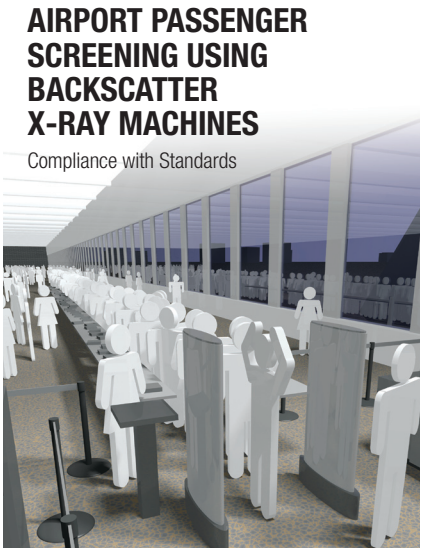
REPORT IN BRIEF

September 2015

National Materials and Manufacturing Board
Nuclear and Radiation Studies Board

Airport Passenger Screening Using Backscatter X-Ray Machines: Compliance with Standards



The Transportation Security Administration (TSA) has employed two types of advanced imaging technology (AIT) to screen travelers at airports: millimeter wave and X-ray backscatter systems. Some stakeholders have raised concerns about the health effects of exposure—both of travelers and operators—to ionizing radiation emitted by previously used X-ray backscatter systems. This report examines the radiation exposures resulting from the legacy system, Rapiscan Secure 1000, and a second generation system, AS&E SmartCheck, to determine if those exposures comply with the relevant health and safety standard and whether the two machines are adequately designed to avoid over exposures. In its work, the authoring committee reviewed previous investigations of X-ray backscatter AITs, measured the beams of both systems, tested and analyzed interlocks and failure modes, and performed detailed calculations of traveler exposures using digitized human phantoms.

This report finds that both machines, as investigated by the committee, comply with the current applicable radiation exposure standard under normal operation and under the worst case scenarios of scanner failure, regardless of the age or gender of the traveler. The report does not evaluate if compliance with the standard appropriately protects human health. A separate and upcoming Academies study will examine millimeter wave AITs.

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BACKGROUND

According to TSA, AIT systems provide enhanced security benefits by detecting both metallic and non-metallic threat items including weapons, explosives, and other concealed objects on passengers that would not be detected by walkthrough metal detectors. TSA deployed the X-ray backscatter AIT, specifically the Rapiscan Secure 1000 unit manufactured by Rapiscan Systems, in airports in 2008. TSA subsequently removed Rapiscan Secure 1000 units from all airports by June 2013 because of the manufacturer's inability to develop privacy software, as

mandated by Congress. As part of a commitment made to the Senate, the Department of Homeland Security, of which TSA is a component, requested in 2012 that the National Academies of Sciences, Engineering, and Medicine examine the radiation exposures resulting from both the Rapiscan and American Science and Engineering Inc. (AS&E) X-ray backscatter systems.[1] Specifically, the Department wanted the Academies to determine if the systems comply with applicable health and safety standards for public and occupational exposures to ionizing radiation and if system design, operating procedures, and maintenance procedures are appropriate to prevent over exposures of travelers and operators to radiation. While TSA had no deployed X-ray backscatter machines at the time of this report's publication, the agency could deploy second-generation X-ray backscatter AITs soon, because such machines, manufactured by AS&E, are under evaluation.

Rapiscan Secure 1000 X-ray backscatter machine. Image Credit: Scott Olson

ANSI/HPS STANDARD

X-ray backscatter AITs must conform to the American National Standards Institute/Health Physics Society (ANSI/HPS) Accredited Standards Committee N43 (Equipment for non-medical radiation applications) N.43.17 standard. The standard provides guidelines for both manufacturers and users of the systems and covers dose to subject, interlocks, operational procedures, and information to be provided to the subject by the operators. It also limits the dose per screening to 250 nanosievert (nSv), called the reference effective dose. The standard does not issue different limits for subgroups of the general population, such as pregnant women and children, implying that the 250 nSv dose limit offers sufficient protection to them as well.

[1] An independent investigation of the safety of X-ray backscatter AIT was also mandated in the Consolidated and Further Continuing Appropriations Act in 2012.

DOSE REPORTED IN PREVIOUS INVESTIGATIONS

The dose received from the X-ray backscatter AIT has been tested in a number of investigations, including the U.S. Food and Drug Administration, Johns Hopkins University Applied Physics Laboratory, U.S. Army Public Health Command, National Institute of Standards and Technology, and the American Association of Physicists in Medicine. These investigations made measurements of the radiation emitted by the machines and calculated the dose to the whole body, which was then compared to the ANSI/HPS standard. This report reviews and summarizes some of the results of these investigations.

Individual Being Screened

FINDING: Previous radiation dose investigations employed different methodologies and instrumentation to estimate the dose delivered by Rapiscan Secure 1000 X-ray backscatter AITs. These investigations generally agreed that the radiation exposure per screening to an average passenger is about a factor of ten below the limit of 250 nanosieverts per screening (nSv/screen), set by the ANSI/HPS standard.

Individual Outside the Screening Area

FINDING: Measurements of radiation outside the inspection area have generally been made with detectors that are calibrated for X-ray energies higher than those scattered from a passenger being scanned by the Rapiscan Secure 1000 X-ray. As a result, the detectors may indicate lower dose than is actually present. The detectors have sometimes failed to distinguish a signal from the background radiation.

RECOMMENDATION: To estimate X-ray radiation exposure outside the inspection area, measurements should be made with detectors calibrated for X-ray energies below the maximum for the system's X-ray tube and for the radiation levels expected. Use of detectors that are appropriate for other applications but not ideal for measuring dose in a X-ray backscatter system may result in inaccurate measurements.

DOSE REPORTED IN THIS STUDY

At the Department of Homeland Security's request, the report's authoring committee contracted with consultants to make dosimetry and beam characteristics measurements for both the Rapiscan Secure 1000 and the AS&E SmartCheck.

Individual Outside the Screening Area

FINDING: Using appropriate detectors, the estimated values of the radiation outside the inspection area that might affect a bystander are so low as to be statistically indistinguishable from the background radiation.

Individual Being Screened

The report's approach in examining dose to the individual being screened differs from that of previous investigations in two ways: 1) it made use of sensitive detectors with tissue equivalent phantoms to verify beam intensity, X-ray quality, and penetration; and 2) it performed computations using estimates of beam intensity, scanning geometry, and digitized human phantoms that have realistic dimensions and morphology. Based on these improvements in approach, the report presents the following key findings:

FINDING: Under routine operations, the computed effective doses using computational X-ray sources and scanning geometries coupled with the digitized hybrid phantoms are similar to the ANSI Reference Effective Dose and an order of magnitude below the limit of 250 nSv/screen.

FINDING: The agreement between the estimated dose results from the NRC study and the results from earlier studies confirms that the calculations performed in the previous studies were adequate to establish compliance with effective dose limits recommended in the ANSI/HPS standard.

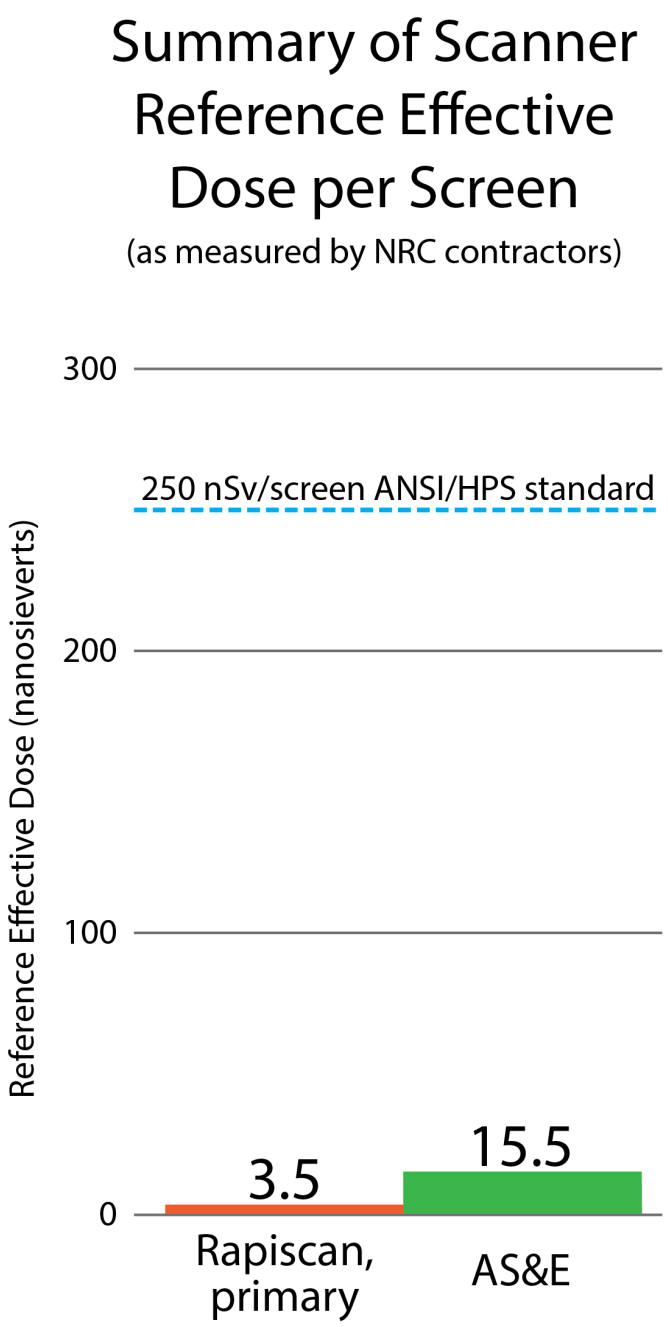
The report also presents a number of more specific findings with regard to individuals being screened. Three of these specific statements are included here, as they address cases of special concern by some stakeholders.

- The absorbed dose per screen to the developing fetus at any of the three stages post conception is less than 0.0002% of the recommended limit for radiation protection of the fetus during the entire gestation period.
- The absorbed dose to the epithelial layer of radiosensitive cells in the skin is not significantly elevated (~1.6%) compared to the average dose to the skin.
- The dose received by the lens of the eye, skin, or female breast during a stationary beam of X-rays for the duration of the scan were at least 2 orders of magnitude below thresholds where tissue injury might occur.

SYSTEM DESIGN EVALUATED IN THIS STUDY

The committee was able to inspect the interior of both the Rapiscan Secure 1000 and AS&E machines. However, due to some limitations on inspection, the committee was unable to unequivocally determine whether the machines have adequate operating safety interlocks under every imaginable situation. With these limitations noted, the report presents several key findings and recommendations regarding the design safety of the two machines.

FINDING: It appears that the X-ray backscatter systems adhere to the recommended safety mechanisms described in the ANSI/HPS standard.



Reference Effective Dose measurements for a single scan by the Rapiscan Secure 1000 and AS&E SmartCheck X-ray backscatter machines compared with the ANSI/HPS limit. For complete measurements see Chapter 7 of the full report.

FINDING: Acceptance tests and periodic inspection tests guided by the safety inspection forms previously used during deployment are sufficient to meet the indicators, controls, and safety interlocks requirements of the ANSI/HPS standard.

FINDING: Equipment manufacturers recommend that a test piece be scanned daily to evaluate proper operation of the machine, because this ensures that many of the needed safety system requirements in ANSI/HPS standard work properly. The committee agrees with this recommendation but was unable to determine if this was being done because of the current lack of X-ray backscatter AITs in the field, at commercial airports.

RECOMMENDATION: Any future testing procedures should at a minimum continue to follow the indicators, controls, and safety interlocks requirements of the ANSI/HPS standard, or similar testing procedures, and include daily verification of safety parameters by a test piece.

FINDING: Based on the committee's review and test of the Rapiscan Secure 1000's interlocks, the committee was unable to identify any circumstances where an accidental failure or deliberate reconfiguration of the machine could result in either a person being screened or the operator receiving an effective dose larger than that from a normal screening.

FINDING: Based on the committee's inspection of the AS&E system, with the AS&E representative present, the committee was unable to identify any circumstances where an accidental failure or deliberate reconfiguration of the machine could result in either a person being screened or the operator receiving a larger X-ray dose than the normal screening dose.

FINDING: Given the results obtained by the committee on radiation measurements and calculations for the X-ray AIT machines investigated, the screening of an individual would need to extend more than 60 seconds for that individual to be exposed to radiation that exceeds the ANSI/HPS standard. In comparison, a typical screen takes about 6 seconds.

RECOMMENDATION: Future X-ray AITs should have some independent mechanism to ensure that the AIT does not screen any person for longer than the time needed to acquire the appropriate image while keeping radiation exposure compliant with the safety principle of ALARA (As low As (is) Reasonably Achievable).

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