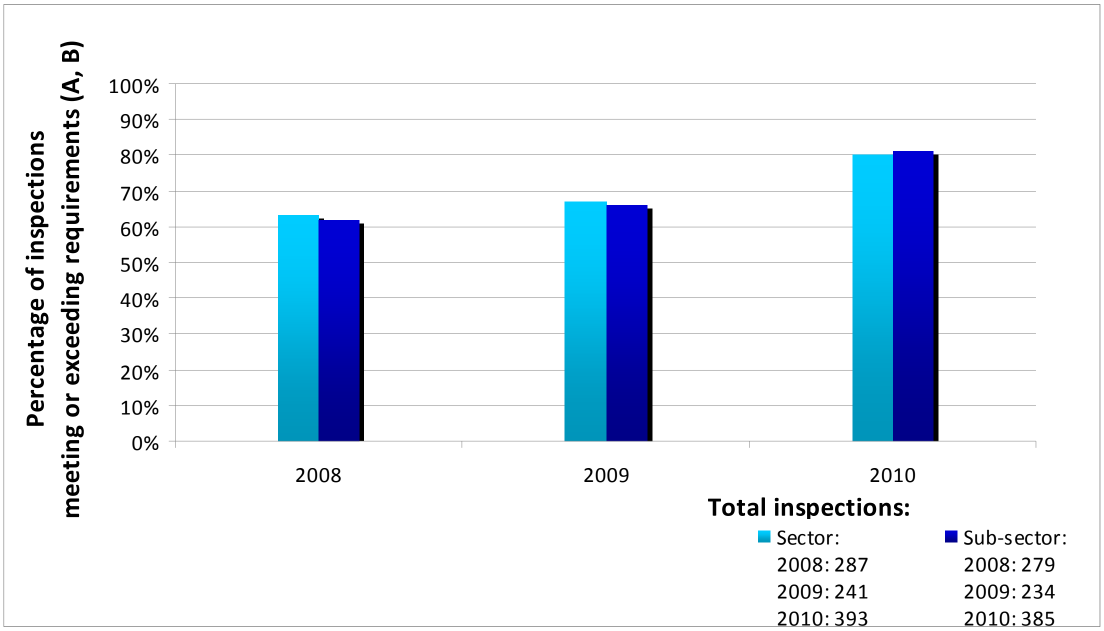

Figure 63: Academic and research sector vs. laboratory studies and consolidated use of nuclear substances sub-sector – Comparison of inspection ratings of radiation protection.

6.8.2 Class IB Research Particle Accelerator Sub-sector

Class IB research particle accelerators are used for research in subatomic physics, determining elemental composition and imaging of materials, and new production methods for medical isotopes. A Class IB research particle accelerator is shown in Figure 64, and a schematic diagram is shown in Figure 65.

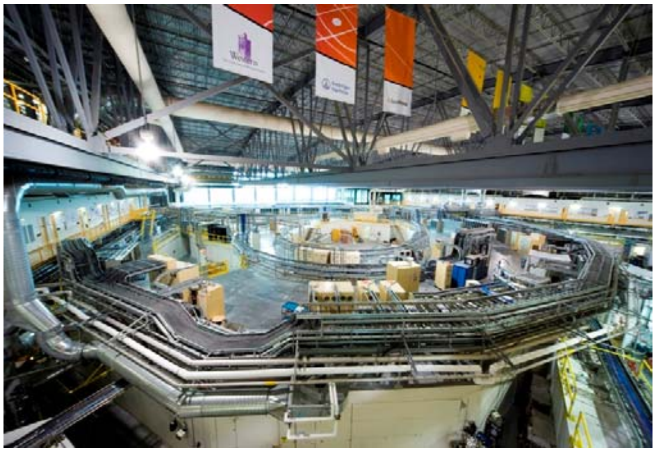

Figure 64: Canadian Light Source, a research facility located in Saskatoon, SK.
Source: Canadian Light Source Inc.

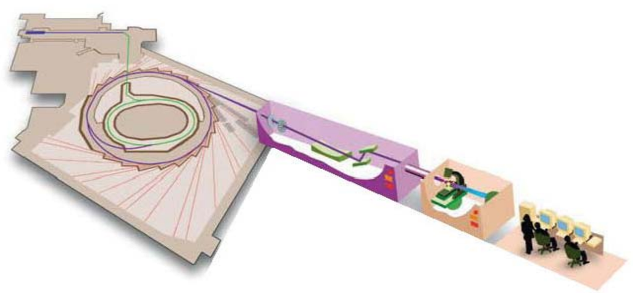

Figure 65: A schematic diagram of a research particle accelerator (not to scale).
Source: Canadian Light Source Inc.

Class IB particle accelerator facilities came under the regulatory mandate of the CNSC's Directorate of Nuclear Substance Regulation in May 2010. The process and methodology that CNSC uses to exercise its regulatory oversight of Class IB accelerators is different from the regulatory oversight of the other activities covered in this report. For that reason, the safety performance of these facilities cannot be reported using the same performance measures. Due to time constraints, this edition of the industry report for these facilities covers only one performance measure, namely doses to workers. The next edition (2011) of this report will contain a more fulsome section on the safety performance of these facilities.

The doses received by workers at Class IB research particle accelerators are shown in Figure 56. All types of workers (Nuclear Energy Workers and others) received less than 20 mSv/year and, although not specifically shown in the figure, all other workers received doses lower than the public dose limit of 1 mSv/year. Those in the higher dose range are primarily involved in isotope production activities at one of the two Class IB research particle accelerators operating in Canada.

Note that there are over 800 users, such as visiting scientists, who are not included in this data but who are monitored. All of these users received doses of lower than 0.02 mSv/year.

Class IB licensees undergo mid-term licence reviews that include grading of their performance. In 2010, one licensee operating a Class IB research particle accelerator underwent a mid-term review and was found to meet all regulatory requirements.

6.9 Academic and Research Sector – Summary Statement

The performance metrics for the academic and research sector indicate this sector is compliant. Non-compliance issues did not significantly affect the safety of the licensed activities.

During 2010, there were no orders issued to licensees in this sector. Ratings of operational procedures and radiation protection have shown an improving trend since 2008. Occupational doses were within regulatory limits.

6.10 Commercial Sector

6.10.1 Description

The commercial sector encompasses a number of licensed activities that provide sales of nuclear substances or servicing of radiation devices and prescribed equipment for commercial gain. In 2010, there were 257 licences in this sector. This sector is broad, and includes applications related to manufacturing, servicing, distribution, production, calibration, and storage of nuclear substances and radiation devices. It includes cyclotron operators, third-party service companies and organizations developing new devices.

For the purpose of this report, only two sub-sectors were identified within the commercial sector: servicing and isotope production accelerator sub-sectors. Together, these sub-sectors account for 32% or 81 of the 257 licences in the commercial sector.

6.10.2 Safety Performance

6.10.2.1 Dose to Workers

The data in this section represents the dose records for persons who may be subjected to occupational exposure to radiation associated with CNSC-licensed activities. The dose data is extracted from dose reports provided by licensees in their annual compliance reports (ACRs) for the 2008 to 2010 reporting period. For the purpose of this performance measure, CNSC staff analyzed a representative sample of worker dose records from randomly selected ACRs from licensees in each sector.

The term "sampled workers" in the figures in this section represents the number of workers whose dose data was analyzed (784 workers were sampled in 2010). As shown in Figure 66, doses were relatively consistent each year, from 2008 to 2010.

Figure 67 and Figure 68 illustrate the whole body doses for Nuclear Energy Workers (NEWs) and for other workers involved in servicing, respectively. Data shows that occupational dose levels in 2010 returned to the levels observed in 2008, and indicates that both NEWs and other workers received doses lower than the regulatory limits.

Almost all isotope production accelerator staff are designated as NEWs, with only five other workers in 2010. As shown in Figure 69, more than 97% of the NEWs received whole body doses of lower than 5 mSv/year in 2010, which is well below the annual regulatory limit of 50 mSv/year. The five other workers received doses of less than 0.5 mSv/year in 2010.

Due to the manual manipulation of instruments during radioisotope processing, occupational doses to workers' hands are also monitored. The data shows a general trend toward a reduction of doses received, and all workers continued to receive doses lower than the regulatory limit of 500 mSv/year (extremity dose limit). This information is presented in Figure 70.

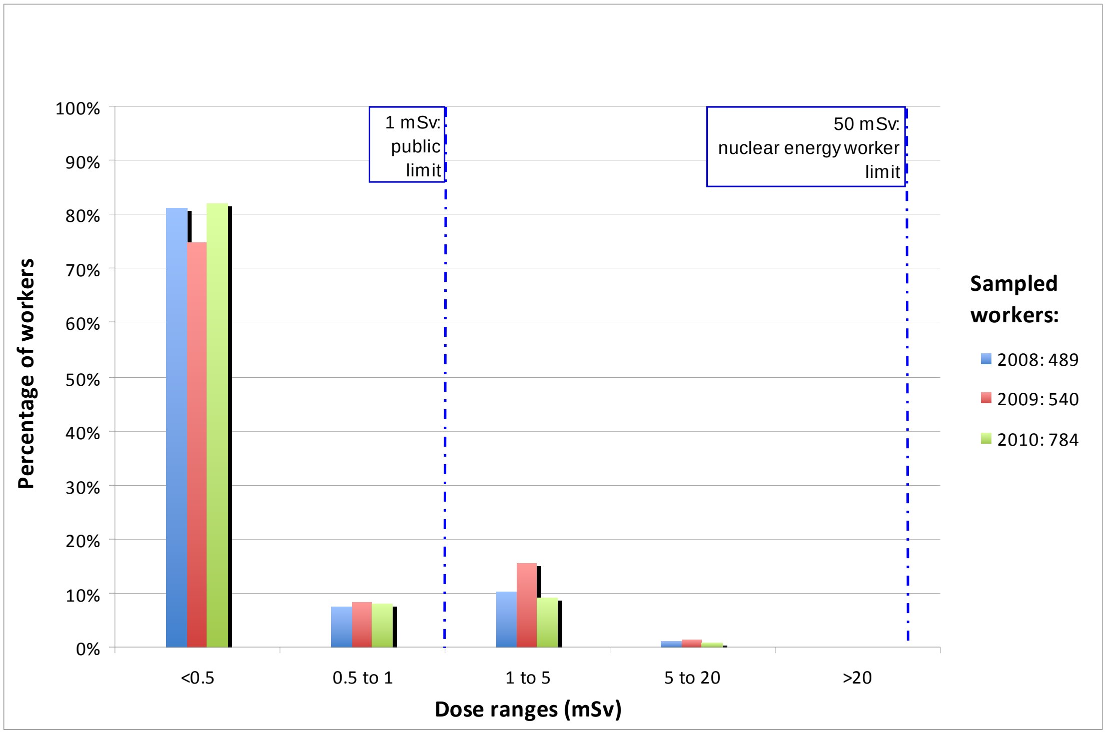

Figure 66: Commercial sector – Annual whole body doses to nuclear energy workers and other workers.

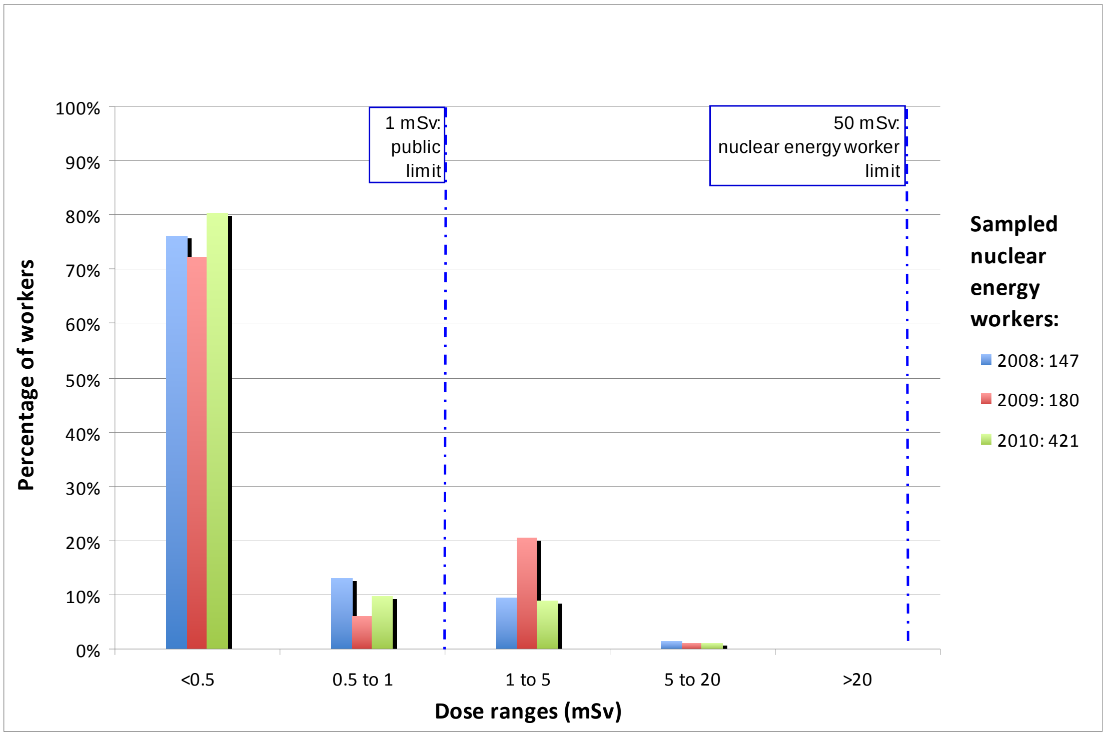

Figure 67: Servicing – Annual whole body doses to nuclear energy workers.

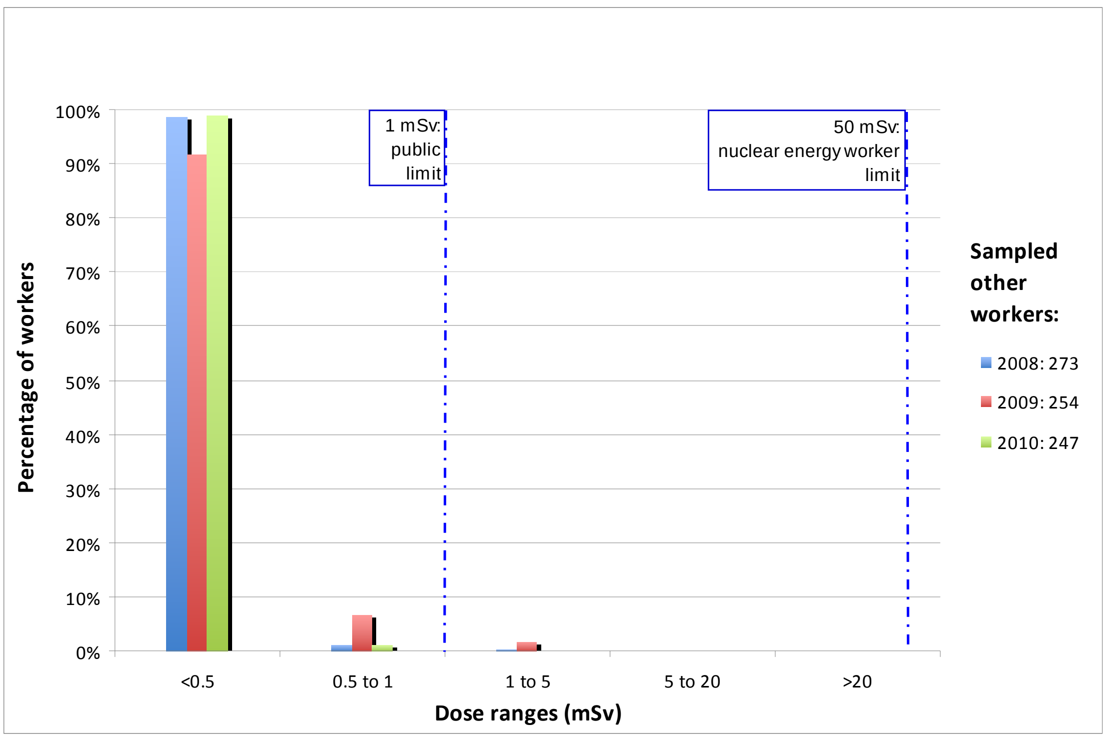

Figure 68: Servicing – Annual whole body doses to other workers.

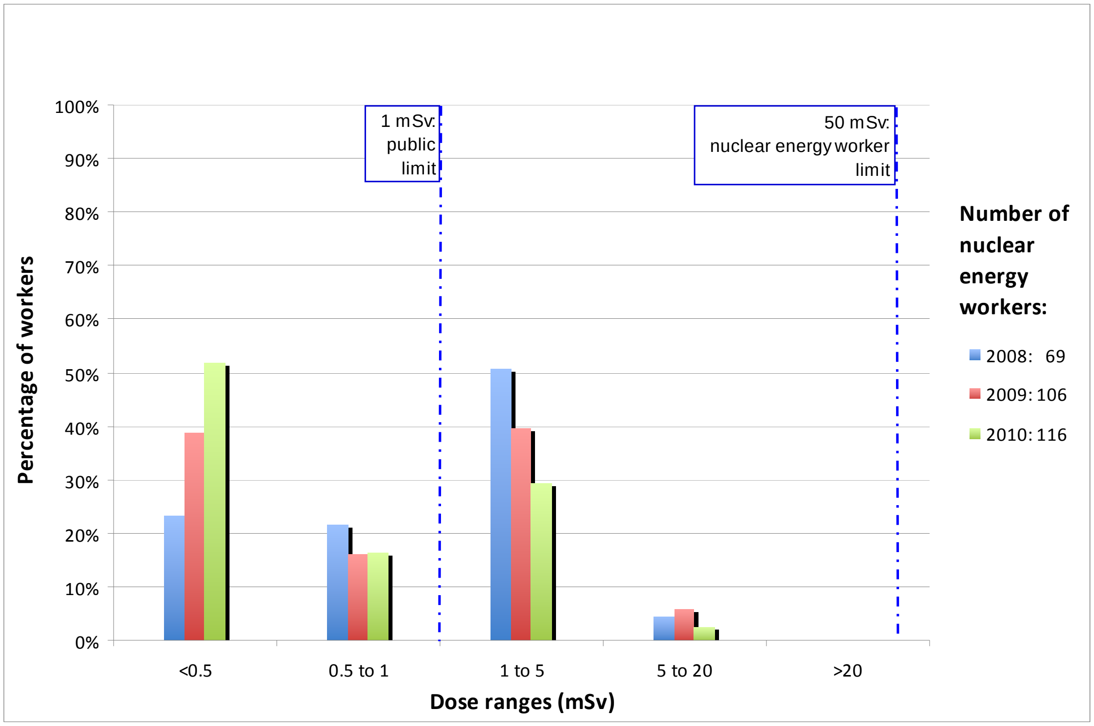

Figure 69: Isotope production accelerators – Annual whole body doses to nuclear energy workers.

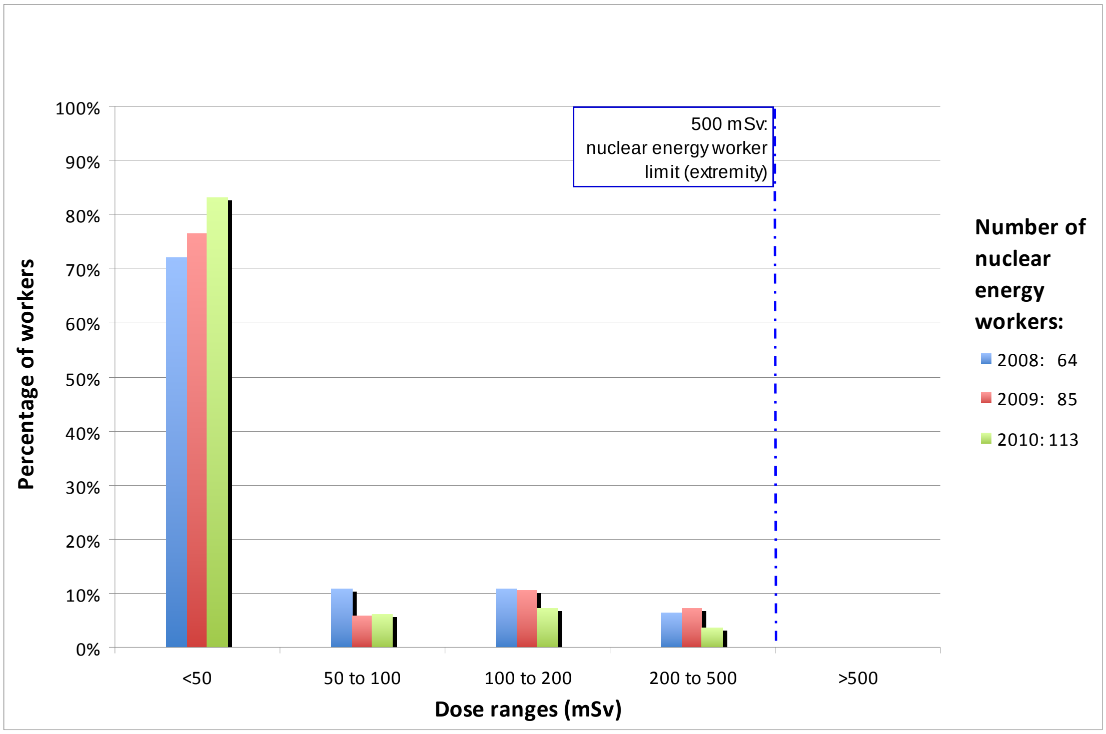

Figure 70: Isotope production accelerators – Annual extremity doses to nuclear energy workers.

6.10.2.2 Inspection Ratings of Operational Procedures

Inspection ratings of operational procedures for the commercial sector are shown in Figure 71. In 2010, 92% of the inspected licensees were found to be compliant in the operational procedures safety area. Of the inspected licensees found to be non-compliant, 7% had “C”-rated non-compliances that did not significantly affect safety, and 1% had “D”-rated non-compliances. A “D” rating is significantly below requirements with deficiencies that could lead to an unreasonable risk to the health and safety of workers, the public or the environment, if left uncorrected. No inspections in 2010 found unacceptable levels of compliance (“E” rating) within this area. The CNSC issued no orders related to non-compliance in this safety area.

Typical non-compliances in this safety area included failure of workers to follow licensee procedures, failure of licensees to maintain appropriate training records, or failure to perform leak tests at prescribed intervals.

The CNSC employs a graduated enforcement approach when addressing non-compliances that do not pose an immediate risk to the health and safety of workers, the public or the environment. The measures used by the CNSC to ensure that licensees regain compliance included written action notices, correspondence and meetings with the licensee’s senior management, and acceptance of licensee plans to voluntarily shut down until operations are in compliance.

The compliance rate of commercial-sector licensees in this safety area was greater in 2010 (92%), demonstrating improvement from 2008 (76%). The number of inspected licensees demonstrating compliance levels “significantly below requirements” decreased from 4% in 2008 to 1% in 2010. For detailed results of inspection ratings, refer to Appendix B.4 and B.7.

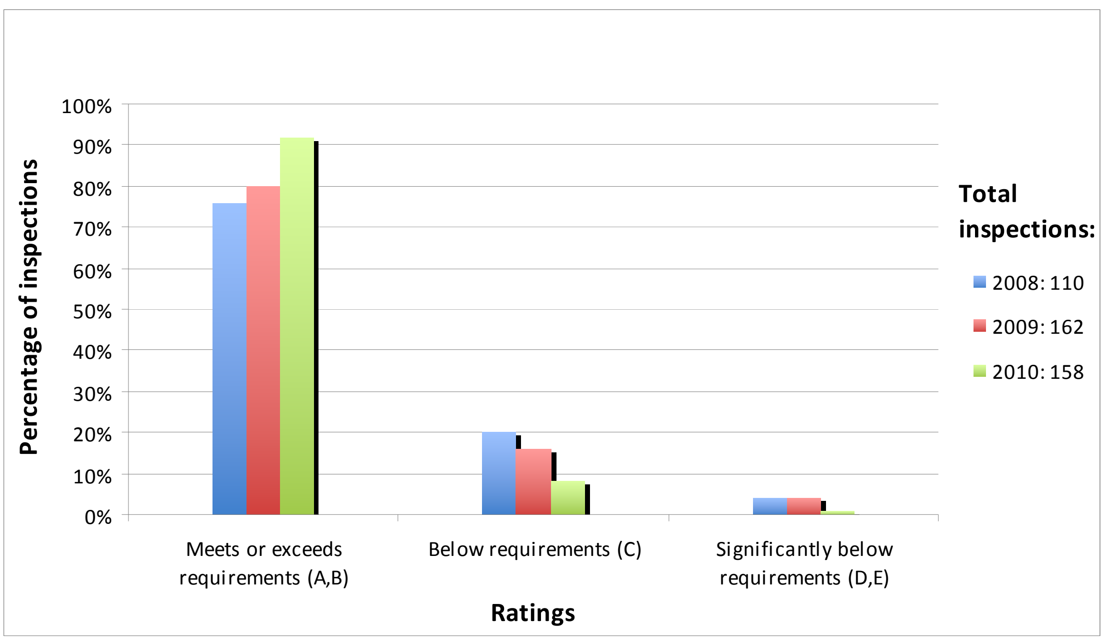

Figure 71: Commercial sector – Inspection ratings of operational procedures.

6.10.2.3 Inspection Ratings of Radiation Protection

Radiation protection inspection ratings for the commercial sector are shown in Figure 72. In 2010, 89% of inspected licensees were found to be in compliance with this safety area. Of the inspected licensees found to be non-compliant, 9% had "C"-rated non-compliances that did not significantly affect safety, and 2% had "D"-rated non-compliances. No inspections in 2010 found unacceptable ("E"-rated) compliance levels within this safety area. The CNSC issued no orders related to non-compliance in this safety area.

Typical non-compliances in this safety area included inadequate labelled devices, improper storage of nuclear substances, or the inability of a licensee to demonstrate that doses are ALARA (As Low As Reasonably Achievable).

The CNSC employs a graduated enforcement approach when addressing non-compliances that do not pose an immediate risk to the health and safety of workers, the public or the environment. The measures used by the CNSC to ensure that licensees regain compliance included written action notices, correspondence and meetings with the licensee's senior management, and acceptance of licensee plans to voluntarily shut down until operations are in compliance.

The commercial sector's compliance level in this safety area showed improvement in 2010, compared to results from 2008 and 2009. The number of compliant licensees increased from 75% in 2008 to 89% in 2010. The number of inspected licensees demonstrating compliance "significantly below requirements" decreased from 10% in 2008 to 2% in 2010. For detailed results of inspection ratings, refer to Appendix B.5 and B.8.

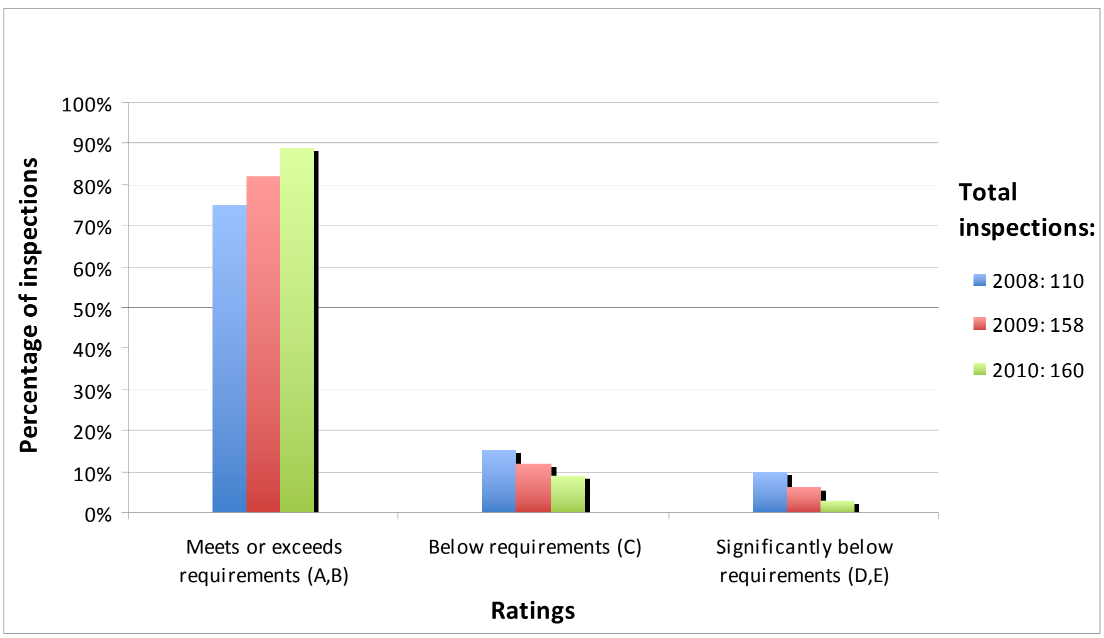

Figure 72: Commercial sector – Inspection ratings of radiation protection.

6.10.2.4 Inspection Ratings of Sealed Source Tracking System (SSTS)

SSTS inspection ratings for the commercial sector over the 2008–10 reporting period are shown in Figure 73. In 2010, the commercial sector returned to full compliance with the SSTS requirements. Previously, in 2008, this sector demonstrated complete compliance with the SSTS requirements. In 2009, the compliance rate decreased to 90% due to the failure of a licensee to inform the CNSC within 48 hours of the receipt of a sealed source categorized as high risk, as per the licence condition. For more information on the SSTS, readers are invited to consult the National Sealed Source Registry and Sealed Source Tracking System annual reports, available on the CNSC Web site[15]. For detailed results of inspection ratings, refer to Appendix B.6 and B.9.

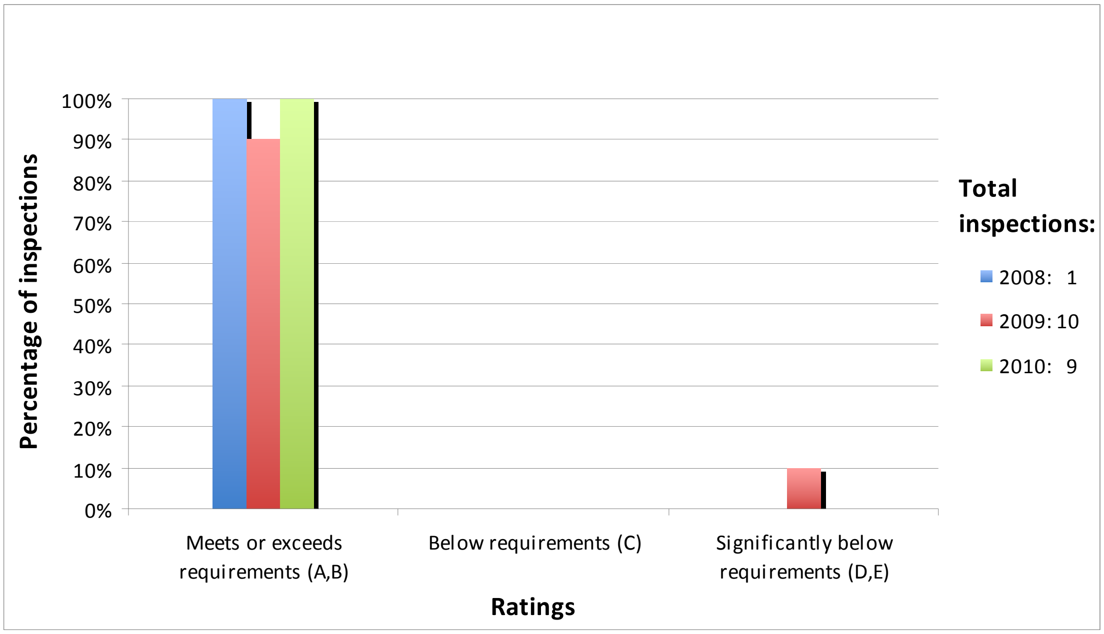

Figure 73: Commercial sector – Inspection ratings of Sealed Source Tracking System.

6.10.2.5 Reported Events and Incidents

As shown in Figure 74, there were 32 reported events for the commercial sector in 2010. Of the 32 events reported, two were related to malfunctioning or damaged devices with no radiological or exposure consequences.

The most common type of incident reported involved spills or contamination in medical isotope production facilities, some of which were caused by blown gas targets inside cyclotron machines. Radiation was contained inside the devices, and there were no radiological consequences or exposure to technicians or members of the public.

There was an increase in reported contamination incidents in 2010, as compared to previous years. The increase is a result of licensees reporting all skin contamination incidents, regardless of the dose received, further to CNSC outreach activities to remind

[15] Available online at http://nuclearsafety.gc.ca/eng/readingroom/reports/ssts/index.cfm

licensees of their obligation to report these types of incidents. Contamination incidents resulted mainly from technicians' handling of nuclear substances. In all cases, licensees implemented measures satisfactory to the CNSC to mitigate the consequences and to limit radiation exposure to workers. None of the events reported by licensees in the commercial sector resulted in a radiation dose in excess of the regulatory limits.

In the area of packaging and transport, there were three reports of damaged packages, all with no loss of containment, and two reports of accidents involving vehicles transporting nuclear substances, with no damage to the packages. There were also three reports of packages misplaced by carriers during transport. In all cases, these packages were recovered and delivered to their destination without further consequences.

In the commercial sector, no nuclear substances were reported missing and no breaches of security were reported in 2010.

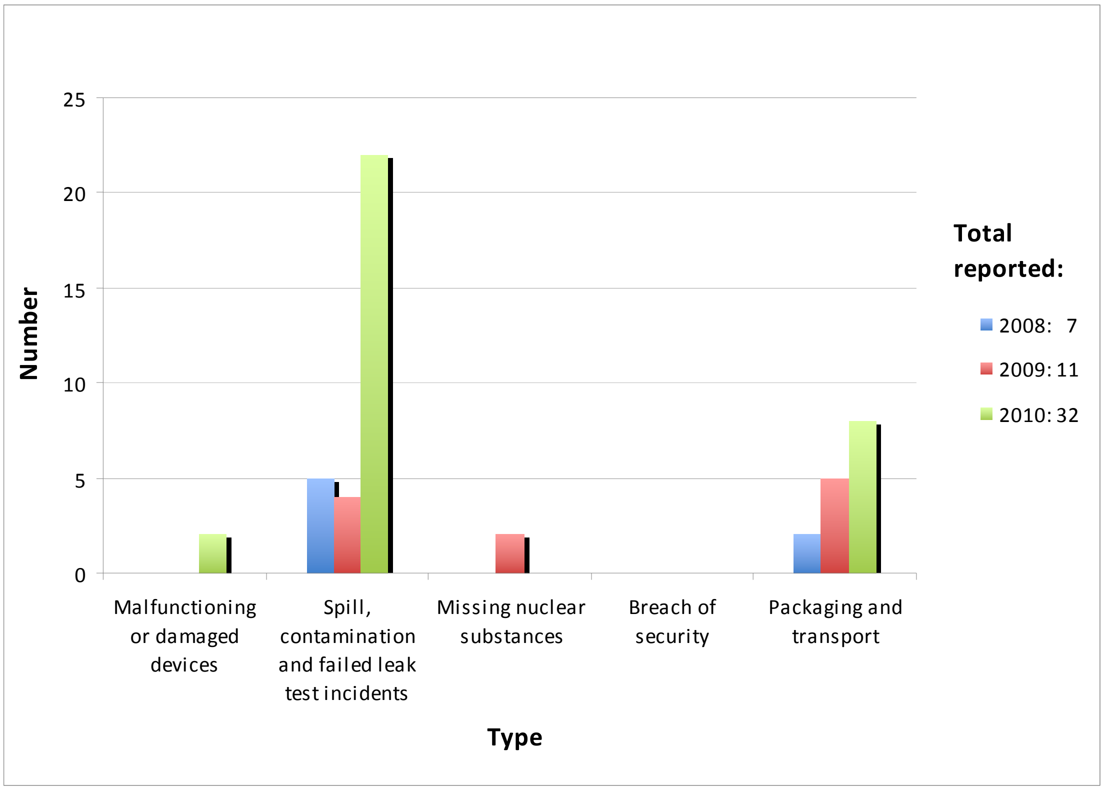

Figure 74: Commercial sector – Reported events and incidents.

6.10.2.6 Enforcement Activities – Orders and Measures to be taken by the Licensees

Table 5 indicates the CNSC order and the measures that had to be taken by the licensee, for the commercial sector in 2010. A CNSC inspector issued one order under the NSCA, which coincided with an order issued to a medical-sector operating facility that was involved with the prescribed equipment. The commercial sector had one order in 2008 and one in 2009, both of which were issued under the NSCA. For more information on orders issued in previous years, readers are invited to consult the previous edition of *Nuclear Substances in Canada: A Safety Performance Report*[16], available on the CNSC Web site.

Licensee	Location	Date order was issued	Measures to be taken by the licensee	Date order was closed
Elekta Inc. (Third-party servicing)	Norcross, Georgia, USA	June 1, 2010	Submission of an application for certification of accelerator to the CNSC and cessation of sale and non-urgent servicing of same equipment until certified.	June 9, 2010

Table 5: Enforcement Activities in 2010 – Order and measures to be taken by the licensee.

6.11 Commercial Sub-sectors

6.11.1 Servicing Sub-sector

Figure 75: Servicing of a certified device (medical linear accelerator). Source: CNSC.

Installation, repair and non-routine maintenance of radiation devices and prescribed equipment require a CNSC-issued servicing licence. A medical linear accelerator being serviced is shown in Figure 75. This activity, often carried out by the supplier or its representative in Canada, must be in accordance with a service licence even if the licensee's headquarters are located outside Canada. Some activities, such as mounting or dismounting of a fixed gauge may be performed by the licensee, provided CNSC approval has been requested and received in writing. Servicing licences can include those for installation, dismantling or decommissioning of devices.

Figure 76 compares the inspection ratings of the servicing sub-sector with those of the commercial sector for operational procedures, and Figure 77 provides a similar comparison of radiation protection inspection ratings. The servicing sub-sector's

[16] Available online at: nuclearsafety.gc.ca/eng/readingroom/reports/use-of-nuclear-substances/index.cfm

inspection ratings in the area of operational procedures improved along with those of the overall sector.

In 2010, this sub-sector showed significant improvement in radiation protection inspection ratings, approaching 100% compliance and considerably outperforming the overall sector.

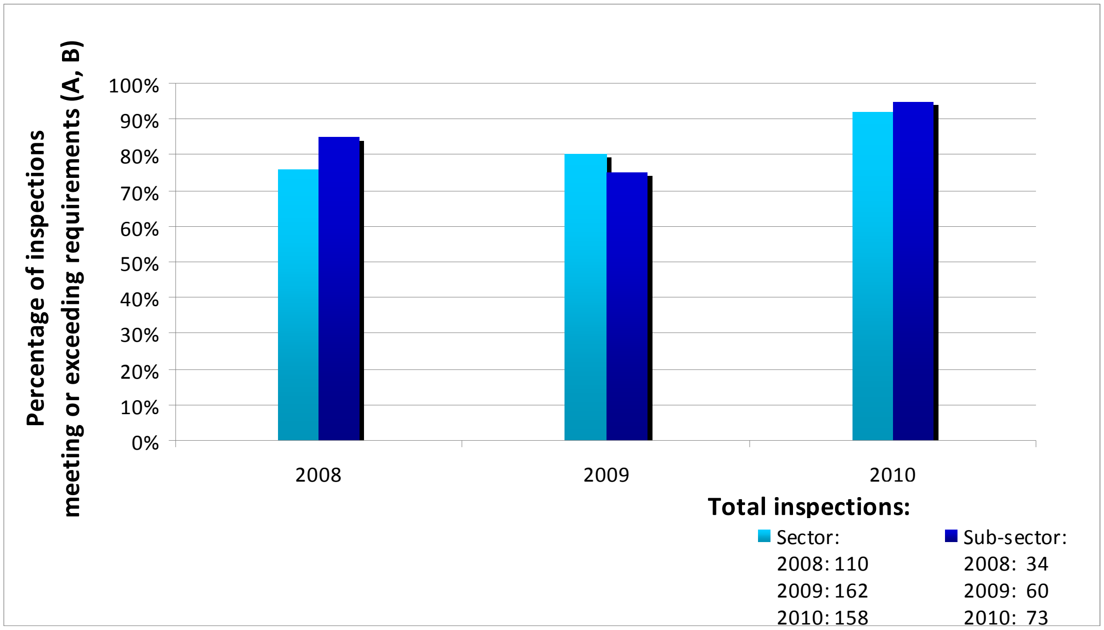

Figure 76: Commercial sector vs. servicing sub-sector – Comparison of inspection ratings of operational procedures.

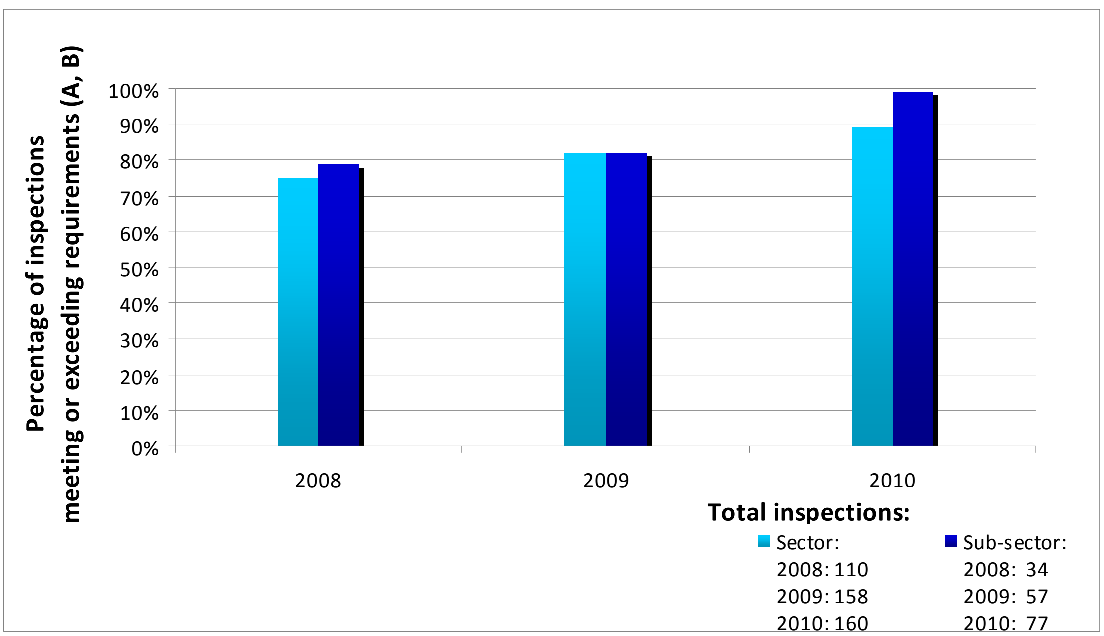

Figure 77: Commercial sector vs. servicing sub-sector – Comparison of inspection ratings of radiation protection.

6.11.2 Isotope Production Accelerator Sub-sector

The 11 isotope production accelerators licensed by the CNSC are primarily concerned with the production of isotopes used in medical imaging. Carbon 11 and, more commonly, Fluorine 18 are incorporated into radiopharmaceuticals used in PET imaging. A cyclotron, the most common type of isotope production accelerator, is shown in Figure 78.

Figure 78: Isotope production accelerator (Cyclotron). Source: CNSC.

6.12 Commercial Sector – Summary Statement

The commercial sector improved its level of compliance in 2010 in the safety areas of operational procedures and radiation protection, compared to 2008 and 2009. Licensees showed an excellent compliance rate with Sealed Source Tracking System (SSTS) requirements, and the sector returned to full compliance within this safety area. Previously in 2009, one inspected licensee had failed to comply with SSTS requirements.

The number of events reported by commercial sector-licensees to the CNSC increased in 2010. The increase was mainly due to the increased reporting of spills and contamination incidents from medical isotope production facilities, as a result of the CNSC request for reporting all skin contamination events, regardless of the dose received.

Significant enforcement actions are rarely taken with this sector's licensees, however one order was issued in 2010. The servicing sub-sector's compliance rating remained approximately the same as the commercial sector average. Whole body occupational doses were at acceptable levels. A decrease in whole body doses to workers in the isotope production sub-sector was observed. A similar decrease was noted in extremity doses to these individuals. Due to the small number of reporting licensees, this data may be subject to important deviations.

7.0 CONCLUSION

In general, the medical, industrial, academic and research, as well as commercial sectors exhibited positive gains in compliance in 2010. Occupational doses were generally well within regulatory limits for the sectors. However, all sectors showed an increase in the number of reported events, compared to 2009. APPENDIX B provides a detailed comparison of the safety performance measures among sectors.

Nuclear medicine and radiation therapy are important fields for diagnosis and treatment in the medical sector. This sector was compliant and demonstrated occupational doses to workers that were relatively low, and doses to radiation therapy workers that were particularly low. One order was issued to the medical sector in 2010.

The number of reportable events increased in 2010 from 2009, returning to about the same number as in 2008. Additionally, the number of CNSC orders issued in the industrial sector was higher than in all other sectors, but relatively consistent with the number of orders issued in 2009. On average, doses in the industrial sector improved in 2010 from previous reporting years, and were on par with those of the academic and research sector. Including portable gauge users, approximately 96% of industrial-sector workers received doses that were under the public dose limit of 1 mSv. Doses to industrial radiography and portable gauge workers were slightly higher, but the vast majority of doses to these workers were under 5 mSv, well under the dose limit of 50 mSv/year for nuclear energy workers.

Licensed activities in the academic and research sector mainly consist of biological and biomedical research with open sources, particle accelerators and research irradiators. Ratings of operational procedures and radiation protection showed an improving trend in 2010, when compared to those from 2009. The occupational doses received were within regulatory limits and among the lowest of all sectors. Overall, this sector is generally compliant, with very low doses to workers, and has not required any enforcement actions in the form of orders over the last three years.

The commercial sector improved its level of compliance in 2010 in the safety areas of operational procedures and radiation protection. Licensees showed an excellent compliance rate with Sealed Source Tracking System requirements, and the sector returned to 100% compliance within this safety area. The number of events reported by this sector increased in 2010. This was mainly due to more spills and contamination incidents being reported by medical isotope production facilities, now that they include all skin contamination events, regardless of the dose received. There was one order issued in 2010, consistent with the number of orders issued in 2008 and 2009.

GLOSSARY

action notice
A written request that the licensee or a person subject to enforcement action take action to correct a non-compliance that is not a direct contravention of the NSCA, applicable regulations, licence conditions, codes or standards, but that can compromise safety, security, or the environment and that may lead to a direct non-compliance if not corrected. (*avis d'action*)

cyclotron
A particle accelerator that speeds up particles in a circular motion until they hit a target at the perimeter of the cyclotron. Some cyclotrons are used to produce medical isotopes. (*cyclotron*)

enforcement
The set of activities associated with re-establishing compliance with regulatory requirements. (*application*)

exposure device
A radiation device designed for carrying out gamma radiography, and includes any accessory to the device, such as a sealed source assembly, a drive mechanism, a sealed source assembly guide tube and an exposure head. (*appareil d'exposition*)

fixed gauge
A radiation device attached to a structure and that enables the nuclear substance contained in it to be used for its radiation properties to measure process-related parameters (e.g., liquid flow, liquid level). (*jauge fixe*)

geophysical well logging
A neutron generator used in a borehole to measure the various geophysical properties of subsurface rock formations. (*diagraphie géophysique des puits de pétrole*)

medical linear accelerator
An accelerator that produces high energy photons (x-rays) for therapeutic purposes, by delivering controlled doses of radiation in a collimated beam. (*accélérateur linéaire médical*)

natural background radiation
Radiation that is emitted from naturally occurring radioactive materials in the earth and from cosmic rays. (*rayonnement naturel*)

nuclear energy worker
A person who is required, in the course of the person's business or occupation in connection with a nuclear substance or nuclear facility, to perform duties in such circumstances that there is a reasonable probability that the person may receive a dose of radiation that is greater than the prescribed limit for the general public. (*travailleur du secteur nucléaire*)

nuclear medicine technologist
A medical radiation technologist certified by the Canadian Association of Medical Radiation Technologists. The nuclear medicine technologist works in the field of nuclear medicine and performs various duties, such as preparing and administering radiopharmaceuticals, taking images of different organs and bodily structures, using computers to process data and enhance images, analyzing biological specimens and working closely with all members of the health care team. (*technologue en médicine nucléaire*)

open source
A radioactive nuclear substance that is not contained in a sealed capsule or cover. (*source non scellée*)

portable gauge
A radiation device that is portable, and that enables the nuclear substance contained in it to be used for its radiation properties to measure material property (e.g., material thickness, density, moisture content). (*jauge portative*)

prescribed equipment
Equipment prescribed by section 20 of the *General Nuclear Safety and Control Regulations*. (*équipement réglementé*)

prescribed information
Information prescribed by section 21 of the *General Nuclear Safety and Control Regulations*. (*renseignements réglementés*)

radiation device
A device that contains a nuclear substance and that enables the nuclear substance to be used for its radiation properties for various purposes, such as in industrial radiography, oil exploration, road construction, industrial processes. (*appareil à rayonnement*)

radiation oncologist
A physician licensed by the appropriate provincial or territorial medical regulatory authorities, who specializes in the treatment of cancer patients, using radiation therapy as the main form of treatment. (*radio-oncologue*)

radiation therapist
A medical radiation technologist certified by the Canadian Association of Medical Radiation Technologists. The radiation therapist works in the field of radiation therapy and performs various duties, such as planning treatment details, calculating radiation dose, positioning the patient, operating the medical linear accelerator equipment, and counselling patients on possible side effects from the treatment, among others. (*radiothérapeute*)

radiopharmaceutical
A drug containing a radioactive substance that is used in medical imaging and cancer treatment. (*produit radiopharmaceutique*)

sealed source
A radioactive nuclear substance in a sealed capsule or in a cover to which the substance is bonded, where the capsule or cover is strong enough to prevent contact with or the dispersion of the substance under the conditions for which the capsule or cover is designed. (*source scellée*)

APPENDIX A – REGULATORY PROCESS FOR NUCLEAR SUBSTANCES

The Canadian Nuclear Safety Commission (CNSC) regulates the development, production and use of nuclear energy and the production, possession and use of nuclear substances, prescribed equipment and prescribed information in Canada. Through its licensing, certification and compliance processes, the CNSC ensures that nuclear activities are carried out safely, in order to protect people, their health and the environment. The CNSC also works to ensure that Canadians and Canadian companies implement Canada's international commitments on the peaceful use of nuclear energy.

The CNSC uses a risk-informed regulatory system based on transparency, integration of effort, and a comprehensive risk-informed approach to licensing and compliance. Facilities and operations are ranked according to the health and safety risks posed by their licensed activities. The CNSC's regulatory effort, from a licensing and compliance perspective, is based on this ranking.

The basis of a risk-informed approach is that licensed activities deemed to be of high or medium risk are subject to a higher degree of regulatory control. This control includes more frequent and in-depth inspections, and other activities to verify compliance with the NSCA, regulations, and licence conditions.

Each licensed activity is assigned a weighting factor to develop an overall risk value. A weighting factor is a coefficient assigned to licensed activities to represent their relative importance in terms of risk. Issues considered in weighting include certain aspects such as the form of the material (sealed source, open source, or radiation device), where the material is used (public or controlled facility), and history of problems with the licensed activity. Other weighting factors, such as compliance histories, are used in determining overall risk values for individual licensees. By using risk values and weighting factors, overall risks are calculated for each licensed activity.

The risk-informed regulatory program is designed to have the following outcomes:

- a risk ranking that recognizes the influence of licensee performance
- effective administration of regulatory effort based on the risk ranking by licensed activity
- licensing and compliance activities that are effective, consistent, fully integrated, risk-informed and communicated to stakeholders

The CNSC licensing process starts with an applicant's submission for a new licence, an amendment, a renewal or a revocation of a current licence. CNSC staff assess the application for such things as completeness, radiation safety and training manuals, as well as previous reports of inspections, events and annual compliance.

Licences can be issued either by the Commission Tribunal or by designated officers, who have been authorized by the Tribunal to issue, renew, amend, revoke or replace a licence, as well as to certify and decertify persons and equipment. If a decision is made not to issue a licence, the applicant has an opportunity to be heard by the designated officer or the Commission Tribunal.

A key part of the CNSC's regulatory approach is its compliance program, which monitors licensee conformance with regulatory requirements and licence conditions. This program also aims to maintain a safe nuclear sector and ensure that Canada meets its international obligations on the peaceful use of nuclear energy and materials.

When performing compliance inspections, CNSC staff focus their attention on the following safety and control areas:

Functional Area	**Safety and Control Area**
Management	Organization and management
	Training and qualification
	Operational procedures
Facility and equipment	Facility shielding design
	Facility safety systems
	Maintenance and servicing
Core control processes	Radiation protection
	Environmental protection
	Emergencies and unplanned events
	Security
	International obligations/safeguards
	Packaging and transport

Although the CNSC adopted a four-level compliance rating system in 2008, the use of nuclear substances in Canada is still using a five-letter system. The following table shows the correspondence between the two rating systems:

<table>
<tr><th colspan="2">Four Compliance Ratings Used in Regulating the Use of Nuclear Substances in Canada</th><th colspan="2">Five Compliance Ratings Used in Regulating Major Nuclear Facilities in Canada</th></tr>
<tr><td>A</td><td>Exceeds requirements</td><td>FS</td><td>Fully satisfactory</td></tr>
<tr><td>B</td><td>Meets requirements</td><td>SA</td><td>Satisfactory</td></tr>
<tr><td>C</td><td>Below requirements</td><td>BE</td><td>Below requirements</td></tr>
<tr><td>D</td><td>Significantly below requirements</td><td rowspan="2">UA</td><td rowspan="2">Unacceptable</td></tr>
<tr><td>E</td><td>Unacceptable</td></tr>
</table>

Finally, enforcement actions are required where CNSC staff identify issues of non-compliance. Enforcement measures follow a graduated approach and can include everything from a simple written notification and the requirement for remedial action to the issuance of an order, increased regulatory scrutiny, and revocation of a licence or prosecution.

Enforcement actions are selected based on the impact or potential impact of the non-compliance on the health and safety of persons, security, the environment and international obligations. Also considered are the circumstances that led to and followed the non-compliance, the licensee's compliance record, and any CNSC operational or legal constraints or risks. In all cases, the CNSC follows up on all enforcement actions until they are resolved or completed.

APPENDIX B – CONSOLIDATED DATA: COMPARISON OF SECTORS

B.1 Number of Licences by Sector

Sector	Number of licences as of December 31, 2008	Number of licences as of December 31, 2009	Number of licences as of December 31, 2010
Medical	635	602	593
Industrial	1,703	1,540	1,482
Academic and research	325	293	290
Commercial	303	278	257
Total	2,966	2,713	2,622

B.2 Percentage of Inspected Licences by Sector

Sector	Percentage of inspected licences (2008)	Percentage of inspected licences (2009)	Percentage of inspected licences (2010)
Medical	38%	48%	44%
Industrial	49%	50%	52%
Academic and research	90%	83%	100%
Commercial	36%	58%	62%

B.3 Doses to Workers

B.3.1 2008 Annual Whole Body Doses to Workers

Sector	Number of workers at sampled ACRs	Percentage of workers by dose range (mSv)				
		<0.5	0.5 to 1	1 to 5	5 to 20	>20
Medical	4,033	90.7%	3.1%	6.1%	0.1%	0.0%
Industrial* (without portable gauges)	4,427	93.1%	2.5%	3.7%	0.7%	0.0%
Portable gauge sub-sector	1,717	91.1%		8.6%	0.3%	0.0%
Academic and research**	1,638	93.0%	2.4%	3.8%	0.8%	0.0%
Commercial	489	81.2%	7.6%	10.2%	1.0%	0.0%

B.3.2 2009 Annual Whole Body Doses to Workers

Sector	Number of workers at sampled ACRs	Percentage of workers by dose range (mSv)				
		<0.5	0.5 to 1	1 to 5	5 to 20	>20
Medical	4,611	92.5%	2.6%	4.8%	0.2%	0.0%
Industrial* (without portable gauges)	7,402	93.8%	2.5%	3.2%	0.4%	0.0%
Portable gauge sub-sector	1,270	85.6%		14.1%	0.3%	0.0%
Academic and research**	1,617	94.4%	1.6%	3.5%	0.5%	0.0%
Commercial	540	74.8%	8.3%	15.4%	1.5%	0.0%

* Since portable gauge licensees use a different dose reporting range in their annual compliance reports, their dose data is reported separately from that of other industrial licensees.

** The 2008 and 2009 reports did not provide data for the Class IB particle accelerators. This edition takes these facilities into account.

Note: Totals may not add up, due to rounding.

B.3.3 2010 Annual Whole Body Doses to Workers

Sector	Number of workers at sampled ACRs	Percentage of workers by dose range (mSv)				
		<0.5	0.5 to 1	1 to 5	5 to 20	>20
Medical	4,826	89.5%	3.4%	6.8%	0.3%	0.0%
Industrial* (without portable gauges)	3,752	97.2%	1.4%	1.1%	0.3%	0.0%
Portable gauge sub-sector	641	80.3%		19.0%	0.6%	0.0%
Academic and research**	1,493	94.6%	1.2%	3.6%	0.5%	0.0%
Commercial	784	81.9%	8.0%	9.2%	0.9%	0.0%

* Since portable gauge licensees use a different dose reporting range in their annual compliance reports, their dose data is reported separately from that of other industrial licensees.

** The 2008 and 2009 report did not provide data for the Class IB research particle accelerators. This edition now takes these facilities into account.

Note: Totals may not add up, due to rounding.

B.4 Inspection Ratings for Operational Procedures (in percentage)

B.4.1 2008 Inspection Ratings of Operational Procedures

Sector	Total inspections	Meets or exceeds requirements (A,B)	Below requirements (C)	Significantly below requirements (D,E)
Medical	242	85%	12%	3%
Industrial	838	76%	16%	8%
Academic and research	291	78%	16%	6%
Commercial	110	76%	20%	4%

B.4.2 2009 Inspection Ratings of Operational Procedures

Sector	Total inspections	Meets or exceeds requirements (A,B)	Below requirements (C)	Significantly below requirements (D,E)
Medical	290	78%	18%	4%
Industrial	769	81%	14%	5%
Academic and research	242	74%	22%	4%
Commercial	162	80%	16%	4%

B.4.3 2010 Inspection Ratings of Operational Procedures

Sector	Total inspections	Meets or exceeds requirements (A,B)	Below requirements (C)	Significantly below requirements (D,E)
Medical	258	83%	14%	3%
Industrial	771	81%	15%	4%
Academic and research	400	85%	14%	1%
Commercial	158	92%	7%	1%

B.5 Inspection Ratings for Radiation Protection (in percentage)

B.5.1 2008 Inspection Ratings of Radiation Protection

Sector	Total inspections	Meets or exceeds requirements (A,B)	Below requirements (C)	Significantly below requirements (D,E)
Medical	242	57%	24%	19%
Industrial	837	72%	14%	14%
Academic and research	287	63%	25%	12%
Commercial	110	75%	15%	10%

B.5.2 2009 Inspection Ratings of Radiation Protection

Sector	Total inspections	Meets or exceeds requirements (A,B)	Below requirements (C)	Significantly below requirements (D,E)
Medical	291	64%	17%	19%
Industrial	772	73%	12%	15%
Academic and research	241	67%	23%	10%
Commercial	158	82%	12%	6%

B.5.3 2010 Inspection Ratings of Radiation Protection

Sector	Total inspections	Meets or exceeds requirements (A,B)	Below requirements (C)	Significantly below requirements (D,E)
Medical	254	69%	24%	8%
Industrial	771	78%	15%	7%
Academic and research	393	80%	19%	1%
Commercial	160	89%	9%	2%

Note: Totals may not add up, due to rounding.

B.6 Inspection Ratings for Sealed Source Tracking (in percentage)

B.6.1 2008 Inspection Ratings of Sealed Source Tracking System

Sector	Total inspections	Meets or exceeds requirements (A,B)	Below requirements (C)	Significantly below requirements (D,E)
Medical	2	50%	0%	50%
Industrial	37	87%	5%	8%
Academic and research	12	100%	0%	0%
Commercial	1	100%	0%	0%

B.6.2 2009 Inspection Ratings of Sealed Source Tracking System

Sector	Total inspections	Meets or exceeds requirements (A,B)	Below requirements (C)	Significantly below requirements (D,E)
Medical	16	94%	6%	0%
Industrial	117	91%	4%	5%
Academic and research	46	96%	2%	2%
Commercial	10	90%	0%	10%

B.6.3 2010 Inspection Ratings of Sealed Source Tracking System

Sector	Total inspections	Meets or exceeds requirements (A,B)	Below requirements (C)	Significantly below requirements (D,E)
Medical	7	100%	0%	0%
Industrial	208	88%	8%	4%
Academic and research	55	96%	4%	0%
Commercial	9	100%	0%	0%

B.7 Inspection Ratings for Operational Procedures (in numbers)

B.7.1 2008 Inspection Ratings for Operational Procedures

Sector	Total inspections	A-rated inspections	B-rated inspections	C-rated inspections	D-rated inspections	E-rated inspections
Medical	242	5	200	29	8	0
Industrial	838	0	636	134	44	24
Academic and research	291	0	226	48	17	0
Commercial	110	0	84	22	4	0

B.7.2 2009 Inspection Ratings for Operational Procedures

Sector	Total inspections	A-rated inspections	B-rated inspections	C-rated inspections	D-rated inspections	E-rated inspections
Medical	290	1	226	51	10	2
Industrial	769	0	625	103	33	8
Academic and research	242	0	178	54	9	1
Commercial	162	0	129	27	6	0

B.7.3 2010 Inspection Ratings for Operational Procedures

Sector	Total inspections	A-rated inspections	B-rated inspections	C-rated inspections	D-rated inspections	E-rated inspections
Medical	258	0	215	36	7	0
Industrial	771	0	625	111	33	2
Academic and research	400	0	338	58	4	0
Commercial	158	0	145	12	1	0

B.8 Inspection Ratings for Radiation Protection (in numbers)

B.8.1 2008 Inspection Ratings for Radiation Protection

Sector	Total inspections	A-rated inspections	B-rated inspections	C-rated inspections	D-rated inspections	E-rated inspections
Medical	242	7	131	57	44	3
Industrial	837	0	602	120	90	25
Academic and research	287	0	182	70	32	3
Commercial	110	0	82	17	11	0

B.8.2 2009 Inspection Ratings for Radiation Protection

Sector	Total inspections	A-rated inspections	B-rated inspections	C-rated inspections	D-rated inspections	E-rated inspections
Medical	291	5	182	49	47	8
Industrial	772	0	560	91	102	19
Academic and research	241	0	162	56	20	3
Commercial	158	0	130	18	10	0

B.8.3 2010 Inspection Ratings for Radiation Protection

Sector	Total inspections	A-rated inspections	B-rated inspections	C-rated inspections	D-rated inspections	E-rated inspections
Medical	254	0	174	60	20	0
Industrial	771	0	603	115	45	8
Academic and research	393	0	315	72	6	0
Commercial	160	0	142	14	4	0

B.9 Inspection Ratings for Sealed Source Tracking System (in numbers)

B.9.1 2008 Inspection Ratings for Sealed Source Tracking System

Sector	Total inspections	A-rated inspections	B-rated inspections	C-rated inspections	D-rated inspections	E-rated inspections
Medical	2	0	1	0	1	0
Industrial	37	0	32	2	3	0
Academic and research	12	0	12	0	0	0
Commercial	1	0	1	0	0	0

B.9.2 2009 Inspection Ratings for Sealed Source Tracking System

Sector	Total inspections	A-rated inspections	B-rated inspections	C-rated inspections	D-rated inspections	E-rated inspections
Medical	16	0	15	1	0	0
Industrial	117	0	106	5	5	1
Academic and research	46	0	44	1	1	0
Commercial	10	0	9	0	1	0

B.9.3 2010 Inspection Ratings for Sealed Source Tracking System

Sector	Total inspections	A-rated inspections	B-rated inspections	C-rated inspections	D-rated inspections	E-rated inspections
Medical	7	0	7	0	0	0
Industrial	208	0	184	16	8	0
Academic and research	55	0	53	2	0	0
Commercial	9	0	9	0	0	0

B.10 Reported Events and Incidents

B.10.1 2008 Reported Events and Incidents

Sector	Total	Malfunctioning or damaged devices	Spill, contamination and failed leak test incidents	Missing nuclear substances	Breach of security	Packaging and transport
Medical	27	3	14	5	0	5
Industrial	55	37	0	7	2	9
Academic and research	3	2	0	0	1	0
Commercial	7	0	5	0	0	2
Total	92	42	19	12	3	16

B.10.2 2009 Reported Events and Incidents

Sector	Total	Malfunctioning or damaged devices	Spill, contamination and failed leak test incidents	Missing nuclear substances	Breach of security	Packaging and transport
Medical	6	0	5	0	0	1
Industrial	27	14	0	4	0	9
Academic and research	4	0	0	3	1	0
Commercial	11	0	4	2	0	5
Total	48	14	9	9	1	15

B.10.3 2010 Reported Events and Incidents

Sector	Total	Malfunctioning or damaged devices	Spill, contamination and failed leak test incidents	Missing nuclear substances	Breach of security	Packaging and transport
Medical	12	2	10	0	0	0
Industrial	52	32	1	10	4	5
Academic and research	6	3	3	0	0	0
Commercial	32	2	22	0	0	8
Total	102	39	36	10	4	13

B.11 Enforcement Activities

B.11.1 Orders

Sector	2008	2009	2010
Medical	0	0	1
Industrial	2	7	7
Academic and research	0	0	0
Commercial	1	1	1
Total	3	8	9

B.11.2 Decertification of Exposure Device Operators

Sector	2008	2009	2010
Industrial* **	0	1	2

*** Note: All certified exposure device operators work in the industrial sector – more specifically, in industrial radiography.

APPENDIX C – ABBREVIATIONS

These abbreviations are also defined when first used in the text.

ACR	annual compliance report
ALARA	As Low as Reasonably Achievable
CNSC	Canadian Nuclear Safety Commission
HDR	high dose rate
LDR	low dose rate
mSv	millisievert
NEW	nuclear energy worker
NSCA	*Nuclear Safety and Control Act*
NSSR	National Sealed Source Registry
PDR	pulse dose rate
PET	positron emission tomography
SCA	safety and control area
SSTS	Sealed Source Tracking System