NRC-RADTRAN v1.1 Updates to RADTRAN 6 Technical Manual

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1 Introduction

Certain updates included in NRC-RADTRAN version 1.1 modify equations found in the *RADTRAN 6 Technical Manual*. In lieu of releasing an updated technical manual, these are documented in the section below. Additionally, one erratum in the document was identified and corrected.

2 Updates

2.1 Equation 23 (page 24) [Code Update]

By comparing the results with other numerical integration methods, it was determined that the integrated form of Equation 22 used to calculate the dose to individuals along the transport link was incorrect. Therefore, Equation 23 on page 24 has been updated to the following:

$$I'(x) = \frac{\text{BSKIN}_{x\cdot\mu_s}}{x} + (a1_s + a3_s \cdot x^2) \cdot \text{BESK0}_{x\cdot\mu_s} + \left(a2_s \cdot x + \frac{a3_s \cdot x}{\mu_s}\right) \cdot \text{BESK1}_{x\cdot\mu_s}, \tag{1}$$

where

x = value passed from function I' from GAUS8; x ranges from min to d,

r = variable of integration (distance from source to receptor) (m),

$B(\mu r)$ = buildup factor for the medium through which the radation is travelling,

μ_s = attenuation coefficient for gamma radiation if $s = G$ or neutron radiation if $s = N$,

a_{1s}, a_{2s}, a_{3s} = unitless coefficients for gamma radiation if $s = G$ or neutron radiation if $s = N$,

BSKIN = SLATEC routine computing repeated integrals of the modified K-zero Bessel function for argument $(x\mu_s)$,

BESK0 = SLATEC routine computing the modified Bessel function of the third kind, order zero, for argument $(x\mu_s)$,

BESK1 = SLATEC routine computing the modified Bessel function of the third kind, order one, for argument $(x\mu_s)$.

2.2 Equation 35a (page 33) [Manual Erratum]

The equation for the traffic factor that accounts for all vehicles except those passing the RAM shipment included the average velocity of the link (V_L). It appears this term was incorrectly added into the RADTRAN 6 Manual; in the RADTRAN 4 manual, the traffic factor definitions were not multiplied by the velocity. Therefore, Equation 35a should read as the following:

$$F_1 = 2Y_V, \tag{2}$$

for

$$Y_V = FG \cdot P_{V,G} + FN \cdot P_{V,N}, \tag{3}$$

where

FG, FN = fraction of gamma and neutron radiation, respectively,

$P_{V,G}, P_{V,N}$ = value defined in Equation 31 on page 32 for the integral shown in Equation (5) below.

2.3 Equation 35b (page 33) [Code Update]

In RADTRAN 3, The formula for the passing lane doses used the following integral:

$$\int_x^{2V} \frac{1}{r^2} dr = \frac{1}{x} - \frac{1}{2V}, \tag{4}$$

where

x = minimum perpendicular distance to adjacent vehicle,

V = average velocity (m/s).

RADTRAN 4 added attenuation and buildup, resulting in the following change to the integral:

$$\int \frac{e^{-\mu r} B(\mu r)}{r^2} dr. \tag{5}$$

Therefore, RADTRAN should be calculating

$$\int_x^{2V} \frac{e^{-\mu r} B(\mu r)}{r^2} dr = \int_x^{\infty} \frac{e^{-\mu r} B(\mu r)}{r^2} dr - \int_{2V}^{\infty} \frac{e^{-\mu r} B(\mu r)}{r^2} dr. \tag{6}$$

However, RADTRAN 6 took the result of the old integration for x. This was corrected in version 1.1. That is, Equation 35b was updated to the following:

$$F_2 = FG * (P_{\frac{x}{2},G} - P_{V,G}) + FN * (P_{\frac{x}{2},N} - P_{V,N}), \tag{7}$$

where $P_{\frac{x}{2},S}$ is the evaluation of Equation 31 on page 33 with $\frac{x}{2}$ substituted for V. See Section 2.2 for an explanation on why the velocity factor V_L was removed.

2.4 MEI Calculation [Code Update]

The equation for the maximally exposed individual is not actually given in the RADTRAN 6 manual. NRC-RADTRAN version 1.0 followed the methodology described in the RADTRAN 4 manual. NRC-RADTRAN

version 1.1 standardized the implementation of buildup for both neutron and gamma for all dose calculations. The updated equation for the MEI dose is given below:

$$\mathrm{MEI} = \frac{2.0 \times 10^{-6} \cdot (FG \cdot I'_G(x) + FN \cdot I'_N(x)) \cdot \mathrm{PPS} \cdot \mathrm{SPY} \cdot k_O \cdot \mathrm{DR}_p}{V} \tag{8}$$

where

$I'_S(x)$ = function whose value is defined in Section 2.1 of this document,

PPS = number of packages per shipment,

SPY = number of shipments,

k_O = point-source package shape factor,

DR_p = package dose rate (mrem/hr),

x = perpendicular distance of the individual from the shipment path (30 m),

V = average velocity of the shipment passing that point (24 km/hr).