External Dose Assessments

Nuclear Secured / Radiation Safety

NS-RS-PR-503, 0

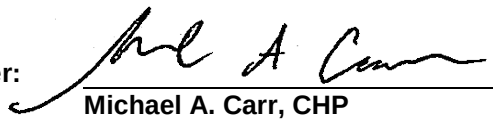
Date Effective: 11 August 2019

History and Approvals

History

Revision	Intent Y/N	Purpose description
0	Y	For Issue (Rebranded CS-RS-PR-017)

Approvals

Preparer: 

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8/5/2019
Date

Approver: 

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8/14/2019
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1. Purpose and Scope

1.1. Purpose

The purpose of this procedure is to provide guidance for performing external dose assessments and documenting the results in accordance with Nuclear Regulatory Commission (NRC) regulations and recommendations. Specific circumstances in which an external dose assessment may be required include:

- Personnel skin contamination(s),
- Hot particle contamination,
- Lost or damaged dosimetry,
- Improperly worn dosimetry,
- Dosimetry off-scale,
- Declaration of pregnancy, and
- Suspect monitoring results.

1.2. Scope

This procedure applies to all project personnel and subcontractors at field project sites where Nuclear Secured (NS) is responsible for personnel monitoring under the NS Radiation Protection Program (RPP).

2. References

2.1. Health Physics Journal – *Electron Dose-rate Conversion Factors for External Exposure of the Skin From Uniformly Deposited Activity on the Body Surface*, Kocher D C and Eckerman K F, Volume 53(2), 135-141, August 1987

2.2. 10CFR20 *Energy – Standards for Protection Against Radiation, Subpart A- General Provisions*

2.3. 10CFR20 *Energy – Standards for Protection Against Radiation, Subpart C- Occupational Dose Limits*

2.4. US NRC, Regulatory Guide 8.13, *Instruction Concerning Prenatal Exposure*

2.5. US NRC, Regulatory Guide 8.40, *Methods for Measuring Effective Dose Equivalent from External Exposure*

2.6. US NRC, Information Notice No. 90-48, *Enforcement Policy for Hot Particle Exposure,* August 1990

2.7. US NRC, NUREG/CR-6918, *Varskin 5: A Computer Code for Skin Contamination Dosimetry*, Rev. 2, July 2014

2.8. AE-SH-PR-002, *Incident Reporting and Notification*

2.9. NS-RS-PG-001, *Radiation Protection Program*

2.10. NS-RS-PR-102, *Project Records Management*

2.11. NS-RS-PR-204, *Personnel Frisking and Decontamination*

2.12. NS-RS-PR-500, *Personnel Monitoring*

3. General

3.1. Definitions

3.1.1. *Absorbed dose* – The energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad and the gray (Gy).

3.1.2. *Deep-dose equivalent (H_d)* – The external whole-body exposure or dose equivalent to a tissue depth of 1 cm (1000 mg/cm^2).

3.1.3. *Dose* - A generic term meaning absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined elsewhere in this section.

3.1.4. *Dose Equivalent (H_T)* – The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and Sievert (Sv).

3.1.5. *Effective Dose Equivalent (H_E)* – The sum of the products of the dose equivalent to the organ or tissue (H_T) and the weighting factors (W_T) applicable to each of the body organs or tissues that are irradiated ($H_E = \Sigma W_T * H_T$).

3.1.6. *External dose* – The portion of the dose equivalent received from radiation sources outside the body.

3.1.7. *Extremity* – A person's hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

3.1.8. *Gray (Gy)* – The SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule per Kilogram (100 rad).

3.1.9. *Hot particle* - A discrete, high specific activity radioactive particle that is typically less than 0.1 cm in any dimension (and normally insoluble in water).

3.1.10. *Individual Monitoring* – (1) The assessment of dose equivalent by the use of devices designed to be worn by the individual; (2) The assessment of committed effective dose equivalent by bioassay or by determination of the time-weighted air concentrations to which and individual has been exposed, i.e, DAC-hours; (3) The assessment of dose equivalent by the use of survey data.

3.1.11. *Individual monitoring device* - A device designed to be worn by a single individual for the assessment of dose equivalent, such as film badge, thermoluminescent dosimeter (TLD), pocket ionization chambers, and personal ("lapel") air sampling devices.

3.1.12. *Lens dose equivalent (LDE)* - The external exposure to the lens of the eye taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm2).

3.1.13. *Monitoring* – The measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive materials and the use of the results of these measurements to evaluate potential exposures and doses.

3.1.14. *Quality Factor (Q)* – The modifying factor used to derive dose equivalent from absorbed dose. Quality factors are listed in the tables as provided in 10 CFR 20.1004.

3.1.15. *Rad* - The special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram (0.01 gray).

3.1.16. *Rem* - The special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor, Q (1 rem = 0.01 Sievert).

3.1.17. *Sievert (Sv)* – The SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in Sieverts is equal to the absorbed dose in grays multiplied by the quality factor, Q (1 Sv = 100 rem)

3.1.18. *Shallow dose equivalent (H_s)* - The external exposure to the skin of the whole body or the skin of an extremity taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm^2).

3.1.19. *Stochastic Effects* – Health effects that occur randomly and for which the probability of the effect occurring, rather than the severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

3.1.20. *Whole body* – A person's head, trunk (including male gonads), arms above the elbow, and legs above the knee.

3.2. Responsibilities

Depending on personnel qualifications and the size of the project, project personnel may be assigned multiple roles and/or responsibilities.

3.2.1. NS Radiation Safety Officer

The NS Radiation Safety Officer (RSO) maintains and oversees the implementation of the NS RPP. The RSO shall ensure that radiation safety, radioactive materials management, and radiological operations procedures and programs are kept up to date such that they comply with current regulations and incorporate current and relevant industry practices and regulatory guidance. The RSO is also responsible for the review of all personnel exposure records and to ensure exposures are maintained below regulatory and NS administrative limits as applicable.

3.2.2. Project Manager

The Project Manager (PM) is responsible for ensuring that the proper program procedures and programs are implemented on the project site as required by customer agreements and contracts. The PM is responsible for ensuring that these programs and procedures are properly incorporated into project specific plans and procedures. The PM is responsible for ensuring that the NS RPP and client programs and procedures, as applicable, are available for use by project personnel.

3.2.3. Project Health Physicist

The Project Health Physicist (PHP) is responsible for assisting the RSO in providing health physics support to the PM and Radiation Protection Supervisor (RPS). This includes technical support, such as the review of exposure records and the performance of external dose assessments, to ensure procedural and regulatory compliance and to ensure that the project-specific Data Quality Objectives (DQOs) are met.

3.2.4. Radiation Protection Supervisor

The Radiation Protection Supervisor (RPS) is responsible for implementing the NS RPP at the project location and oversees project personnel in regards to radiation and respiratory protection and reports directly to both the PM and the RSO. The RPS shall support the PHP and the RSO in all external dose assessments as necessary and to provide the necessary supporting documentation.

3.2.5. Project Personnel

All project personnel are responsible for wearing the required personnel monitoring devices as directed by the RPS and as specified in the RWP. In the event of any loss or damage to personnel monitoring devices or any skin contamination, they shall report it to the RPS for proper follow-up, notifications and the performance of an external dose assessment as required.

3.3. Precautions and Limitations

3.3.1. When using an SRD to estimate personnel dose, be aware that as a general rule, they are highly energy dependent.

3.3.2. Hot particles are mobile and can move due to static charges. Secure hot particles using tape or other means.

3.3.3. Surveys of skin or clothing contamination should be done at a distance of about one cm using a beta sensitive instrument. The gamma contribution to skin dose is generally only a few per cent. Due to their low penetrating power, alpha particles and tritium beta particles do not contribute to shallow dose.

3.3.4. For general skin contamination, the shallow dose equivalent is averaged over the contiguous 10 cm^2 of skin receiving the highest exposure.

3.3.5. For hot particles, the shallow dose equivalent is calculated by using a 1 cm^2 contaminated area when using VARSKIN and 0.1 cm^2 for manual calculations due to the high specific activity and small size of the particles.

3.3.6. The shallow dose equivalent must be determined and assigned accordingly depending on the location of contamination either for the skin of an extremity or the whole body.

3.3.7. For skin dose calculations, if more than one radionuclide is present including daughter products, the shallow dose equivalent must be calculated for each radionuclide independently. The total shallow dose equivalent is determined by summing the dose from all radionuclides combined.

3.3.8. As part of any investigation for elevated or off-scale dosimetry, test and assess whether the dosimetry is operating properly as it may be faulty.

4. Pre-Requisites / Requirements

4.1. When determining whether a hot particle exposure has exceeded the limits of 10CFR20.1201 for the skin dose criterion, hot particle exposures will not be added to skin doses from general contamination, nor will hot particle exposures from different particles be summed unless the different particles result in doses to the same area or location of the skin.[1]

4.2. Hot particles will be assumed to have been in contact with the skin throughout the possible irradiation period, even if the particle was found on the hair or clothing of the exposed individual, unless it can be determined that the hot particle was never in contact with the skin.

[1] US NRC, Information Notice No. 90-48, *Enforcement Policy for Hot Particle Exposure,* August 1990

4.3. Document the exposure investigation on an exposure investigation form, Attachment 7.1 or equivalent.

4.4. Document any assigned exposure in an external dose assessment report, see Section 5.7 including exposure estimate methods, analyses and any supporting documentation.

5. Procedure

5.1. Assessment Determination

5.1.1. Determine whether an External Dose Assessment is warranted. Situations which may warrant an investigation and external dose assessment include but are not limited to the following:

- Hot particle contamination identified either on the skin or clothing,
- General skin contamination in excess of 10,000 dpm/100 cm^2,
- Contaminated primary dosimeter,
- Lost or damaged TLD or SRD,
- Off-scale SRD,
- Wrong dosimetry worn,
- Dosimetry not worn properly,
- Entry into an area without required dosimetry,
- Potential over-exposure,
- Declaration of pregnancy,
- As requested by the RPS, PHP and/or RSO.

5.1.2. Notify the RPS, PM and RSO and initiate an incident report in accordance with AE-SH-PR-002, *Incident Reporting and Notification* for any skin contamination event, lost dosimetry or off-scale dosimeter. If there are any questions as to whether an incident report is required, contact the PHP, PM and/or RSO for guidance.

5.1.3. If there are any questions as to whether an external dose assessment is required, contact the PHP and RSO for guidance.

5.2. External Exposure Investigation

5.2.1. Make an initial assessment whether a potential over-exposure may have occurred and notify the RSO in order to make the proper regulatory notifications in accordance with NS-RS-PR-500, *Personnel Monitoring*.

5.2.2. If an SRD is off-scale and initial assessments indicate a potential personnel over-exposure, immediately pull the persons TLD(s) and ship them priority over-night for processing.

5.2.3. Restrict the person's work activities as necessary until the external exposure investigation and dose assessment are complete.

5.2.4. If required, document the reason for performing an external dose assessment as part of the exposure investigation.

5.2.5. Interview the individual and any co-workers to determine the following for the period in question.

- Specific dates of entries into radiological areas,
- Specific work activities performed,
- Radioactive materials that were handled,
- Work being performed in the general area,
- Estimated duration of exposure.

5.2.6. Determine the data needed to estimate the person's dose equivalent including deep dose, shallow dose, extremity and/or the lens of the eye as required.

5.2.7. Gather the available information that can be used to estimate the person's external dose. This may include:

- Skin contamination survey results,
- Hot particle surveys and analyses,
- RWP access and egress logs,
- Area survey results,
- Secondary dosimeter readings,
- Results of dosimeters worn by other individuals working in the same work area under similar exposure conditions and exposure period,
- Prior exposure results for similar work and duration, or
- Other exposure data (e.g., area TLDs).

5.2.8. For hot particles:

5.2.8.1. Isolate and save the particle(s) for assessment.

5.2.8.2. Obtain open window and closed window dose rate measurement on contact and varying distances from the particle as directed by the PHP and/or RSO for dose modeling purposes.

5.2.8.3. The PHP or RSO shall model the hot particle as a point source and assess the particle activity based on the dose rate measurements.

5.2.8.4. Submit the particle for additional analyses as directed by the PHP and/or RSO.

5.2.9. Review the radiation work permit and survey data to determine if the radiological controls imposed were adequate.

5.2.10. Perform additional surveys in the affected work area to determine if radiological conditions might have changed.

5.2.11. Re-create the exposure scenario as necessary through mock-ups, models and diagrams and/or verbally walking through the event as necessary.

5.2.12. Identify any events that led to the potential exposure event, why it may have happened (root causes), and what can be done to prevent further potential exposures. Possible contributing factors to be considered include:

- Areas not properly posted,
- Existing radiological controls are not adequate,
- Poor work practices,
- Personnel training,
- Unplanned event.

5.2.13. If the investigation shows that poor radiological work practices, inadequate training, or unidentified working conditions were the cause of exposure, provide recommendations for corrective actions and submit to the PHP and/or RSO for review and approval. This may include either a stop work order to re-assess existing work controls and/or refresher training for personnel.

5.2.14. Submit the exposure investigation for review and approval by the PHP and/or RSO.

5.2.15. Include a copy of the exposure investigation as part of the external dose assessment report.

5.2.16. Perform the external dose assessment for the individual in accordance with Sections 5.3 through 5.5 as applicable and document the methods used to estimate the personnel's exposure.

5.3. Deep Dose Assessment

5.3.1. Based on the exposure investigation and available information, the PHP and/or RSO shall determine and document the best method for calculating and assigning dose to the individual. Depending on the dose assessment method, all steps as follows may not necessarily apply.

5.3.2. Document the timeline in question including all areas entered and estimated durations.

5.3.3. Perform and update any area surveys for all areas entered. Concentrate surveys within areas the individual entered based on the exposure investigation.

5.3.4. As applicable, identify all primary sources of exposure and general area dose rates in the area.

5.3.5. Pull and read any dosimetry worn by the individual or by co-workers from within the same general work areas as applicable.

5.3.6. Review any RWP entry logs and exposure results for temporary dosimetry such as self-reading and electronic dosimeter results.

5.3.7. Estimate the individual's exposure based on the general area dose rates as measured and the estimated time the individual was in the area.

5.3.8. For discrete sources of exposure, dose modeling using Microshield or other methods may be used depending on the radionuclides of concern.

5.3.9. Review prior exposure history records for personnel in the area performing similar types of work as applicable.

5.3.10. Account for all areas entered and potential sources of exposure in the assessment.

5.3.11. Exposure estimates should be based on the best information available such as the following, as applicable:

- Results of primary and/or secondary dosimeters worn by other individuals working in the same work area under similar exposure conditions during the same exposure period.
- Calculations based on measured dose rates and the estimated time spent in the work area by the individual involved.
- Investigation of survey data and comparisons of results.
- Dose modeling.

5.3.12. Revise any dose estimates accordingly as additional information is obtained as applicable.

5.4. Shallow Dose Assessment (i.e., Skin Dose)

5.4.1. During personnel frisking, if someone is determined to be contaminated above the personnel contamination limits, assess the following parameters:

- Is the contamination a hot particle or general contamination

- Is the contamination on the skin or clothing
- Average and maximum levels of contamination
- Size of the contaminated area for general contamination
- Estimated total time of exposure
- Radionuclides of concern
- Type of clothing and the distance of contamination from the skin as applicable.

5.4.2. Perform a shallow dose assessment to the skin of the whole body or extremity for:

- General contamination on the skin or clothing greater than 10,000 dpm/100 cm^2 beta/gamma
- Any hot particles.

5.4.3. Determine the 10 cm^2 with the highest contamination levels and use it as the basis for estimating shallow dose to the skin for general contamination. In cases of hot particle contamination, the dose is averaged over an area of 1 cm^2.

5.4.4. If decontamination is performed, record the contamination levels before and after each stage of decontamination in accordance with NS-RS-PR-204, *Personnel Frisking and Decontamination* and an estimate of the total amount of time that contamination remained on the skin or clothing for each stage of decontamination.

5.4.5. If using VARSKIN to calculate exposure, follow Section 5.5; otherwise, calculate the shallow dose equivalent (H_s) to the skin using the following:

$$H_S = R * DCF_i * t$$

Where:

H_s	=	Shallow Dose Equivalent
R	=	Average activity of beta-gamma skin contamination in Bq / cm^2
DCF_i	=	Dose conversion factor for radionuclide i in units of Sv / yr per Bq / cm^2
t	=	Total time contamination was present on skin.

5.4.6. The dose conversion factors (DCF) are dependent on the location of the body as a result of skin thickness. Table 5-1 provides typical skin thickness for various parts of the body.

Table 5-1
Skin Thickness[2]

Item	Density Thickness (mg/cm^2)
USNRC Regulatory value	7
Head, trunk, upper arms, upper legs	4
Lower arms, wrist, back of hand, lower leg, top of foot	8
Palm of hand, sole of foot	40

5.4.7. If more than one radionuclide is present (including daughter products), and the mixture is known, calculate an average DCF based on the relative fractions for each radionuclide. If the mixture is unknown or if a conservative calculation is acceptable, use the radionuclide with the highest dose conversion factor.

5.4.8. For more accurate dose estimates, use the DCF for the appropriate skin thickness; however for reporting purposes, the NRC recognized values shall be used.

5.4.9. If contamination is present on clothing, use the density thickness of common clothing shown Table 5-2 to account for any beta attenuation.

Table 5-2
Typical Dimensions of Clothing[3]

Item	Thickness (cm)	Density (g/cm^3)	Density Thickness (mg/cm^2)
Coveralls	0.07	0.4	28.0
Surgeons gloves	0.005	0.9	4.5
Cotton glove liner	0.03	0.3	9.0
Thick outer glove	0.045	1.1	49.5
Plastic bootie	0.02	0.6	12.0
Rubber Shoe Cover	0.12	1.0	120

[2] Health Physics Journal – *Electron Dose-rate Conversion Factors for External Exposure of the Skin From Uniformly Deposited Activity on the Body Surface*, Kocher D C and Eckerman K F, Volume 53(2), 135-141, August 1987
[3] US NRC, NUREG/CR-6918, *Varskin 5: A Computer Code for Skin Contamination Dosimetry*, Rev. 2, July 2014

5.4.10. Guidance pertaining to the estimation of dose from hot particles is contained in US NRC, Information Notice No. 90-48, *Enforcement Policy for Hot Particle Exposure,* August 1990.

5.5. VARSKIN Calculations

The most widely accepted commercially available software for calculation of shallow dose due to contamination on skin or clothing is VARSKIN, US NRC, NUREG/CR-6918, *Varskin 5: A Computer Code for Skin Contamination Dosimetry*, Rev. 2, July 2014.

5.5.1. Gather the following information required to calculate shallow dose using VARSKIN:

- Radionuclide(s)
- Location of contamination on skin (or on clothing near skin)
- Size of the contamination area in cm^2
- Source strength (input as either total µCi or a concentration in $\mu Ci/cm^2$)
- Exposure time (amount of time contamination was present on the skin)
- Thickness and density of any materials between contamination and skin

5.5.2. Select the source geometry applicable for the assessment. Typically point or disk source geometries are used for hot particles and general skin contamination respectively.

5.5.3. Select the radionuclides that contribute to the dose.

5.5.4. Input the size of the contamination area in cm^2. Use the highest 10 cm^2 activity for general contamination and the highest 1 cm^2 for a hot particle.

5.5.5. Input source strength in µCi or concentration in $\mu Ci/cm^2$.

5.5.6. Input exposure time in desired units.

5.5.7. If applicable, input the density and thickness of material between contamination and skin. (See Table 5-1)

5.5.8. Use the VARSKIN default skin density thickness of 0.007 g/cm^2 or 7 mg/cm^2 for all shallow dose assessments for reporting purposes.

5.5.9. After entering all required data, run the calculation, review the VARSKIN output file for accuracy, and adjust the parameters as necessary as additional information is available to refine the dose results.

5.6. Declared Pregnancy

5.6.1. Document any declared pregnancy in accordance with NS-RS-PR-500, *Personnel Monitoring*.

5.6.2. The PHP and/or RSO shall meet with the individual and re-review the pregnancy declaration policy.

5.6.3. Document the estimated conception date and perform an external dose assessment in accordance this procedure as applicable for the duration of the pregnancy to date.

5.6.4. Restrict the individual's duties in accordance with NS-RS-PR-500, *Personnel Monitoring* until the dose assessment is complete.

5.7. Exposure Record and Approval

5.7.1. The PHP and/or RSO shall prepare an External Dose Assessment report summarizing the dose assessment results including the basis and methods used for the dose assessment.

5.7.2. Attach copies of all supporting information including the External Dose Investigation form, personnel survey and decontamination forms, hot particle surveys and analyses, TLD reads, area surveys, RWP entry logs and any other pertinent information as applicable.

5.7.3. Submit the completed Dose Assessment to the RSO for review and approval. If the RSO prepared the report, an independent review shall be made by someone other than the RSO.

5.7.4. Once the assessment has been approved, the assessment shall be placed in the personnel dose record with all supporting documentation including all information needed to complete the NRC Form 5 or equivalent.

6. Records

6.1. External Exposure Investigation Report

6.2. External Dose Assessment

7. Appendices and Forms

7.1. External Exposure Investigation

Attachment 7.1 **External Exposure**

Last Name:	**First Name:**	
SSN:	**RWP:**	
Reason for Investigation:		
Date and Time of Event:	**Estimated DDE:**	**Estimated SDE:**
Summary of Events:		
Interview / Investigation Results:		
Root Causes:		
Basis and Method of Dose Assessment:		
Recommendations / Restrictions:		
Review and Approval		
Performed by:	**Signature/Date:**	
Reviewed by:	**Signature/Date:**	