SURFACE RELEASE CRITERIA
TECHNICAL BASIS DOCUMENT

for

Battelle Columbus Laboratories
Decommissioning Project (BCLDP)

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EXECUTIVE SUMMARY

Surface release criteria and procedures have been developed for the unrestricted release of materials, equipment, and facilities by the BCLDP. Latest instrumentation technology and nuclear industry standards have been utilized to develop and apply these criteria and procedures. The BCLDP will release materials, equipment, and facilities at or below the limits defined in Table 1. In addition, it is BCLDP's policy to use ALARA principles and analyses to determine what actions are necessary or warranted when materials, equipment, areas, and/or buildings have residual contamination below the Table 1 limits.

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Introduction

The BCLDP is an extensive project to remediate 13 buildings and associated facilities such that they can be released for unrestricted use to the general public. This document establishes the technical basis by which present radiological surface release criteria are applied to accomplish the remedial action.

Radiological release criteria for surfaces were first defined in ANSI N13.11 (draft), "Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to Be Released for Uncontrolled Use" and were later published in U.S. Nuclear Regulatory Commission Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors". There is little difference between these two standards, and both serve as guidance documents when establishing release criteria. The Department of Energy (DOE) Order 5400.5, "Radiation Protection of the Public and the Environment" also provides release criteria for surface radioactivity and the criteria stated therein contain only subtle differences from those in the other reference documents. For the BCLDP, DOE 5400.5 and Regulation Guide 1.86 will be used to provide criteria that are followed as upper limits of radioactive surface contamination for unconditional release of equipment, materials, and areas. DOE Order 5400.5 requirements are mandatory for the BCLDP because the radioactive material being removed is the property of the DOE and the DOE provides 90% funding for the project. Regulatory Guide 1.86 requirements are mandatory because Battelle is an NRC Licensee and the BCLDP is being conducted under an NRC required decommissioning plan.

Release Criteria

The surface radiological contamination release criteria for the BCLDP are shown in Table 1, "Surface Contamination Guidelines for BCLDP." These criteria are provided by DOE Order 5400.5 "Radiation Protection of the Public and the Environment," which reference Regulatory Guide 1.86. DOE Order 5400.5 does not define the release levels for nuclides such as transuranics (TRU), Ra-226 and Th-230, therefore, BCLDP will adopt the guidance of Regulatory Guide 1.86 for these isotopes and these limits are also shown in Table 1. The criteria in Table 1 are the maximum allowable quantities of radioactive material that may be left on surfaces of equipment and buildings that are released to the general public for unrestricted use. The term "Unconditional Free Release" is a generally accepted term in industry that is used synonymously with this unrestricted use. It is the policy of the BCLDP to aggressively apply the principles of As Low As Reasonably Achievable (ALARA) to release criteria. The release criteria stated in Table 1 shall be applied as an upper limit of radioactive surface contamination for free release of equipment, materials, and areas by BCLDP.

Release limits are grouped into several categories depending on the radiotoxicity of the radioisotope as seen in Table 1. For each area, BCLDP will identify radioisotopes through analytical techniques and determine their corresponding activity fractions. Release limits can then be determined on the weighted activity fraction of each radioisotope. If radioisotopes or activity fractions are not known or vary significantly, then release limits will be based on the most restrictive nuclides to be encountered by the BCLDP. These release limits for gross alpha and gross beta-gamma activity are shown in Table 2. Table 2 is taken from BCLDP Procedure HP-OP-011, "Release of Materials From Radiologically Controlled Areas."

Radiological Release Logic for the BCLDP

Consistent with the requirements of DOE Order 5400.5, Section II.5, "Release of Property Having Residual Radioactive Material," and the DOE Radiological Control Manual, Section 422, "Release to Uncontrolled Areas," all facilities, areas, buildings, equipment, and materials, having surface activity or activity concentrations in excess of applicable limits (Table 1) shall require decontamination; and/or removal and disposal as radioactive waste. Facilities, buildings, areas, equipment, and materials that do not have detectable contamination, (i.e., above the LLD) and are not suspected of potential internal contamination, shall be released without any further assessment or evaluation. As required by DOE Order 5400.5, Section II.2.b, "ALARA Evaluations," formal ALARA evaluations and cost benefit analyses shall be performed as part of Decontamination and Decommissioning Plans for facilities, buildings, and large volumes of associated equipment and materials with residual radioactivity above the LLD.

As dictated in DOE Order 5400.5, Section II.5.c.1-4, "Release of Materials and Equipment," individual items not addressed by specific Decontamination & Decommissioning plans with residual radioactivity above the LLD but below applicable limits will also be subjected to an ALARA process and assessed for potential contamination prior to release by the BCLDP. This ALARA process consists of a field assessment by a trained evaluator (usually a Health Physics Supervisor) prior to releasing any materials or equipment with detectable contamination below the limit. BCLDP Procedure HP-OP-011, "Release of Materials from Radiologically Controlled Areas" further defines and establishes requirements for the uncontrolled release of materials and equipment from radiological areas. Figure 1 contains a flow chart which graphically depicts the release logic utilized by the BCLDP.

In summary, it is the practice of the BCLDP that all releases of buildings, areas, materials, and/or equipment will meet or better the limits and criteria found in Table 1. In addition, for buildings, areas, materials, and/or equipment with residual radioactivity below those in Table 1 but above the LLD of our radiation detection equipment, it is the practice of the BCLDP to use sound ALARA principles and analyses to determine what, if any, decontamination actions are warranted prior to release. It should be made clear this does not mean that all materials, equipment, areas, or buildings will be released at or near the LLD since there may not be a reasonable ALARA basis to do so.

Table 1. Surface Contamination Guidelines for BCLDP

Radionuclides[2]	**Allowable Total Residual Surface Contamination ($dpm/100\ cm^2$)**[1]		
	Average[3,4]	**Maximum**[4,5]	**Removable**[4,6]
Transuranics, I-125, I-129, Ra-226, Ac-227, Ra-228, Th-228, Th-230, Pa-231	**Reserved** (100)*	**Reserved** (300)*	**Reserved** (20)*
Th-Natural, Sr-90, I-126, I-131, I-133, Ra-223, Ra-224, U-232, Th-232	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay product, alpha emitters	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.[7]	5,000	15,000	1,000

(1) As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation

(2) Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

(3) Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

(4) The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr and 1.0 mrad/hr, respectively, at 1 cm.

(5) The maximum contamination level applies to an area of not more than 100 cm^2

(6) The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

(7) This category of radionuclides includes mixed fission products, including the Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

* Regulatory Guide 1.86

Table 2. Release Limits for Gross Activity (Unknown Isotopes) - Regulatory

EMISSION	REMOVABLE (dpm/100 cm^2)	TOTAL (Fixed and Removable) (dpm/100 cm^2)
Alpha	*20	*100
Beta - Gamma	**200	**1000

* Based on TRU, Ra-226 and Th-230
** Based on Sr-90 and Th-232

Natural and Electronic Background

The application of release criteria standards cannot be successfully applied without the understanding of background. Two types of background exist: natural and electronic. Natural and electronic background significantly impact the release criteria by the following:

- Natural background, by providing a quantity of radioactive material which is available to be detected.
- Electronic background, by influencing the least amount of radioactivity that can be measured by a particular instrument.

It is necessary to distinguish the difference of the two types of background. Obviously, the term background could apply to either. The following are the terms as accepted by industry practice.

<u>Generic term - natural background</u>, the amount of radioactive material that exists in a substance, surface, or material as a result of nature. The quantity of natural background is generally expressed in terms of picocuries/gram (pCi/g), femtocuries/liter (10^{-15} Ci/l), milligrams/milliliter (mg/ml), disintegrations per minute (dpm), or other suitable combinations of activity or quantity per unit mass or area. Cosmic radiation is also considered a part of natural background. Natural background is detectable and must be accounted for when making activity determinations. For example, field beta/gamma type instruments, might have background that ranges from 100 to 500 counts/minute. For a laboratory type alpha scintillation counter, the background might be 1 count per 2 minutes of counting time.

Generic term - electronic background, the amount of electronic signal produced by electronic noise which results in a meter or scaler deflection. Instrument background is generally expressed in counts per minute (cpm), picocuries/gram (pCi/g), milligrams/liter (mg/l), or other suitable units. Electronic background (background) is determined by measuring the signal output for a particular instrument when subjected to an area or matrix that contains no radioactive material other than natural or cosmic radiation.

Determining Background

Accurately determining both types of background must be accomplished before applying release criteria. Two industry accepted practices exist for determining natural background in materials. The first method is to accurately measure the naturally-occurring radioactivity in materials with the appropriate analytical instrument. This is accomplished by collecting a clean sample of similar material from an uncontaminated source. An example of this type of natural background determination is to measure the radioactivity in a piece of lumber from the hardware store or a quart of motor oil from Wal-Mart®. The expected results for such an analysis would be 1 to 2 pCi/g in wood for natural uranium and less than 0.1 pCi/l for mixed fission products in oil. This same process can also be applied to chemical contaminates in various matrices.

The other type of material background analysis is a statistical procedure called Chauveneus Determination. This process requires making a large number of radiation measurements in a defined area and then casting out the larger measured results. The average of the smaller remaining results is considered to be background for the defined population.

Both of these techniques are applied for determination of natural background for the BCLDP.

Instrumentation and Application

Release surveys will be performed using suitable instrumentation and industry standards. It should be noted that the upper end of the release criteria defined in the applicable regulatory standards and being applied to the BCLDP were developed in part based on the detection limitations of the field instruments available at the time the standards were published. The BCLDP will utilize field instruments, laboratory techniques, and survey techniques capable of achieving detection limits at or below the upper bounds of the release criteria stated in Table 1. Current BCLDP instruments have detection limits lower than the surface contamination guidelines for the most restrictive nuclides shown in Table 1. However, the BCLDP will not continue to upgrade with state-of-the-art detection systems simply to drive the lower limit of detection (LLD) continually lower. Surfaces with detectable radioactive contamination levels greater than the LLD but less than the stated release criteria will be evaluated based upon ALARA analyses for decontamination, disposal, or free release. Materials greater than the release criteria will be decontaminated or disposed of as of radioactive waste.

Lower Limits of Detection

The lower limit of detection (LLD) as used in this technical basis document is the smallest amount of sample activity that will yield a net count for which there is a 95% confidence level that the activity is, in fact, present. The LLD is an *a priori* (before the fact) estimate of the capabilities of a given detection system. The LLD does not depend on the sample activity but rather on the detection capability of the detection process itself (i.e., detection efficiency and background count rate).

The formula for LLD is given below:

$$LLD = \frac{3 + 4.65(S_b)}{Eff\,(T)}$$ [See Equation 6, Attachment 1]

where

S_b = standard deviation of background or blank counts (c) for a counting time, defined as $\sqrt{C_b}$

T = counting time for samples, background or blanks; in units of minutes (m). All counting times are set equal.

Eff = counting efficiency in units of c/d; the number of counts (detections) per the number of disintegrations from a calibration source.

An excerpt from Brodsky's and Gallaghar's Paper, "Statistical Considerations in Practical Contamination Monitoring" published in Radiation Protection Management, Volume 8, No. 4 is found in Attachment 1. The paper discusses the derivation of the LLD formula and discusses Type I α (false detection) and Type II β (false non-detection) errors. For radioactivity measurements performed by BCLDP, the LLD, as defined above, establishes a 5% chance of incorrectly detecting activity when it is absent and a 95% confidence that activity will be detected when it is present.

Typical LLDs have been calculated for the detection equipment used by BCLDP to determine contamination levels for free release. Attachments 2, 3, and 4 show the LLD calculations for the Tennelec 5100 counter, the Ludlum 2929 counter, and the NE Alpha/Beta Contamination Detector.

Attachments 2 and 3 also show a typical determination of LLDs for the Tennelec 5100 and the Ludlum 2929 counters used by BCLDP. These detectors both are utilized to determine alpha and beta-gamma activity on smears generated during wipe tests for removable contamination. Both counters are capable of detecting removable activity levels well below those defined for the most conservative nuclides listed in Table 1 (i.e., 20 dpm/100 cm^2 alpha, 200 dpm/100^2 beta-gamma).

Attachment 4 also shows the estimate of the LLDs for the NE alpha/beta contamination detector for uniform distributed sources and for point sources during contamination surveys. As shown in Attachment 4, the NE detector is capable of detecting below the total activity levels (fixed plus removable) of the most restrictive nuclides of Table 1 for distributed source configurations of surface radioactivity. Also, the NE instrument can detect below the maximum activity levels of the most restrictive nuclides in Table 1 for point sources of surface radioactivity.

Instrument Calibration

Field instruments and laboratory instruments shall be calibrated in accordance with ANSI N323, "Radiation Protection Instrumentation Test and Calibration". Instrument calibrations will be in accordance with formal procedures including reference checks and documented maintenance programs.

Quality Assurance

Instrument calibrations shall be performed with National Institute of Standards and Testing (NIST) traceable standards. Reference checks shall be performed in accordance with formal BCLDP procedures. Final release of buildings and grounds shall be verified by an Independent Verification Contractor (IVC).

Release surveys will be performed or directed by technicians whose qualifications meet ANSI/ANS 3.1, "Selection, Qualification, and Training of Personnel for Nuclear Power Plants" and DOE Order 5480.11, "Radiation Protection for Occupational Workers". Routine oversight of the release program will be performed by a department of the BCLDP other than that of those performing the release surveys.

Attachment 1

Attachment 2

ATTACHMENT 2

<u>LLD for Tennelec 5100 Counter</u>

Tennelec 5100 Data

t = 2 min.
R Bkg α = 0.1 cpm
R Bkg β = 1.0 cpm
Eff α = .21
Eff β = .42

$S_b = \sqrt{CBkg}$
C Bkg α = 0.2 c
C Bkg β = 2.0 c
$S_{b\,\alpha} = 0.45$
$S_b\,\beta = 1.41$

$$LLD\alpha(dpm) = \frac{3 + (4.65)\ (S_b\alpha)}{(Eff\alpha)(T)}$$

$$= \frac{3 + 4.65\ (0.45)}{(.21)(2)}$$

$$= \boxed{12.13 \text{ dpm}}$$

$$LLD\beta(dpm) = \frac{3 + 4.65\ (S_b\beta)}{(Eff_\beta)(T)}$$

$$= \frac{3 + 4.65\ (1.41)}{(.42)(2)}$$

$$= \boxed{11.38 \text{ dpm}}$$

Attachment 3

ATTACHMENT 3

<u>LLD for Ludlum Model 2929 Counter</u>

Ludlum 2929 Data

T = 1 min.

R Bkg α = 0.2 cpm

R Bkg β^- = 28 cpm

Eff α = 0.36

$Eff_{\beta-}$ = 0.36

$S_b = \sqrt{CBkg}$

C Bkg α = 0.2 c

C Bkg β^- = 28 c

$S_{b\,\alpha}$ = 0.45

S_b β= 5.29

$$LLD\alpha(dpm) = \frac{3 + (4.65)\ (S_b\alpha)}{(Eff\alpha)(T)}$$

$$= \frac{3 + 4.65\ (0.45)}{(0.36)(1)}$$

$$= \boxed{14.11 \text{ dpm}}$$

$$LLD\beta(dpm) = \frac{3 + 4.65\ (S_b\beta)}{(Eff_\beta)(T)}$$

$$= \frac{3 + 4.65\ (5.29)}{(0.36)(1)}$$

$$= \boxed{76.68 \text{ dpm}}$$

Attachment 4

ATTACHMENT 4

LLD for the NE Alpha/Beta Contamination Monitor

LLDs for 1 minute static counts:

NE Data

T = 1 min.

R Bkg α = 0.2 cpm

R Bkg β^- = 200 cpm

Eff α = 0.35 c/d (Pu-239)

Eff $_{\beta-}$ = 0.18 c/d (Tc-99)

$S_b = \sqrt{C_{Bkg}}$

C Bkg α = 0.2 c

C Bkg β^- = 200 c

$S_{b\,\alpha}$ = 0.45

S_b β= 14.14

$$LLD\alpha(dpm) = \frac{3 + (4.65)\ (S_b\alpha)}{(Eff\alpha)(T)}$$

$$= \frac{3 + 4.65\ (0.45)}{(0.35)(1)}$$

= 14.55 dpm per 100 cm^2 probe area

$$LLD\beta(dpm) = \frac{3 + 4.65\ (S_b\beta)}{(Eff_\beta)(T)}$$

$$= \frac{3 + 4.65\ (14.14)}{(0.18)(1)}$$

= 382 dpm per 100 cm$_2$ probe area

LLDs for Scanning Uniformly Distributed Sources of Surface Radioactivity

LLDs for uniformly distributed sources are expected to approach those of the minute static counts. BCLDP Procedure HP-OP-011 also instructs technicians to perform a static 1-minute count if increased count rate is detected.

LLDs for Scanning Point Sources of Surface Radioactivity

Width of NE probe = 6.7 cm
Assume Scanning Speed = 3 cm/sec
Time for Probe to Pass Over Point Source = 2.23 sec = 0.04 min

LLD α Point Source Scan

$$C_{Bkg}\alpha = \frac{0.2\ c}{\min}\ x\ 2.23\ \sec\ x\ \frac{1\ \min}{60\ \sec} = 0.01C$$

$$S_b\alpha = \sqrt{C_{Bkg}\alpha} = \sqrt{0.01} = 0.09$$

$$\frac{3 + 4.65\ (0.09)}{.35\ (0.04)} = 244\ dpm \simeq 250\ dpm$$

$$= 244\ dpm \simeq 250\ dpm$$

LLD$_{\beta}$ Point Source Scan

where: $S_b\beta^- = \sqrt{C_{\beta^-}} = 2.73$

$$C_{\beta^-} = \frac{200c}{\min}\ x\ 2.23\ \sec\ x\ \frac{1\ \min}{60\ \sec} = 7.43c$$

$Eff_{\beta-} = 0.18$

$$t = 2.23\ \sec\ x\ \frac{1\ \min}{60\ \sec} = 0.04\ \min$$

LLD$_{\beta-}$ Point Source Scan

$$\frac{3 + 4.65\ (2.73)}{.18\ (0.04)} = 2179\ dpm \simeq 2200\ dpm$$

Many assumptions are made when estimating the LLD for detection of a point source of surface radioactivity (i.e., scanning speeds, distance of probe from the source, background rates, etc.) and all may fluctuate given field conditions. Based on the above assumptions, the LLDs for the NE instrument for a point source of surface radioactivity are approximately 250 dpm (alpha) and 2200 dpm (beta). Both activity levels are significantly less than the most restrictive "maximum" values given in Table 1.