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CONTAINMENT BARRIER CRITERIA

D. S. Cunningham

(Revision to ARH-CD-983)

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CONTAINMENT BARRIER CRITERIA

D. S. Cunningham

Environmental and Occupational
Safety Department

October, 1977

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PREFACE

This document is a revision of ARH-CD-983, "Containment Barrier Criteria", D. S. Cunningham, May, 1977.

This revision incorporates the comments of Letter No. 9603, G. J. Mishko, ERDA-RL to General Manager, Rockwell Hanford Operations, July 27, 1977.

The lines changed are indicated by a bar in the margin.

APPROVALS:

Prepared by [signature] 10/19/77
D. S. Cunningham Date
Radiological Engineering Section

Approved by [signature] [illegible]
G. C. Owens, Manager Date
Environmental and Occupational
Safety Department

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1.0 INTRODUCTION

People and the environment must be protected from the hazards of radionuclides to the maximum extent practicable. The onsite personnel and public exposure to penetrating radiation is limited to the lowest practical levels by relatively well defined methods and criteria. The control of exposure from internally deposited radionuclides is not as well defined.

The analysis described here will allow a determination of the "barrier" requirements to control the inhalation hazards of handling radioisotopes in the 200 Areas at Hanford. Other hazards such as penetrating radiation, chemical toxicity, ingestion, absorption, puncture wound potential, or allowable surface contamination may require additional protection or controls.

The criteria for barriers were developed from theoretical considerations. The difficulty of applying these criteria to existing facilities is recognized; however, the criteria will be applied when technically and economically practicable. These criteria define containment systems that assure an extremely low probability of personnel or environmental damage. Certain operations can go beyond these guidelines with supplemental administrative controls and with recognition of the risk involved.

2.0 GENERAL CRITERIA

Sufficient barriers will be imposed between any radioisotope and personnel/environment to limit the potential internal exposure to the lowest practical level. Generally, a minimum of two independent barriers are required. A barrier is defined as:

> "A single physical restriction limiting the release or inhalation of material during any single accident and which, while intact, prevents any release or inhalation."

Barriers are considered independent if they are not subject to a common, single accident failure. Verification of the integrity of an inner barrier should be possible without violating an outer barrier.

The volume of the inner (primary) barrier should be as small as practical to minimize the area to be decontaminated or the waste requiring disposal.

At least one of the barriers will be designed to withstand the effect of any credible energy release (maximum impulse) within the system. In certain cases the primary barrier should be designed with a planned release point such as a vent or rupture disk to prevent overpressurization and thus limit the impulse or the total release.

3.0 EFFECTIVENESS OF BARRIERS

The effectiveness of a barrier for limiting a release or inhalation is determined by several factors such as:

1. The inherent strength of the container
2. Maintenance of a preferred air flow
3. Susceptibility to damage from an off-standard condition.

The barrier grouping, Table I, is a consensus, considering the probable fraction of contained material released as a result of an accidental barrier violation. The group number represents the logarithm (base 10) of the reciprocal of the fraction released. For example, barriers in group number 2 would release about 0.01 of the contained material. Since there is considerable uncertainty in the fraction released, the order of magnitude grouping is as much accuracy as is warranted.

Included in Table I are several factors other than containment barriers. The factors are included as safety considerations since they limit the material that can be inhaled.

4.0 HAZARD OF DIFFERENT RADIONUCLIDES

The inhalation hazard of a radioisotope is a function of the quantity inhaled and the radiobiology of the isotope. The hazard grouping in Table II is based on reference 1. The group number represents the logarithm (base 10) of the amount, in curies, to give a dose equivalent to the critical organ comparable to a unit curie amount of the most hazardous radionuclides, such as ^{239}Pu. For example, 100 curies of nuclides in group number 2 give a dose equivalent comparable to one curie of nuclides in group number 0.

5.0 CALCULATION OF GUIDE QUANTITY

5.1 Basic Equations

The calculation of the guide quantity uses one of the following equations:

$$QP = 10^{-6} \text{ Ci} \times 10^{(H+B)} \qquad \text{Eq. 1}$$

$$QE = 10^{-1} \text{ Ci} \times 10^{(H+B)} \qquad \text{Eq. 2}$$

where,

QP is the guide quantity for personnel considerations.
QE is the guide quantity for environmental considerations.
H is the Hazard Group Number from Table II.
B is the sum of the applicable Barrier Group Numbers from Table I.

To convert the quantity in curies to grams, divide by the specific activity from Table II.

The 10^{-6} Ci in Equation 1 was derived from three assumptions:

1. An "allowable" lung burden from an accident is 0.0016 μ Ci, i.e. 0.1 MPBBl of ^{239}Pu as the most limiting case (considering all common radioisotopes).

2. One-eighth of the quantity inhaled is cleared slowly from the lungs, while seven-eighths is cleared rapidly.

3. One percent of the quantity released as the result of a barrier failure, is inhaled.

Therefore,

$$\frac{0.0016\ \mu\text{Ci}}{1/8 \times 1\%} = 1.3\ \mu\text{Ci} \approx 10^{-6}\ \text{Ci}$$

The 0.1 in Equation 2 was derived from two assumptions.

1. Considering ^{239}Pu as the most limiting case of all common radionuclides, analyses (reference 2) predict that a release of 0.001 Ci from any 200 Area facility as an airborne release of respirable particles would result in a maximum annual dose equivalent of 25 mrem to any internal organ of any person in an uncontrolled area.

2. One percent of the total quantity in question is released as respirable particles.

Therefore,

$$\frac{0.001\ \text{Ci}}{1\%} = 0.1\ \text{Ci}$$

5.2 Examples of Calculations

1. Plutonium process sample being carried to laboratory.

   H = 0

   B = 2 (Plastic Bottle) + 1 (Plastic Bag) + 3 (Wet Material)

   $QP = 10^{-6}$ Ci X $10^{(0+6)}$

   = 1 Ci

   = 16 g if assumed to be ^{239}Pu.

2. ^{137}Cs in open hood, open containers

   H = 4

   B = 2 (Open Hood)

   $QP = 10^{-6}$ Ci X $10^{(4+2)}$

   = 1 Ci

   NOTE: External exposure rate would be a more limiting factor.

6.0 CRITERIA FOR CONTAINMENT

Suitable containment of radioactive material is achieved when two criteria are met:

1. A minimum of two independent barriers are imposed between radioactive material and personnel/environment.

2. The quantity of contained radionuclides does not exceed the guide as calculated from the hazard of the isotopes and the effectiveness of the barriers.

7.0 EXCEPTIONS TO CRITERIA

7.1 Two Barriers - Environment

Those situations resulting from either procedures, equipment, or facilities, in which two independent barriers are not imposed between radioactive material and the environment will be identified. The situations in which the criteria are not met must be reviewed to assure that any environmental release would be limited to the lowest levels technically and economically practicable.

The review will be accomplished as soon as posisble but not later than the next review date for any current (or the issue date for any new) procedure which causes the exceptional situation. The review will include an assessment of the specifics of the situation and of the administrative controls in place to assure adequate control of the radioactive material. This review and the continued operation of an exceptional situation will require the approval of the Manager, Environmental Protection.

7.2 Two Barriers - Personnel

Frequently, the only possible second barrier (inhalation) between radionuclides and personnel is respiratory protection, either filtered or air-supplied. The disadvantages of wearing respiratory protection are recognized; therefore, in certain cases, one barrier between material and personnel is allowable. Some cases in which a single barrier is allowable are:

1. When an employee is handling radionuclides in a barrier which is ventilated (such as a glovebox or hot cell), the employee's head does not enter the containment, the ventilation source has a capacity to assure a minimum air flow of 125 feet per minute through any credible breech of containment, and the quantity being handled does not exceed the guide quantity as calculated from equation 1.

2. When an employee is handling radionuclides in a container and in a manner which is approved for transportation of radioactive material outside a facility.

3. When an employee is handling small amounts* of radionuclides in a nondispersible form such as a check source.

Situations resulting from either procedures, equipment, or facilities, in which there are not two barriers between radioactive material and personnel will be identified. If the situation is not allowed as one of the above cases, the situation will be reviewed to assure that any personnel exposure to air borne radioactivity would be as low as is reasonably achievable.

The review will be accomplished as soon as possible but not later than the next review date for any current (or the issue date for any new) procedure which causes the exceptional situation. The review will include an assessment of the physical characteristics and the administrative controls in place to assure adequate control of the radioactive material. This review and the continued operation of an exceptional situation will require the approval of the Manager, Radiological Engineering Section.

7.3 Quantity

Those situations resulting from either procedures, equipment, or facilities in which the amount of radioactive material exceeds the guide quantity as calculated from either equation 1 or 2 will be identified. They will be reviewed to assure that personnel and/or the environment are protected to the maximum extent practicable.

The review will be accomplished as soon as possible but not later than the next review date for any current (or the issue date for any new) procedure which causes the exceptional situation. The review will include an assessment of any extenuating factors and of the administrative controls in place to assure adequate control of the radioactive material. This review and the continued operation of an exceptional situation will require the approval of the Manager, Environmental and Occupational Safety.

* A "small amount" is defined for this application as less than 0.05 microcuries.

APPENDIX

TABLE I

Barrier Groups

Group Number	Barrier or Safety Consideration
-1	Door or other potential opening in room structure
1	Cardboard containers: ice cream carton, box - sealed with tape * Distance, 1-3 meters Glass bottle Metal can, unsealed Plastic bag, less than six months old
2	* Distance, greater than 3 meters Non-respirable particle size, greater than 10 microns Open-faced hood, airflow of greater than 125 ft/m and sufficient drip pan Plastic bottle, capped, less than one year old Slip lid metal can, sealed with tape
3	Glass bottle, protected from breaking High Efficiency Particulate Air filter Open hood, with shield with armholes the only openings * Respiratory protection, filtered Wet material, unless corrosion or absorption problem
4	Metal can, sealed by crimping, solder, or weld Non-respirable particle size, greater than 100 microns Open hood, with shield with armholes with hood gloves with HEPA filtered supply * Respiratory protection, supplied air
5	Glovebox Room structure, metal, or concrete block, with negative dP to atmosphere
6	Room structure, reinforced concrete, with negative dP to atmosphere

NOTE: Implied in the above is the requirement that all common, currently acceptable controls or methods of operation are incorporated. For example, HEPA filters must be tested at least annually in accordance with ANSI-N510.

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* Only for personnel considerations

TABLE II

HAZARD GROUP

GROUP NUMBER	ISOTOPE	SPECIFIC ACTIVITY*	ISOTOPE	SPECIFIC ACTIVITY*
0	^{227}Ac	7.2 (1)	^{240}Pu	2.3 (-1)
	^{230}Th	2.0 (-2)	^{241}Am	3.2 (0)
	^{237}Np	7.1 (-4)	^{242}Pu	3.9 (-3)
	^{238}Pu	1.7 (1)	^{243}Am	2.0 (-1)
	^{239}Pu	6.1 (-2)		
1	^{144}Nd	1.2 (-12)	^{241}Pu	9.9 (1)
	^{147}Sm	2.3 (-8)	^{244}Cm	8.2 (1)
	^{226}Ra	9.9 (-1)		
2	^{90}Sr	1.4 (2)	^{232}Th	1.1 (-7)
	^{210}Pb	7.6 (1)	^{233}U	9.7 (-3)
	^{210}Po	4.5 (3)	^{235}U	2.2 (-6)
	^{223}Ra	5.1 (4)	^{238}U	3.4 (-7)
	^{227}Th	3.1 (4)	^{242}Cm	3.3 (3)
3	^{99}Tc	1.7 (-2)	^{129}I	1.7 (-4)
4	^{32}P	2.9 (5)	^{140}Ba	7.3 (4)
	^{36}Cl	3.3 (-2)	^{144}Ce	3.2 (3)
	^{45}Ca	1.8 (4)	^{147}Pm	9.3 (2)
	^{60}Co	1.1 (3)	^{154}Eu	2.7 (2)
	^{85}Kr	3.9 (2)	^{170}Tm	6.0 (3)
	^{89}Sr	2.9 (4)	^{181}Hf	1.7 (4)
	^{91}Y	2.5 (4)	^{182}Ta	6.2 (3)
	^{126}I	8.0 (4)	^{192}Ir	9.2 (-3)
	^{131}I	1.2 (5)	^{234}Th	2.3 (4)
	^{137}Cs	8.7 (1)		
5	Mixed Fission Products		^{85}Sr	2.4 (4)
	^{32}S	4.3 (4)	^{95}Nb	3.9 (4)
	^{47}Ca	6.1 (5)	^{132}I	1.0 (7)
	^{58}Co	3.2 (4)	^{140}La	5.6 (5)
	^{59}Fe	5.0 (4)	^{141}Ce	2.9 (4)
	^{65}Zn	8.3 (3)	^{198}Au	2.5 (5)
6	^{51}Cr	9.3 (4)	^{82}Br	1.1 (6)
	^{55}Fe	2.4 (3)		
7	^{3}H	9.7 (3)	^{14}C	4.5 (0)

*Specific activity in curies per gram. Notation of 7.2 (1) is more commonly 7.2×10^{1}

REFERENCES

1. Brodsky, Allen, "Determining Industrial Hygiene Requirements for Installations Using Radioactive Materials", Handbook of Laboratory Safety, Second Edition, Editor: Steere, N. V., Chemical Rubber Company, 1971.

2. Letter, May 26, 1977, G. E. Backman to D. S. Cunningham, "Estimation of Radiation Dose From Release of Plutonium to the Environs"