INSPECTION SURVEYS OF X-RAY INSPECTION SYSTEMS: RESULTS OF FIVE YEARS AND IMPLICATIONS ON FUTURE MANAGEMENT OF RADIATION RISKS

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Abstract

Purpose: Until the mid-1980s, federal inspectors performed radiation surveys annually on individual x-ray inspection systems which were operated for security screening purposes in federal facilities nationwide, and problems identified were corrected. The surveys were undertaken because of perceived high radiation risks and a need to ensure worker and public external exposures were minimized. The x-ray inspection systems are federally regulated under the Radiation Emitting Devices (RED) Act[1] and, initially they were assessed by model type against the design, construction and performance criteria specified in the applicable RED regulations (Schedule II, Part IV)[2] and were found compliant. A subsequent study not only demonstrated a much lower radiation risk attributed to a combination of technological advances in x-ray system design with narrow primary beams, high efficiency detectors and image processing capability, but also stressed the need for proper equipment maintenance and continued education of operators and maintenance personnel. Survey frequency was thus reduced to once every 2-3 years in accordance with a 1993 federal operational standard (Safety Code 29)[3]. The radiation protection principles in Safety Code 29 are similar to those of the 1996 International Atomic Energy Agency (IAEA) Basic Safety Standards[4] for the protection against ionizing radiation and the safety of radiation sources. The purpose of this study was to assess inspection-survey data from 1993 through 1997 to elicit guidance toward the future management of radiation risks associated with the operation of such x-ray systems.
Materials and methods: Data were retrieved from an inspection database containing survey records and problems identified on individual x-ray inspection systems operated in federal facilities for 1993 through 1997 inclusive. Problems identified in the records were divided into three groups: hazardous elements which included x-ray system's components or operational conditions or unsafe practices deemed to compromise safety and potentially increase risks; inactions of x-ray inspection systems' owners/users to promote safety and minimize risks; and problems not resolvable through the operational standard.
Results and discussions: Cumulatively from 1993 to 1997, 314 surveys were performed on specific x-ray inspection systems deployed nationwide in various federal facilities, and 115/314 (37%) x-ray inspection systems presented 128 problems. Re-surveys were done on a number of x-ray systems during that time, implying that survey distribution was neither equal annually nor geographically. Recurring problems were observed on some x-ray inspection systems, implying that the respective user facilities were probably incapable of resolving such problems, or there was a lack of post-inspection survey follow-up, or a combination of both. Of the problems identified in the 5-year period, 54/128 (42%) were attributed to unavailability of the operational standard, or its improper use or consultation by x-ray systems' operators and facility personnel; 32/128(25%) were linked to missing

or unclear view of x-ray warning signs; 17/128 (13%) were associated with malfunctioning or blocked x-ray warning lights; 11/128 (9%) were identified as mechanically-related to the lead drapes, or conveyor, or foot-mat switch, or anode/cathode attachment components; 6/128 (5%) were attributed to unsafe acts committed by x-ray systems' operators; 5/128 (4%) were linked to improper functioning of interlocks and switches; and 2/128 (2%) were associated with stray x-radiation emissions not in accord with the regulatory limit, but which did not create any risk to the operator or the public. The most frequent problem identified, including those related to the committed unsafe acts strongly suggest that user facilities need to strengthen their use and consultation of the operational standard in order to prevent an increased risk of radiation exposure. The remaining problems were related to maintenance activities which are inextricably coupled to the x-ray system owner/user responsibilities and which are resolvable through Safety Code 29. Only one x-ray system presented 3 problems, eleven x-ray systems were identified with 2 problems, and the remaining (103) presented 1 problem each. No x-radiation exposure hazard was found, and no adverse safety condition was revealed for which Safety Code 29 did not apply. In terms of problem distribution by facility, 95/314 (30%) x-ray systems were located in airports, and 9% found for each of the years 1993 and 1995; 8/314 (3%) were found at penitentiaries; 6/314 (2%) were operated in military establishments; 3/314 (1%) were found at customs centers; and 1/314 (<1%) each existed at a political site, an international business site and a postal depot. This facility-problem distribution, when coupled with the problems identified, does not support the misconceived notion that safety is being extensively compromised in federal facilities that use such x-ray inspection systems, thereby, elevating radiation risks. On the contrary, fewer problems were identified in recent years, suggesting 1) improved user responsibility to achieve conformity with the operational standard, and 2) a need to work closer with some user facilities and promote more use of the operational standard in developing good administrative, operating and maintenance practices to ensure radiation risks remain low in the workplace. Overall, the evidence does not support a need for federal inspectors to continue inspection surveys, respecting the routine operation of x-ray inspection systems. Instead, it suggests a quality system to be established and implemented by user facilities for the ongoing operation and maintenance of such x-ray systems with appropriate guidance from the regulatory agency. Auditing would constitute part of the process to ensure risks are kept low.

Conclusion: There were no unusual hazards identified or undue risks of x-radiation exposure posed to the x-ray system workers or to the public. The identified problems that could compromise safety were generally related to maintenance activities, which are the x-ray system owner/user responsibilities; fewer problems were found in recent years and are resolvable through Safety Code 29 which promotes good operating and maintenance practices. Safety Code 29 contains the administrative and technical requirements necessary to effectively manage the radiation risks potentially associated with the future operation of these x-ray inspection systems. Based on the results of this review, inspection surveys of such x-ray inspection systems by federal inspectors appear tenuous or unwarranted, and a quality system for the ongoing operation and maintenance of such x-ray systems appear feasible. Regulatory guidance and audits are necessary to assure radiation risks remain low in the workplace in accordance with the operational standard.

References : [1] Department of National Health. *Radiation Emitting Devices Act, Chapter 34 (Suppl. 1)*; Ottawa, Canada: Queen's Printer: Revised Statutes of Canada, Canada Gazette: 1970.

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Introduction

Since their inception in the 1960s to curb hijacks in the aviation industry, x-ray inspection systems have been in widespread use for security screening purposes. They provide useful information for the detection of weapons, explosives, narcotics and contraband in baggage, parcels, packages, incoming mail and freight. Generally, such systems are classed as radiation devices and are designed to generate x-rays in the low-to-medium keV energy region for use in security screening applications. They are federally regulated in Canada under the Radiation Emitting Devices (RED) Act [1] and Regulations (Schedule II, Part IV) [2]. Prior to field use, the x-ray systems were assessed by model type against the design, construction and performance criteria specified in the applicable RED regulations and were found compliant.

Until the mid-1980s, federal inspectors performed radiation surveys annually on individual x-ray inspection systems utilized for security screening purposes in various federal facilities nationwide. Problems identified were corrected at the time of the survey or within a reasonable time ($\leq$30 days) thereafter. The surveys were undertaken because of perceived high radiation risks and a need to ensure worker and public external exposures were minimized.

A subsequent study [3] not only demonstrated a much lower radiation risk attributed to a combination of technological advances in x-ray system design with narrow primary beams, high

efficiency detectors and image processing capability, but also stressed the need for proper equipment maintenance and continued education of operators and maintenance personnel. The latter is reflected in a 1993 federal operational standard, Safety Code 29 [4]. This Safety Code is also used by several provinces but provincial applications are not discussed further herein. Because of improvements in the education of the maintenance worker [5] and system operator, survey frequency was reduced to once every 2-3 years. The operational standard contains radiation protection principles similar to those of the 1996 International Atomic Energy Agency (IAEA) Basic Safety Standards [6] for the protection against ionizing radiation and the safety of radiation sources. The purpose of this study was to assess inspection-survey data from 1993 through 1997 to elicit guidance toward the future management of radiation risks associated with the operation of x-ray inspection systems.

Materials and methods

Data were retrieved from an inspection database developed in-house about a decade ago, and currently used for surveillance planning purposes. It contains survey records and problems identified on individual x-ray inspection systems operated in federal facilities. Problems identified in the records for 1993 through 1997 inclusive were divided into three groups: hazardous elements, which included x-ray system's components or operational conditions or unsafe practices deemed to compromise safety and potentially increase risks; inactions of x-ray inspection systems' owners or users to promote safety and minimize risks; and problems not resolvable through the operational standard.

Results and discussion

The results are summarized in Table 1. The first part of the table shows the number of x-ray inspection systems inspected each year since 1993 to 1997 in federal facilities, and the number of systems that were found to be noncompliant with the requirements of Safety Code 29. The specific items that constituted a Safety-Code deficiency are listed in the remaining part of the table. The last entry summarizes the total numbers of specific identified problems.

Thus cumulatively from 1993 to 1997, 314 surveys were performed on specific x-ray inspection systems deployed nationwide in various federal facilities in Canada, and 115/314 (37%) x-ray inspection systems presented 128 problems considered to be in violation of Safety Code 29. In reviewing the inspection data files it became apparent that re-surveys were done on a number of x-ray systems during that period, implying that survey distribution was neither equal annually nor geographically. Problems were found to recur on some x-ray inspection systems, implying that the respective user facilities were probably unable to resolve such problems, or that there was a lack of post-inspection survey follow-up, or a combination of both. Determining the root cause of the recurrence was not part of this work.

Of the problems identified in Table 1 for the 5-year period considered, 42% (54/128) were attributed to unavailability of the operational standard, or its improper use or consultation by x-ray systems' operators and facility personnel. Next, 25% (32/128) of the problems were linked to missing or unclear view of x-ray warning signs. Thus unsafe acts, such as reaching into the irradiation cabinet to retrieve or insert objects when the x-ray beam is on, are likely to be committed by unsuspecting individuals. About 13% (7/128) of the problems were associated with malfunctioning or blocked x-ray warning lights. Under these conditions it would not be apparent to an individual when the x-ray

beam is on, hence, potentially causing a breach of safety rules and the likelihood of unnecessary radiation exposure. Eight percent (11/128) of the problems were identified as mechanically-related to the conveyor, or the foot-mat switch, or the anode/cathode attachment components on the x-ray tube assembly of some systems' designs, or to the non-replacement of missing or frayed lead drapes. The latter can permit high radiation levels at the entrance or exit ends of the irradiation cabinet which could result in unnecessary exposure to individuals in close proximity to such areas. About 5% (6/128) were attributed to unsafe acts committed by x-ray systems' operators. Unsafe acts constitute lifting the lead drapes when the x-ray beam is on; deliberate covering of the x-ray warning lights; placing heavy objects on the foot-mat switch; and placing open-top or improperly sealed liquid filled containers on top the x-ray machine to name a few. Committing these acts would appear to follow directly from unavailability of the operational standard on-site, or possibly the inaction of the responsible user to ensure operators adopt and implement appropriate safety procedures. Another 5% (6/128) were linked to improper functioning of interlocks and safety switches which, potentially, may not provide a fail-safe condition when necessary. Only 2% (2/128) were associated with stray x-radiation emissions in excess of the regulatory limit. In these cases the x-ray systems were promptly removed from service, and a radiological assessment revealed that no undue radiation risk was posed to the operator or the public. Overall, only one x-ray system presented 3 problems, eleven x-ray systems were identified with 2 problems, and the remaining (103) presented 1 problem each. No x-radiation exposure hazard was found, and no adverse safety condition was revealed for which Safety Code 29 did not apply.

The most frequent problem identified pertains to Safety Code 29 violations. This finding,

including those related to the committed unsafe acts, strongly suggest that user facilities need to strengthen their use and consultation of the operational standard in order to prevent an increased risk of radiation exposure. The remaining problems were related to maintenance activities which are inextricably coupled to the x-ray system owner/user responsibilities and which are resolvable through the administrative requirements in Safety Code 29.

Roughly, two-thirds of all the x-ray inspection systems inspected were compliant with the operational standard, and the remaining one-third presented problems (Table 1). In terms of problem distribution by facility, 30% (95/314) of the x-ray systems were located in airports, and 9% found for each of the years 1993 and 1995; 3% (8/314)) were found at penitentiaries; 2% (6/314) were operated in military establishments; 1% (3/314)) were found at revenue customs centers; and less than 1% (1/314) at other facilities, comprising a political site, an international business site and a postal depot. This facility-problem distribution, when coupled with the problems identified in Table 1, does not support the misconceived notion that safety is being extensively compromised in federal facilities that use such x-ray inspection systems, thereby, elevating radiation risks. On the contrary, fewer problems were identified in 1996 and 1997, suggesting 1) improved user responsibility to achieve conformity with the operational standard, and 2) a need to work closer with user facilities and promote more use of the operational standard in developing improved administrative, operating and maintenance practices to ensure radiation risks remain low in the workplace. Overall, the findings do not support a need for federal inspectors to continue inspection surveys, respecting the routine operation of x-ray inspection systems. However, what the findings do suggest is a quality system to be established and implemented by user facilities for the ongoing operation and maintenance of such

x-ray inspection systems with appropriate guidance from the regulatory agency to ensure risks are kept low. Auditing would comprise an integral part of this process.

Conclusion

During the period from1993 to 1997, there were no unusual hazards identified or undue risks of x-radiation exposure posed to the x-ray system workers or to the public. The identified problems that could compromise safety were generally related to maintenance activities, which are the x-ray system owner/user responsibilities; fewer problems were found in recent years and are resolvable through Safety Code 29 which promotes good operating and maintenance practices. Safety Code 29 contains the administrative and technical requirements necessary to effectively manage the radiation risks potentially associated with the future operation of these x-ray inspection systems. Based on the results of this review, inspection surveys of such x-ray inspection systems by federal inspectors appear tenuous or unwarranted, and a quality system for the ongoing operation and maintenance of such x-ray systems should be developed and implemented by user facilities with guidance from and audits by the regulatory agency to assure radiation risks remain low in the workplace in accordance with the operational standard.

References

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Table1: Summary of problems identified on x-ray inspection systems inspected from 1993 to 1997 in federal facilities.

X-ray inspection systems inspected			Problems identified							
Year	Total	Number noncompliant[a]	Safety Code 29	X-ray warning sign	X-ray warning light	Mechanical[b]	Interlocks/ Switches	Unsafe acts	Radiation emission	Total
1993	92	30	-	Air (21)[c]	Air (5)	Air (3)	-	Air (1)		(30)
1994	53	21	Air (14) Rev (2) Mil (2)	Air (1)	Air (1*)[d]	Air (1*)[d]	-	Air (3)	Air (1*)[d] Air (1)	(26)
1995	101	38	Air (8) Pen (6) Mil (2) CaP (1) Rev (1)	Air (8)	Air (4)	Air (7)	Air (2)	Air (1)	-	(40)
1996	49	22	Air (13) Pen (2) IntA (1)	Air (2)	Air (6)	-	Air (3)	Air (1)	-	(28)
1997	19	4	Air (2)	-	Mil (1)	-	Mil (1)	-	-	(4)
1993 to 1997	314	115	(54)	(32)	(17)	(11)	(6)	(6)	(2)	(128)

[a] With respect to the requirements of Safety Code 29, the operational standard.
[b] Includes the lead drapes component.
[c] Initial characters refer to facility code, and the value in parentheses refers to the number of x-ray inspection systems presented with the problems identified.
[d] Identifies the three problems found on the single x-ray inspection system.