**Department of Energy**
Washington, DC 20585

NOVEMBER 30, 2005

MEMORANDUM TO: DISTRIBUTION

FROM: RICHARD STARK
DNFSB 2005-1 IMPLEMENT PLAN
RESPONSIBLE MANAGER

Richard Stark

SUBJECT: Draft Repackaging Prioritization Methodology

On August 17, 2005, the Secretary of Energy approved the DOE Implementation Plan (IP) that addresses Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 2005-1, Nuclear Material Packaging. The IP establishes requirements for an independent Technical Review Board to provide a disciplined peer review of the products developed by the DOE 2005-1 Working Group.

Per the Implementation Plan, I am providing the 2005-1 Working Group draft risk prioritization methodology. Please review the attached document and provide your comments to me by December 20, 2005.

The 2005-1 working group has developed the attached draft risk prioritization methodology. The failure index portion of the methodology contains two options. One option (option 1) is more complex and detailed. The other option (option 2) is a simpler version. The TRB should specifically comment on both failure index options. Please advise me if we should pick one or the other or both or rework the options.

Attachment
As Stated

# (Draft) Prioritization Methodology for DOE/NNSA Nuclear Material for Interim Storage Deemed to need Repackaging

## Abstract

Safe handling and storage of nuclear material at U. S. Department of Energy facilities relies on the use of adequate containers to prevent container breaches and subsequent worker contamination and uptake. The U. S. Department of Energy is establishing uniform requirements for packaging and storage of nuclear materials other than those declared excess and packaged to DOE-STD-3013-2000. This report describes a methodology for prioritizing the inventory of nuclear material containers deemed to need repackaging based on the above uniform requirements. The prioritizing methodology seeks to repackage the highest risk packages first by utilizing expert judgment to assign worker hazard factors such as respirable fractions and reactivity factors to accountable levels of nuclear material. A relative risk factor is assigned to each nuclear material container based on a calculated potential accident dose to a worker due to a failed container barrier and a calculated or estimated probability of container failure based on factors such as material reactivity and container age. This risk-based methodology uses all readily accessible information to prioritize the repackaging effort. All packages that appear on the attached dose vs failure plot are deemed to need repackaging. (See attached Notational Approach Chart). This risk methodology provides a relative estimation of which packages should be repackaged first and which have lower priority for repackaging. This methodology is NOT a safety analysis and cannot be used for DSA, SAR, or authorization basis purposes. It is only to be used for establishing the order and priority of necessary repackaging of nuclear material.

The approach is generic for application at all DOE sites. It is recognized that each DOE site has a different level of package information. Prioritization efforts require the use of process knowledge based on largely qualitative information and judgement.

## List of Acronyms

| | |
|---|---|
| *ARF* | Airborne Release Fraction – the amount X of aerosolized by the event |
| *DCF* | Dose Conversion Factor |
| *DOE* | U. S. Department of Energy |
| *DR* | Damage Ratio – the fraction of the MAR contributing to the release |
| *F* | Failure Probability of a Package |
| *I* | Overall Reactivity Index |
| $I_1$ | Corrosion Reactivity Index |
| $I_2$ | Pressure Reactivity Index |
| $I_3$ | Pyrophoricity Reactivity Index |
| $I_4$ | Oxidation Expansion Reactivity Index |
| *IDES* | Item Description IP Implementation Plan |
| *LANL* | Los Alamos National Laboratory |
| *LPF* | Leak Path Factor – the fraction of container contents that is spilled |
| *MAR* | Material-At-Risk – the contents of the container |
| *MASS* | Material Accountability and Safeguards System |
| *MRR* | Materials Recycle and Recovery |
| *MT* | Material Type |
| *R* | Risk |
| *rem CEDE* | Committed Effective Dose Equivalent |
| *RF* | Respirable Fraction – the fraction of aerosolized material that is respirable |
| *RRF* | Respirable Release Fraction |
| *SMT* | Summary Material Type |
| *SNM* | Special Nuclear Material |
| *T* | Proportional to the Age of the Package |
| *W* | rem CEDE/g lung clearance class W |
| *Y* | rem CEDE/g lung clearance class Y |

## Introduction

Several incidents have occurred within the DOE/NNSA complex that have resulted in personnel contaminations and/or exposures due to container failures. The container failures were caused by container degradation over time or by handling mishaps. Numerous types of materials and container configurations exist within the complex. Some combinations of material and container configurations were perhaps adequate for the originally anticipated short period of storage or for a particular use, but are not now adequate because of a longer than anticipated storage condition or change in mission.

- This document outlines a methodology for the prioritization of existing packaging configurations deemed to need repackaging across the DOE complex and meets a DNFSB 2005-1 commitment to develop a prioritized methodology for implementing the repackaging criteria based on the hazards and risks posed by the existing nuclear material.

. The methodology acknowledges the relevant physical, reactive, and radiological properties of the stored material as well as the containment barriers offered by the packaging system. The intent it to allow the sites and the complex to identify the stored items that may pose a higher than acceptable risk of containment breach and to permit an understanding of the logic necessary to devise an adequate containment system.

The methodology focuses on interim storage packages. The approach is generic enough to be applicable to a wide range of materials, forms, and hazards. The proposed evaluation technique acknowledges the variety of packaging systems available and provides a means to evaluate existing packages. The prioritization provides a means to focus on the most urgent items as well as providing a means to justify an implementation plan that employs a graded approach based on an objective measure of risk to the facility workers.

## Approach

The purpose of the prioritization methodology is to provide a uniform means of evaluating the containerization of stored nuclear material across the complex that results in an objective measure of the risk posed by the item. The risk is the potential and consequences of a container breach that results in release of the material. The receptors of interest are primarily the facility workers and others who may be impacted by such a release.

With this prioritization methodology, the sites and the complex can focus the appropriate resources on corrective actions, such as repackaging of the material, to reduce or minimize the risks posed by the containers. In many cases, the material may be suitably packaged and this methodology provides a measure of surety of the containment. In other cases, where the calculated risk is higher, further attention can be directed to correcting the issues.

The methodology is based on an understanding of the nuclear material itself and those characteristics that could increase the consequences of a release, such as high specific radioactivity or physical state. For example, a finely divided powder presents a greater dispersion consequence than a solid metallic object would. The other material characteristics of interest are those that would promote, or lead to a container breach, such as radiolytic decomposition of organic polymers or corrosivity.

With a clear understanding of the material characteristics, one can better estimate the challenges the containment system must endure to adequately contain the material.

Next, the characteristics of the containment system must be evaluated. Obviously, a cardboard box is inappropriate for a material that has the potential for spontaneous combustion. Likewise, various materials of construction, sealing/venting systems, and design issues, such as burst strength must be considered. Often multiple layers of containment are necessary to adequately address the multiple challenges posed by the material. Likewise, additional containment may be necessary for handling and transfer during the packaging process to enable attainment of ALARA goals at the facility level.

Dose Consequence Model

To this end, a dose consequence model has been constructed that addresses the source term that the material in the container poses to the local workers. This is done by calculating a value that incorporates the material at risk (MAR) in the container, the respirable release fraction (RRF), and a leak path factor (LPF: measure of the fraction of the container that is spilled). The relationship is as follows:

(1) $S = MAR \times RRF \times LPF$

(2) where $RRF = DR \times ARF \times RF$

The RRF is composed of the damage ratio (DR), airborne release fraction (ARF), respirable fraction (RF).

Details of this calculation may be found in LA-UR-05-3864.

For example, a solid metallic object with no fines or dust associated with the object would have an RRF of zero. Therefore, the object presents an essentially zero source term for a containment breach scenario. On the other hand, a gas, for example would be effectively released by a containment breach such that the RRF for a gas would approach unity (1.0). Powdered materials and liquids lie somewhere in between depending on the specific characteristics of the material.

A useful way of grouping the materials is necessary to avoid the necessity of evaluating all of the individual items in a large inventory. The recommended grouping is by the descriptor used in the Item Description Implementation Plan (IDES). This permits the source term calculation to be performed on classes of materials, thus simplifying the prioritization exercise. Assumptions on the maximum quantity available or permitted in a given container are applied to derive the maximum source terms for the classes of materials.

The source term has units of grams. The consequence of releasing a particular material is also driven by the specific activity of the radioactive material. This is recognized by applying a dose conversion factor (DCF) to the source term. The DCF has the units of rem CEDE/g. Thus, when multiplied, a dose consequence can be calculated for each container or class of materials.

Container Failure Probability Model (Option 1)

The failure probability of a package is a function of its mechanical robustness, the reactivity of its contents, and the compatibility of its contents with the packaging barriers. Age of the container is obviously a driver in the ability of the package to maintain the initial barrier characteristics. Evaluation of the relative failure risks of the packages is based on the expert judgment of the packaging experts and results in a more qualitative result than the dose consequence model.

Several packaging characteristics are important to ensure the maintenance of a suitable containment barrier, such as resistance to corrosion by the contents, resistance to or venting of pressure buildup within the container, temperature effects, and the potential for the material to physically expand due to oxidation. This last phenomenon is termed "oxidative expansion" and can lead to internal forces by the material on the container that could cause the container to stretch, break, tear or otherwise be breached. Each package is therefore evaluated against the following indices: corrosion, pressure, pyrophoricity, and oxidative expansion. Each of these indices is assigned a relative value ranging from zero for very low potential for the index to three for a very high potential for the index.

The risk of failure is then computed using the following relationship:

$$F = I \bullet C \tag{3}$$

where: I is called the Reactivity Index and C is the called the Vulnerability Index.

Reactivity Index, I

The Reactivity Index I describes the characteristics of a given packaged material having four components,

$I = (I1, I2, I3, I4, I5)$ corresponding to the characteristics of
I = (corrosivity, pressure, pyrophoricity, oxidation expansion, placeholder = 1)

Each value (i.e., I1, I2, I3, I4) can range from 0, 1, 2, 3 corresponding to very low, low, medium, or high. I5, as a placeholder, will always be equal to 1. For example, a very fine, plutonium metal powder might have an index of

I = (0, 1, 2, 3, 1)

indicating that it is not very corrosive, it may generate some gas because of the potential of having water adsorbed on the surface, it is fairly pyrophoric, and its potential for oxidation expansion is great. Each of the reactivity indices is generated from the IDES database at a given site, as determined by subject matter experts.

Vulnerability Index, C

The Vulnerability Index describes how a given package configuration matches to the Reactivity Index of the contents. It contains the four characteristics for the Reactivity Index, plus a fifth one for radiolysis.

C = (C1, C2, C3, C4, C5) corresponding to the vulnerability of a given package configuration to

C = (corrosivity, pressure, pyrophoricity, oxidation expansion, radiolysis)

For example, given the metal powder given above (with its I = (0,1,2,3)) packaged in a stainless steel, cross-taped slip lid can might have Vulnerability index of:

C = (0, 0, 2, 3, 0)

C1=0, the powder will not corrode the can;
C2=0, the cross-tape will not impede the inside of the can to "breathe";
C3=2, depending on how fine the powder, how passivated it already is, it might be fairly pyrophoric;
C4=3, the powder will very likely over time convert to oxide, resulting in a huge expansion of the can contents;
C5=0, the can will not suffer radiolysis.

The Failure Probability is then the "dot product" of I and C, the product of multiplying each of the first indices together, then the second, then the third, etc, and then summing all five products together. Using the above example:

F = I•C
F = (0, 1, 2, 3, 1) • (0, 0, 2, 3, 0)
F = (0x0 + 1x0 + 2x2 + 3x3 + 1x0)
F = ( 0 + 0 + 4 + 9 + 0 )
F = 13

For a multiple packaging configuration, C then becomes CT, the total Vulnerability Index of all packages, and that is calculated as a product (n.b., neither the dot product nor the vector cross product, simply the product of each of the indices) of each of the containers. For example, two packages, package i inside of package o, each have vulnerability indices of Ci and Co respectively,

$Ci = (0,1,0,2,3)$
$Co = (1,2,0,0,1)$

Then

$CT = Ci \times Co$
$CT = (0,1,0,2,3) \times (1,2,0,0,1)$
$CT = (0\times1, 1\times2, 0\times0, 2\times0, 3\times1)$
$CT = ( 0 , 2 , 0 , 0 , 3 )$

This CT would be the C that would be dotted with I in the above equation, F = I•CT:

$F = I \bullet CT$
$F = (0, 1, 2, 3, 1) \bullet (0, 2, 0, 0, 3)$
$F = (0\times0 + 1\times2 + 2\times0 + 3\times0 + 1\times3)$
$F = ( 0 + 0 + 0 + 0 + 3 )$
$F = 3$

The age the package is taken into account by multiplying by a factor, T, which has the units of years.

The risk of package failure is then the product of the deterministic dose result and the qualitative failure probability as follows:

(4) $\text{Risk} = \text{Dose} \times F \times T$

Further details and specific examples of materials and the calculations may be found in LA-UR-05-3864.

## Discussion and Model Evaluation

It is recognized in general that the model is conceptual and that it will need to be calibrated against experience and engineering judgment by exercising it and comparing the results to actual inspection data. Its value lies in its ability to systematize and automate the ranking of thousands of containers in order to prioritize the repackaging campaign, a task that would otherwise be extremely tedious. Furthermore, the model is flexible and easily accommodates insights derived from package inspection during the repackaging campaign. Another key benefit of an automated nature of this approach is that it provides a tool to examine the relative importance of various input parameters and thus provides for expedient sensitivity analyses.

Risk in this abbreviated model is therefore defined by $R = \text{Dose} \times \text{trace } I^2 \times T(\text{years})$.

It was assumed that the age of the package would play a greater role in potential package failure for those packages that had higher reactivity indices (i.e., age would be much more detrimental to a package with a total reactivity index of, say, 7 versus of one with a 2). Furthermore, it was determined that a simple linear scaling would be inadequate to capture the effect (i.e., For a given reactivity index, a ten-year-old package was much more than two-times likely to fail than a five-year-old package). Therefore, package age (time in years) was scaled by a factor I/Imax:

$$R = \text{Dose x (some I)}$$
$$R = \text{Dose x (I x (IxT))}$$
$$R = \text{Dose x I2 x T}$$

This effectively makes the package failure probability proportional to the square of the trace of the reactivity index vector for its contents.

A scatter-plot of Dose vs. $I^2 \times T$ for a representative set of package provides a visualization of the relative risks of all packages in Fig. 1 below. Each point represents a container of nuclear material in an inventory, and the packages in the upper right portion are determined by the model to have the highest failure risk. The packages are plotted on a log-log plot to accomodate the broad range of risk values of packages in the inventory.

It is noteworthy that the items that have failed in recent incidents are found to have among the highest failure risk of all packages in study populations. In general, packages with the highest source term, the highest reactivity indices, and longest shelf life fall into the highest risk percentiles.

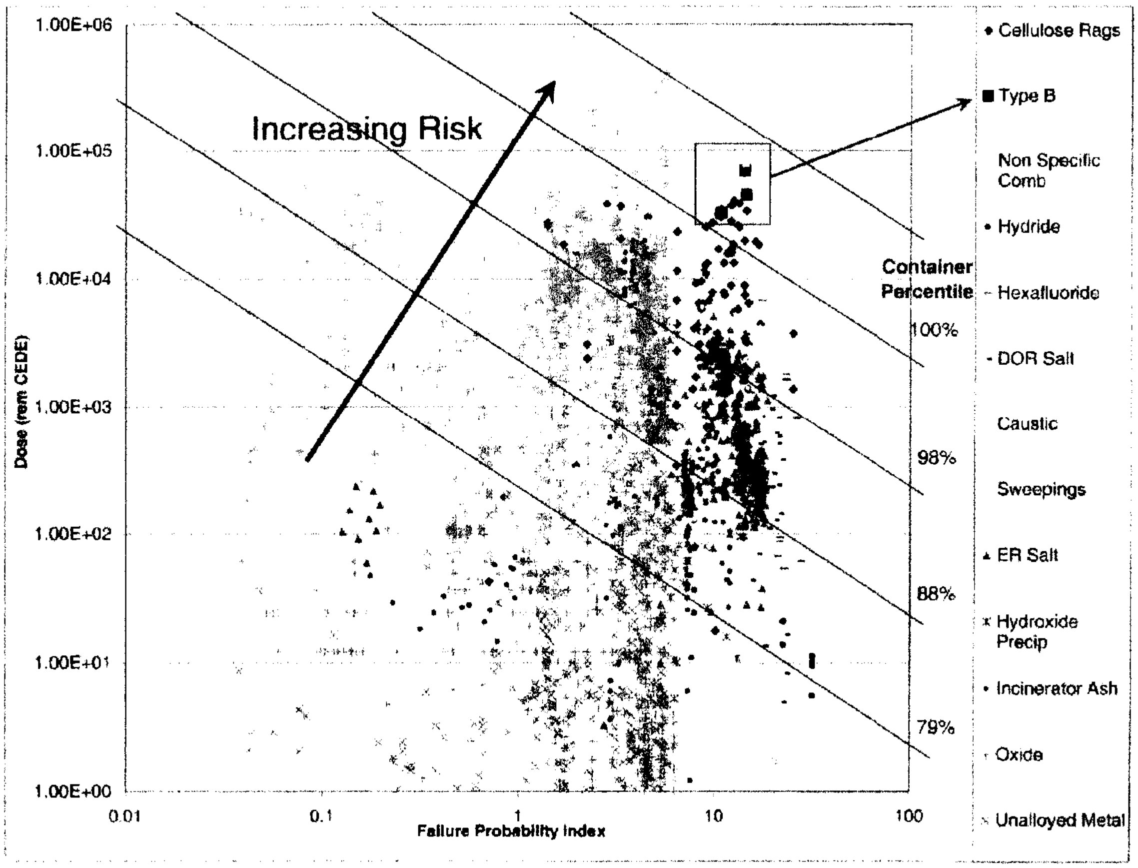


Figure 1 Container Failure Probability

Therefore, on a plot such as the one depicted in Figure 1, the items in the upper right quadrant pose the highest risk, whereas the items in the lower left quadrant pose the lowest risk. Funds and efforts should be focused on the items in the upper right quadrant before items in the lower left quadrant. This provides a means to prioritize the corrective actions for specific containers or classes of containers to effectively utilize limited available resources to address this concern. (Please see attached 11/29/05 update which describes the ongoing actions on option 1 to reduce uncertainties in estimating package failure probability)

Container Failure Probability Model (Option 2)

This is another method to provide a relatively simple objective method using available information (or defaults where it isn't available) to determine the failure probability index factor for prioritization of repackaging nuclear material that is in interim storage and is not likely to be repackaged for permanent storage. This along with the potential dose associated with a package failure can be used to estimate the repackaging priority.

Container Robustness (CR) = A + B + C + D + E + F + G + H + I
The higher the number, the safer the package and the lower the priority to repackage
Therefore:

Repackaging Priority (RP) = 1/CR X Time (in years)

Where A = Type of Material of Container

| | |
|---|---|
| 10 | Stainless Steel |
| 8 | Aluminum |
| 6 | Tinned Steel |
| 4 | Plastic |
| 2 | Glass |
| 0 | Other |

B = Type of Container Closure

| | |
|---|---|
| 10 | Welded Top |
| 9 | Bolted top with gasket |
| 8 | Screw top with gasket |
| 7 | Swaged top (food pack can) |
| 5 | Slip lid top, taped |
| 0 | No top |

C = Container Venting Mechanisms

| | |
|---|---|
| 10 | Vented and Filtered |
| 5 | Sealed |
| 5 | Vented without filter |
| 0 | No top |

D = Number of Containers

| | |
|---|---|
| 10 | Three or More |
| 8 | Double |
| 5 | Single |

E = Material State/ Form of the Smallest Items/ Particles

| | |
|---|---|
| 10 | Monolithic metal/solid |
| 8 | Large Chunks, no powder |
| 5 | Large Particle size powder |
| 3 | Fine powder |
| 0 | Unknown |

F = Other materials in container

| | |
|---|---|
| 10 | No |
| 8 | Yes – non- combustible |
| 5 | Yes – plastic or other material than can generate gas |
| 3 | Yes – potentially combustible |
| 0 | Unknown |

G = Challenges

| | |
|---|---|
| 10 | Non – corrosive |

| | |
|---|---|
| 8 | Slightly corrosive |
| 5 | Corrosive |
| 5 | Pyrophoric Material |
| 0 | Unknown |

H = Conditions when material packaged

| | |
|---|---|
| 10 | Dry/ inert atmosphere |
| 5 | Ambient Conditions |
| 3 | Unknown |
| 0 | Wet atmosphere |

I = Potential for Radiolytic Damage

| | |
|---|---|
| 10 | Low |
| 5 | Medium |
| 3 | Unknown |
| 0 | High |

## Conclusions

The approach outlined in this report offers an objective measure of the relative risks of individual or classes of packaged materials. The methodology considers both characteristics of the material and the container. The relative risk determination is a useful tool to prioritize repackaging or disposition activities based on the potential exposure dose and failure probability of the container. A consistent approach also permits evaluation and prioritization across the DOE sites and acknowledges various site-specific packaging approaches. Either or both options could be used with the atached Notational Approach Chart.

# Appendix A. Physical Characteristics and Release Parameters for a Spill – by IDES – LANL Example data

| IDES | Description | Physical Characteristic | *DR* | *ARF* | *RF* | *RRF* |
|---|---|---|---|---|---|---|
| A11 | Sub-assembly | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| A75 | Hemi | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| A95 | RTG | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| A99 | Pit | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| B52 | Non-Weap Nitrate Assembly | large pieces, < 10% fines in bottom | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| C02 | Acetate | small chunks/powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| C13 | Carbide | non-disp. mat. (ceramic pellet) | 0 | 0 | 0 | 0 |
| C19 | Chloride | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| C21 | Dioxide | loose, free-flowing powder | 1 | 2.0E-03 | 0.3 | 6.0E-04 |
| C21 | Dioxide - $^{238}$Pu | loose, free-flowing powder | 1 | 2.0E-03 | 1 | 2.0E-03 |
| C28 | Fluoride | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| C40 | Hydride | loose, free-flowing powder | 1 | 2.0E-03 | 0.3 | 6.0E-04 |
| C40 | Hydride - $^{238}$Pu | loose, free-flowing powder | 1 | 2.0E-03 | 0.3 | 6.0E-04 |
| C52 | Nitrate | small chunks/powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| C54 | Nitride | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| C66 | Phosphate/Phosphoric | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| C77 | Sulfate | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| C80 | Tetrafluoride | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| C82 | Trichloride | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| C86 | Trioxide | loose, free-flowing powder | 1 | 2.0E-03 | 0.3 | 6.0E-04 |
| C88 | U308 | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| E54 | Nitride - Reactor Element | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| G00 | Non-Specific Gas | gas | 1 | 1 | 1 | 1 |
| G00 | Non-Specific Gas - $^{238}$Pu | gas | 1 | 1 | 1 | 1 |
| G36 | Hexafluoride | gas | 1 | 1 | 1 | 1 |
| G36 | Hexafluoride - $^{238}$Pu | gas | 1 | 1 | 1 | 1 |
| K00 | Non-specific Comb. | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| K00 | Non-specific Comb. - $^{238}$Pu | contamination on flexible substrate | 1 | 1.0E-03 | 1 | 1.0E-03 |
| K15 | Cellulose Rags | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| K15 | Cellulose Rags - $^{238}$Pu | contamination on flexible substrate | 1 | 1.0E-03 | 1 | 1.0E-03 |
| K30 | Wooden HEPA Filter | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| K60 | Paper/Wood | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| K60 | Paper / Wood -$^{238}$Pu | contamination on flexible substrate | 1 | 1.0E-03 | 1 | 1.0E-03 |
| L14 | Caustic | liquid | 1 | 2.0E-04 | 0.5 | 1.0E-04 |
| L19 | Chloride Solution | liquid | 1 | 2.0E-04 | 0.5 | 1.0E-04 |
| L19 | Chloride Solution - $^{238}$Pu | liquid | 1 | 2.0E-04 | 0.5 | 1.0E-04 |
| L52 | Nitrate | liquid | 1 | 2.0E-04 | 0.5 | 1.0E-04 |
| L52 | Nitrate - $^{238}$Pu | liquid | 1 | 2.0E-04 | 0.5 | 1.0E-04 |
| L58 | Organic Solution | liquid | 1 | 2.0E-04 | 0.5 | 1.0E-04 |
| L61 | Perchlorate | liquid | 1 | 2.0E-04 | 0.5 | 1.0E-04 |
| L77 | Sulfate | liquid | 1 | 2.0E-04 | 0.5 | 1.0E-04 |
| L90 | Water | liquid | 1 | 2.0E-04 | 0.5 | 1.0E-04 |
| M32 | Beryllide | non-disp. mat. (encaps. neut. source) | 0 | 0 | 0 | 0 |
| M32 | Beryllide - $^{238}$Pu | non-disp. mat. (encaps. neut. source) | 0 | 0 | 0 | 0 |
| M44 | Unalloyed Metal | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| M44 | Unalloyed Metal - $^{238}$Pu | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| M74 | Alloyed Metal | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| M74 | Alloyed Metal - $^{238}$Pu | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |

| IDES | Description | Physical Characteristic | DR | ARF | RF | RRF |
|---|---|---|---|---|---|---|
| M76 | Alloyed Turnings | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| N00 | Non-spec. Noncombustibles | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| N00 | Non-spec. Noncomb. - $^{238}$Pu | contamination on flexible substrate | 1 | 1.0E-03 | 1 | 1.0E-03 |
| N05 | Asbestos | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| N24 | Filter Media | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| N24 | Filter Media - $^{238}$Pu | contamination on flexible substrate | 1 | 1.0E-03 | 1 | 1.0E-03 |
| N27 | Fire Brick | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| N29 | Glass | contamination on flexible substrate | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| N29 | Glass -$^{238}$Pu | contamination on flexible substrate | 0.01 | 2.0E-03 | 1 | 2.0E-05 |
| N31 | Graphite | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| N33 | Heating Mantles | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| N35 | HEPA Filters | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| N35 | HEPA Filters -$^{238}$Pu | contamination on flexible substrate | 1 | 1.0E-03 | 1 | 1.0E-03 |
| N48 | Leaded Gloves | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| N48 | Leaded Gloves - $^{238}$Pu | contamination on flexible substrate | 1 | 1.0E-03 | 1 | 1.0E-03 |
| N50 | MgO | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| N55 | Non-actinide Metals | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| N55 | Non-actinide Metals - $^{238}$Pu | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| N67 | Plastic / Kim Wipes | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| N67 | Plastic/Kim Wipes - $^{238}$Pu | contamination on flexible substrate | 1 | 1.0E-03 | 1 | 1.0E-03 |
| N69 | Resin | non-disp. mat. (large resin beads) | 0 | 0 | 0 | 0 |
| N70 | Rubber | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| N70 | Rubber -$^{238}$Pu | contamination on flexible substrate | 1 | 1.0E-03 | 1 | 1.0E-03 |
| N89 | Unleaded Gloves | contamination on flexible substrate | 1 | 1.0E-03 | 0.1 | 1.0E-04 |
| N89 | Unleaded Gloves - $^{238}$Pu | contamination on flexible substrate | 1 | 1.0E-03 | 1 | 1.0E-03 |
| R03 | Hydrogenous Salt | small chunks/powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R04 | Al2O3 crucible pieces | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| R09 | Calcium Salt | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R09 | Calcium Salt - $^{238}$Pu | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R10 | CaO | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R12 | Calcium Metal | large pieces, < 10% fines in bottom | 0.01 | 2.0E-03 | 0.3 | 6.0E-06 |
| R18 | Cemented Residue | non-disp. mat. (cemented piece) | 0 | 0 | 0 | 0 |
| R22 | Evaporator Bottom | liquid | 1 | 2.0E-04 | 0.5 | 1.0E-04 |
| R26 | Filter Residue | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R26 | Filter Residue - $^{238}$Pu | small chunks and powder | 0.1 | 2.0E-03 | 1 | 2.0E-04 |
| R41 | Hydroxide Precip. | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R41 | Hydroxide Precip - $^{238}$Pu | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R42 | DOR Salt | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R47 | Incinerator Ash | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R47 | Incinerator Ash - $^{238}$Pu | small chunks and powder | 0.1 | 2.0E-03 | 1 | 2.0E-04 |
| R59 | Oxalate Precip. | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R65 | ER Salt | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R71 | Misc. Salt | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R73 | Silica | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |
| R78 | Sweepings | loose, free-flowing powder | 1 | 2.0E-03 | 0.3 | 6.0E-04 |
| R78 | Sweepings - $^{238}$Pu | loose, free-flowing powder | 1 | 2.0E-03 | 1 | 2.0E-03 |
| R83 | MSE Salt | small chunks and powder | 0.1 | 2.0E-03 | 0.3 | 6.0E-05 |

The MASS accountability system is used to track special nuclear material (SNM) inventory by material type (MT) and summary material type (SMT), two groupings that bin commonly associated radioisotopes found in materials of interest at DOE sites. Using the LANL standard isotopic compositions of MT's and SMT's and specific activities of the isotopes from the Federal Guidance Report #11 [1] the association [2] of rem CEDE per inhaled gram of the material shown in Table 2 can be developed: (DOE sites may find it necessary to augment this table with material specific to their facilities.)

---

[1] DE89-011065, Limiting Values of the Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Keith F. Eckerman, Anthony B. Wolbast, and Allan C.B. Richardson, 1988.

[2] LA-UR-04-6820, Consequence Calculations for Safety Analysis at TA-55 and the CMR Facility, Hans Jordan and Gregory D. Smith, September 2004.

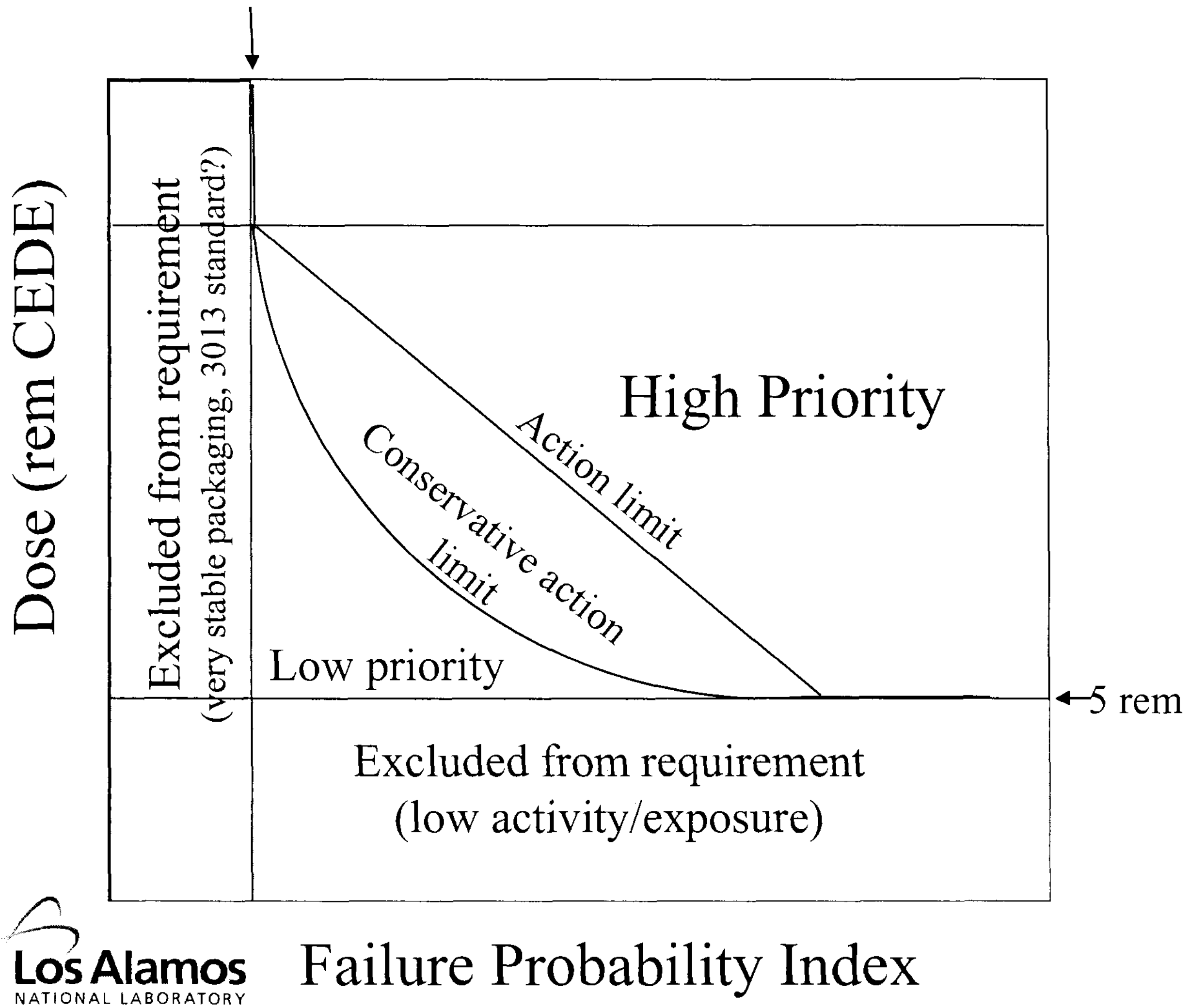
## Appendix B Dose Conversion Factors (*DCF*s) for Various Material Types

| SMT | MT | Description | rem CEDE/g | |
|---|---|---|---|---|
| | | | *W* | *Y* |
| 10 | | Depleted uranium | 2.36 | 39.8 |
| 20 | | Enriched uranium | 5.15E+02 | 8.66E+03 |
| 40 | 42* | Pu-242 | 1.46E+08 | 1.14E+08 |
| 44 | | Am-241 | 1.52E+09 | NA |
| 45 | | Am-243 | 8.76E+07 | NA |
| 46 | | curium | 1.39E+08 | NA |
| 47 | | berkelium | 2.32E+09 | NA |
| 48 | | californium | 7.37E+10 | 8.44E+10 |
| 50 | | plutonium | 3.74E+07 | 2.75E+07 |
| | 51 | | 3.09E+07 | 2.24E+07 |
| | 52 | | 3.58E+07 | 2.62E+07 |
| | 53 | | 4.22E+07 | 3.12E+07 |
| | 54 | | 5.43E+07 | 4.10E+07 |
| | 55 | | 6.23E+07 | 4.73E+07 |
| | 56 | | 6.65E+07 | 5.07E+07 |
| | 57 | | 1.23E+08 | 9.51E+07 |
| 60 | | enriched lithium | | *Stable* |
| 70 | | uranium enr. U-233 | 7.74E+04 | 1.31E+06 |
| 81 | | natural uranium | 2.36 | 39.8 |
| 82 | | Np-237 | 3.82E+05 | NA |
| 83 | | heat source Pu | 5.99E+09 | 4.42E+09 |
| 86 | | deuterium | | *Stable* |
| 87 | | tritium | 6.14E+05 | NA |
| 88 | | thorium | 1.80E+02 | 1.27E+02 |

* SMT consists of MT-41 and MT-42. Only MT-42 is present at LANL in appreciable amounts.

In this table, the inhalation dose is the 50-year Committed Effective Dose Equivalent or rem CEDE. It is shown for both lung clearance classes W and Y. For this analysis, salts and solutions were assigned class W; all other physico-chemical forms were assigned class Y.

# Notional approach to defining “In-scope” packages and possible action limits for 05-1 packaging effort



## Notes:

1. I refer to this document as a “requirement.” It might end up something else (“standard” ?).

2. I believe Glenn’s suggestions are right: first establish what is excluded (the horizontal and vertical lines), then address an action limit which further separates “in-scope” v. “out-of-scope” items or packages.

3. This addresses only packages factored in the MAR calcs; the 3013 standard is considered to remove material from MAR (essentially 0 failure probability).

4. LANL has recently been required to remove all very high activity packages above the Leak Path Factor “limit” out of the MAR (mostly Pu-238 items). Items in this category would only be excluded if expressly covered by another requirement.

5. The “low-activity” exclusion should give consideration to whether other limits (such as criticality) dictate the maximum credible amount of, say U-235, that is typically stored, rather than A2 limits (unlimited for U-235).

6. I favor more of the “conservative action limit” line v. the “action limit.” How each would be established is TBD.

The results of trying to "tighten up" the statistics of the expert-panel-assessment of the reactivity indices for various storage material forms (as of November 29, 2005)

Robert Margevicius and Paul Smith
Los Alamos National Laboratory
29 November 2005

In an attempt to reduce the standard deviations that resulted when five, complex-wide experts were surveyed to assess the reactivity indices of various material type/condition combinations, we decided to contact a much larger number of LANL experts in order for them to give their assessments of a subset of the list of materials addressed by the five-expert panel. The criteria for their selection were that 1) they were technical staff members; 2) they had good knowledge of chemistry; and 3) they have worked in the plutonium facility for some period in their careers.

We sent the survey to approximately 40 LANL experts. They were asked to assess the potential of a material form to four reactivity indices (see table below). As of 29 November 2005, we received 14 responses; we had hoped for more and still hope for more responses in the future. Not all responded to each assessment: where they felt they had good knowledge, they responded; where they felt their knowledge was lacking, they did not did not respond (unlike the prior expert panel of 5 where each expert responded to each assessment). Considering the number of assessments for each category (28 total: seven material forms and four indices, i.e, corrosion, pressure, oxidative expansion, and pyrophoricity), the range of number of responses went from four (i.e., four individuals felt they had enough knowledge to asses the pyrophoricity of a carbide compound) to fourteen (the corrosivity of a chloride solution), i.e., everyone—all 14—assessed the corrosivity of chloride solutions (interesting sidenote: all fourteen rated the corrosivity of a chloride solution as a 3, the most corrosive case). The "average" number of assessments was about 8.

The results of the assessments are given in the table below. The left column gives the material against the four reactivity indices, $I_1$, $I_2$, $I_3$, and $I_4$. For each of the indices, the assessment of the earlier 5 complex-wide expert panel referred to in Smith *et al.* (LANL LA-UR-05-3864, Table 3) is denoted as a blue 5. The more recent assessment performed by the LANL experts is given as the red N (since the number of responses ranged from 4 to 14). Below each of those sub-columns is given the average assessment (possible range from 0 to 3) as $x_i$ and the standard deviation as σ.

| | $I_1$ Corrosion | | | | $I_2$ Pressure | | | | $I_3$ Oxid. Expansion | | | | $I_4$ Pyrophoricity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | | N | | 5 | | N | | 5 | | N | | 5 | | N | |
| | $x_i$ | σ | $x_i$ | σ | $x_i$ | σ | $x_i$ | σ | $x_i$ | σ | $x_i$ | σ | $x_i$ | σ | $x_i$ | σ |
| Cellulose rags | 2.4 | 33 | 0.8 | 109 | 2.7 | 19 | 1.2 | 92 | 2.1 | 56 | 1.1 | 127 | 0.3 | 172 | 0.3 | 71 |
| Metal turnings | 1.0 | 0 | 0.3 | 50 | 0.8 | 48 | 0.3 | 50 | 1.7 | 76 | 2.4 | 70 | 0.7 | 113 | 1.6 | 97 |
| Chloride Solution | 3.0 | 0 | 3.0 | 0 | 2.0 | 55 | 1.1 | 105 | 0.3 | 172 | 0.1 | 33 | 0.3 | 172 | 0.1 | 33 |
| Incinerator ash | 1.3 | 62 | 1.0 | 120 | 1.7 | 72 | 0.6 | 52 | 0.6 | 88 | 0.1 | 33 | 0.3 | 172 | 0.1 | 38 |
| Tetrafluoride cmpnd | 1.7 | 58 | 1.4 | 106 | 0.5 | 100 | 0.8 | 89 | 0.3 | 172 | 0.4 | 79 | 0.3 | 172 | 0.2 | 41 |
| Fluoride compound | 2.3 | 35 | 1.4 | 106 | 0.8 | 96 | 0.8 | 89 | 0.6 | 88 | 0.4 | 79 | 0.3 | 172 | 0.2 | 41 |
| Carbide compound | 0.7 | 70 | 0.2 | 45 | 0.5 | 100 | 0.8 | 84 | 1.0 | 100 | 1.2 | 110 | 0.6 | 140 | 0.8 | 50 |

Overall, the results trend in the right direction, just not convincingly enough. (Ignore for the moment the averages, $x_i$; they tell an interesting story in themselves, but comparing the average assessed values was *not* the purpose of this exercise.) In ten cases the standard deviation increased, and in 18 it decreased. The average standard deviation decreased from 93% to 71%. Granted, a standard deviation based on eight assessments will not change too much from that of five. Therefore, we would say that the results here are weak, if not inconclusive. We believe that we should try to keep gathering assessments to determine if the standard deviation decreases significantly.

Another possibility brought to light as a result of this exercise stemmed from the very common comment that "not enough detail is given to give a good assessment." This begs the question whether, instead of a blind assessment done here, that one based on consensus might be better. That is, take your 10-20 experts, lock them in a room for two days, and have them hash out a list of material/conditions with numerical values. Where there is disagreement, pick a conservative case. We simply throw this out for contemplation.