National Institute of Standards and Technology
Assessment of Radiation Safety and Compliance with ANSI N43.17-2002
Rapiscan Dual Secure 1000 Personnel Scanner

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This report is based on a review of the [redacted] report of compliance, dated June 5, 2008; information received by Rapiscan; and measurements made at the FDA/CDRH labs on the single-source version of the Secure 1000 (SN S701201213) in April, 2006.

Summary

The dual Secure 1000 as described by Rapiscan and tested by [redacted] conforms to all the dose limitation requirements of ANSI N43.17-2002. For the screened individual the dual Secure 1000 is at least as safe as the single-source version as tested at FDA/CDRH in 2006. That is, an adult person being scanned with the Dual Smart Check receives an effective dose no higher than a person receiving a front and a back scan using the single-source Smart Check. Some recommendations are provided to keep employee exposures no higher than necessary. The effect of a curved front panel was also considered.

Assessment of effective dose to the screened individual

The [redacted] report indicates a skin entrance exposure of 5.75 μrem per scan at the reference point (i.e. 30 cm from the surface of one, active, unit and about 1 m from the floor). It appears that for the purpose of this measurement the second x-ray unit was deactivated. The measurement is consistent with the previous measurement of 9.6 μrem/scan performed at CDRH on the single-source Secure 1000 and modifications made to the scan mechanics of the dual system to produce a higher throughput (e.g. faster scan). Consequently, the effective dose received from a dual, front and back, scan using the Dual Secure 1000 is lower than the effective dose received from the equivalent two scans using the single-source Smart Check. The HVL measurement by [redacted] indicates an energy spectrum similar to that of the single source version, therefore the following conclusions can be made:

Reported exposure at 30 cm due to only one source: ~ 5.8 μR[1]
Exposure to effective dose conversion, front scan: ~ 0.25 rem/R
Exposure to effective dose conversion, back scan: ~ 0.09 rem/R
Adult effective dose from the front scan alone: ~ 1.5 μrem
Adult effective dose from the back scan alone: ~ 0.5 μrem
Adult effective dose from a dual, front and back, scan: ~ 2 μrem

[1] Exposure in roentgens, R, is roughly equal to entrance skin dose in rems. Both the roentgen and the rem are considered obsolete units by the international radiation protection community. The S. I. unit of equivalent dose is the sievert, Sv. One Sv is equal to 100 rem.

The 10 μrem dose limit of the ANSI N43.17-2002 standard applies to the effective dose from the front scan alone. The adult effective dose from the front scan alone, as measured by [redacted] is 5.8 μrem, so the dual Secure 1000 easily meets the ANSI requirement. It should be noted that measurements made by [redacted] in 2006 using the same technique on the single-source version were more conservative than the CDRH measurements by about 40% (albeit different production units were tested). This is due to the rate dependence correction applied by [redacted] which may be too conservative.[2] So it is likely that the current estimates may also be conservative.

Cabinet shielding

No data was provided on radiation "leakage" emissions from the two cabinets. These are not expected to be significantly different than the single-source version of the Secure 1000, except for the area opposite the inspection zone, where the primary beam from the opposite unit is transmitted. Even in this area, by virtue of distance alone, the dual Secure 1000 is expected to meet the ANSI shielding requirement of 0.25 mrem in any one hour at 30 cm from any surface (see also <u>Radiation emissions from the cabinet enclosure below</u>).

Inspection Zone

The inspection zone, as defined in ANSI N43.17-2002, is the area where the dose rate is greater than 2 mrem in any one hour. For this case, the entire area between the two units should be considered the inspection zone.

Assessment of effective dose to workers and bystanders

<u>Primary beam</u>

Each of the two units acts as a beam stop for the other unit. However, the geometry is such that the scanning beam emanating from one unit overshoots the cabinet of the other unit by a few inches on each side. The [redacted] measurements just outside the corner of one cabinet, in the area of the overshoot, are consistent with the primary beam intensity at that distance and angle. The overshoot results in four radiation beams each along a line intersecting the focal spot of one x-ray tube and an edge of the opposing cabinet face. The single-source unit tested at CDRH had a 60 inch wide beam stop that was positioned roughly at the location of the second cabinet of the dual system. The beam stop comfortably intercepted the entire scan beam. The Rapiscan drawings of the dual system show each unit to be about 54 inches wide, including the handles

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[2] Most of the recombination loss is expected to be from volume recombination, occurring over the ion chamber volume as ions are collected. The ion densities over the IC volume are better described by the exposure rate measured by the chamber than by the instantaneous rate inside the pencil beam. Moreover, a correction using measurements at different distances should not be based on the inverse square law because the law does not hold in this case. The recombination loss of the Radcal 1800cc ion chamber was assessed at CDRH in conjunction with the testing of the single-source Secure 1000. Using a collecting potential technique the ion recombination loss was found to be negligible.

overhanging on each side. If the handles each overhang 2 inches, then a 5 inch wing shield on each side would provide the equivalent coverage of the back plate. The shields can be made narrower if they are rotated perpendicular to the edge of the scanning radiation field.

In the absence of the four shields described, the exposure at the cabinet corners was measured by [redacted] to be 0.68 μR/scan. The width of the overshoot beam is expected to increase linearly with distance from the focal spot of the x-ray tube. The exposure is expected to decrease roughly as the inverse of the distance from the focal spot. That means that the exposure would be about half, or 0.34 μR/scan, at roughly 1.5 m from the corner being overshot by the scanning beam (distance measured along the beam direction). [redacted] also tested a 3 inch steel shield placed at the corner and found it to be effective (however, because of the size of the ion chamber used it is uncertain if the shield intercepted the entire beam, since measurements outside the shield may include a small contribution from the primary beam).

If wing shields are not used, either the occupancy of areas traversed by the four overshoot beams or the scan rate should be controlled to be made consistent with the recommended annual (skin entrance) dose limit of 100 mrem to employees. [redacted] estimate of 0.68 μR/scan applies to a beam about 5 inches wide. For the purpose of calculating whole body skin entrance exposure for people stationed in the zone of interest but with some freedom of movement, it is reasonable to decrease the estimate by a factor of two to 0.34 μR/scan. This means that the scan rate averaged over 2000 full-time hours should not exceed about 150 scans/h. Alternatively, assuming the maximum sustainable scan rate to be 240 scans/h, no employee should be at this location more than about 3/5 of full time. Given these numbers it can be argued that shields are not required. It should be noted, however, that this analysis is based on a measurement that is approximate. A set of four wing shields would provide a sense of security and preclude further analysis.

Scatter radiation

No data was received regarding radiation scattered from the screened individuals into adjacent areas. For the single-source unit previously tested at CDRH the scatter directly to the side of the screened person, at 30 cm from plane of the side of cabinet, was about 0.20 μR/scan. Applying a scaling factor of 1.2 (i.e. [2 x 5.8]/9.6 based on the dual and single units measured reference exposures) this becomes about 0.24 μR/scan. For 180 scans/h and 2000 hours occupancy per year this translates to an integrated exposure of about 86 mR per year, which is below the ANSI recommended 100 mrem. However, consistent with the principle of ALARA (keeping exposures as low as reasonably achievable) it is recommended that employees do not routinely occupy the immediate open area next to the inspection zone.

Radiation emissions from the cabinet enclosure

No data was provided on radiation "leakage" emissions from the two cabinets. These are not expected to be significantly different than the single-source version of the Secure

1000, except for the area opposite the inspection zone, where the primary beam from the opposite unit is transmitted. It is recommended that some measurements be performed in the center of the back of the cabinet, where the beam from the opposite unit is not shielded by the vertical detectors. Particular attention should be given to vent holes and spaces the cracks around the cabinet doors. Note that in the absence of any shielding the exposure in this region would be about 3 μR/scan.

Recommendations

It is recommended that the cost effectiveness of wing shields be assessed in view of the considerations above.

Although it is unlikely that the annual permissible dose be exceeded, it is recommended that full-time employees do not occupy the immediate area next to the inspection zone at each side of the opening between the two cabinets for long periods of time. This also applies to the adjacent areas beside each cabinet if wing shields are not implemented. This is especially important for heavy machine use.

Exposure measurements should be made at the back of each unit while the opposite unit is scanning to verify proper shielding of the primary beam.

Other considerations

There was a design change to the front panel of the Secure 1000 since the [redacted] test. The change consists of replacing the flat front panel with a curved front panel (see attachment 3). Assuming that there is no significant difference in the composition and thickness of the material, this modification is not expected to significantly affect the dose distribution. However, because of the curvature, the reference measurement point is now a few inches closer to the x-ray source (i.e. 30 cm from the surface of the front panel at the center). The effect of this is that the subject dose, for the purpose of the ANSI standard, will increase. The increase is roughly inversely proportional to the distance from the x-ray anode.[3] That is, if the curvature moves the reference point inward by 10% of the distance from the anode, then the subject dose will increase by about 10%. The amount of curvature does not seem enough to affect conformance with the ANSI standard. However, unrestricted access to points extremely close to the x-ray tube is not recommended.

Attachments

1. [redacted] report
2. Rapiscan drawings and specs.
3. Photo of latest version

[3] This is true as an average dose received by the skin surface. Points on the skin will receive different doses, particularly in regions where the sweeps of the x-ray beam do not touch or overlap.