Department of Energy
Washington, DC 20585

March 30, 2006

The Honorable A. J. Eggenberger
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, SW.
Suite 700
Washington, D.C. 20004-2901

Dear Mr. Chairman:

In the Department of Energy's (DOE) Implementation Plan for Recommendation 2005-1, *Nuclear Material Packing,* we committed to issue a repacking risk methodology in Commitment No. 5.3-2. The enclosure provides the deliverable for that commitment. The enclosure consists of a memorandum to the site managers introducing the requirements that will be forthcoming later this year regarding packing of nuclear materials for interim storage and a copy of the document referenced in the memorandum entitled, *Methodology for Determining repacking Needs and Prioritization for Repackaging Nuclear Materials.*

Please contact me at (202) 586-6151 if you have questions or comments.

Sincerely,

RJHardwick Jr
for C. Russell H. Shearer
Acting Assistant Secretary for
Environment, Safety and Health

Enclosure

cc: R. Hardwick, EH-2
R. Stark, EH-2
M. Whitaker, DR-1
C. Lagdon, US-1
J. McConnell, NA-1

06.0497

Department of Energy
Washington, DC 20585

March 30, 2006

MEMORANDUM FOR: DISTRIBUTION

FROM: C. RUSSELL H. SHEARER RJHardwill
ACTING ASSISTANT SECRETARY FOR
ENVIRONMENT, SAFETY AND HEALTH

SUBJECT: Defense Nuclear Facilities Safety Board
Recommendation 2005-1

On August 17, 2005, Secretary Bodman approved the Department of Energy's (DOE) Implementation Plan (IP) to address the safety issues raised by the Defense Nuclear Facilities Safety Board (DNFSB) in Recommendation 2005-1, *Nuclear Material Packaging.* The DOE IP committed the Department to developing requirements for nuclear material packaging for the safe storage of nuclear materials outside of engineered contamination barriers. These requirements are being developed in the format of a new manual. After the DOE manual is finalized (scheduled to be submitted to the Directives System process at the end of June 2006) the following site activities need to occur:

- Each site will evaluate their stored materials to establish which actions are necessary for implementing the DOE manual,
- A site implementation plan will be prepared to identify which packaging must be replaced or qualified,
- The site implementation plan will include a prioritization assessment to determine an appropriate order in which to repackage materials, as applicable, and
- Each site will develop a resource loaded schedule and funding plan for implementing the DOE manual.

In addition, the DOE IP stated that the Department would develop a risk ranking methodology which each site will use to prioritize repackaging of stored nuclear materials.

The Department established a complex-wide working group to develop the requirements and the risk methodology. The working group is drafting a DOE manual (to be DOE M 441.1) in support of 10 CFR 835 which defines the requirements. The draft DOE manual establishes the isotopes to be considered and the isotope thresholds below which the requirements do not apply. The draft manual also excludes classes of materials and excludes materials already stored in packaging per approved DOE or Department of Transportation (DOT) requirements and associated standards. The working group has developed the risk ranking methodology to assist each site in implementing the requirements.

The purpose of this memo is to provide the prioritization methodology (see attachment) to assist site managers in developing site implementation plans. Per the DOE IP this methodology is to be issued before issuance of the DOE manual to allow DOE sites to begin their preparations. The DOE IP (Section 5.3 and Appendix D) provides additional description of the site's implementation plan development as well as the schedule for the development of the site implementation plan. The DOE IP can be found on the Departmental Representatives Website at: [http://www.deprep.org/]. Because some site information needed in estimating existing packaging integrity may not currently exist (such as estimating the integrity of inner containers within sealed outer containers), each site plan should include specific checks during the initial repackaging efforts to confirm that their existing package assumptions and estimations in their implementation plan remain valid or whether the prioritization plan needs to be appropriately modified. A sampling plan may be employed to achieve this confirmation.

Your Recommendation 2005-1 IP working group member can assist you as you develop your plan. You may also contact Mr. Richard Stark, EH-24, 301-903-4407 for additional site implementation information and assistance.

Attachment:
As Stated

cc:
J. McConnell, NA-1
C. Lagdon, US-1
R. Hardwick, EH-2
R. Stark, EH-2
R. McMorland, DR-1

See next page for
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METHODOLOGY for DETERMINING REPACKAGING NEEDS and PRIORITIZATION of REPACKAGING NUCLEAR MATERIALS

OFFICE OF ENVIRONMENT, SAFETY AND HEALTH

HELPING THE FIELD SUCCEED WITH SAFE AND RELIABLE OPERATIONS

Office of Facility Safety

Office of Environment, Safety and Health

March 30, 2006

U.S. Department of Energy

Helping the Field Succeed
with
Safe and Reliable Operations

Methodology for Determining Repackaging Needs and Prioritization of Repackaging Nuclear Materials

Abstract

Safe handling and storage of nuclear material at U. S. Department of Energy facilities relies on the use of adequate containers to prevent worker contamination and uptake of radioactive material. The U. S. Department of Energy is establishing requirements for packaging and storage of nuclear materials other than: those declared excess, those packaged to DOE-STD-3013-2004 and U-233 packaged to DOE-STD 3028-2000. This report describes a methodology to assist managers in prioritizing the current inventory of nuclear material containers deemed to need repackaging. The prioritization methodology establishes worker hazards for managers to prioritize the repackaging of Nuclear Material packages based upon worker risk. A risk factor is developed for each nuclear material package based on a calculated potential accident dose to a worker due to a failed container barrier and an estimated probability of container failure. This risk-based methodology uses all accessible information to prioritize the repackaging effort. All packages that exceed the threshold and appear on the attached dose vs. failure chart are deemed to need repackaging. (See attached Chart in Appendix C) This risk methodology determines which packages need to be repackaged and which of these should be repackaged first. This methodology is NOT a safety analysis and cannot be used for Documented Safety Analysis (DSA), Safety Analysis Report (SAR), or Authorization Basis (AB) purposes. It is *a tool that management can use* to establish the priority of necessary repackaging of nuclear material.

This methodology is generic for application at all DOE sites. It recognizes that each DOE site has a different level of package information.

List of Acronyms

ALARA	As Low As Reasonably Achievable
ARF	Airborne Release Fraction – the fraction material aerosolized by the event
C	Vulnerability Index
C_1	CorrosionVulnerability Index
C_2	PressureVulnerability Index
C_3	Pyrophoricity Vulnerability Index
C_4	Oxidative Expansion Vulnerability Index
C_5	RadiolysisVulnerability Index
DSA	Documented Safety Analysis
DCF	Dose Conversion Factor
DOE	U. S. Department of Energy
DR	Damage Ratio – the fraction of the MAR impacted by the actual accident
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	Oxidative Expansion Reactivity Index
I_5	Radiolysis Reactivity Index
IDES	Item Description
IP	Implementation Plan
LANL	Los Alamos National Laboratory
LPF	Leak Path Factor – the fraction of airborne material transported from containment
MAR	Material-At-Risk – amount of material available for release (Usually the contents of the container)
MASS	Material Accountability and Safeguards System
MRR	Materials Recycle and Recovery
MT	Material Type
R	Risk
CEDE	Committed Effective Dose Equivalent, in rem
RF	Respirable Fraction – the fraction of aerosolized material that is respirable
RRF	Respirable Release Fraction – RRF = DR x ARF x RF
S	Source Term, in g
SAR	Safety Analysis Report
SMT	Summary Material Type
SNM	Special Nuclear Material
T	Age of the Package
W	CEDE lung clearance class W, in rem/g
Y	CEDE lung clearance class Y, in rem/g

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. The combinations of material and container configurations were adequate for the originally anticipated period of storage or for a particular use, but some are no longer adequate because of a longer than anticipated storage condition caused by a change in mission.

This document outlines the methodology for DOE Managers to determine the Nuclear Material packages that need to be repackaged and for the prioritization of existing packaging configurations deemed to need repackaging across the DOE complex. Additionally, this document meets a DNFSB 2005-1 commitment to develop a prioritization methodology for implementing the repackaging criteria based on the hazards and risks posed by the existing nuclear material.

The methodology uses the relevant physical, reactive, and radiological properties of the stored material as well as their interactions with the containment barriers of the packaging system. The methodology is generic and covers a wide range of materials, forms, and hazards. The evaluation techniques acknowledge the variety of packaging systems available and provide a means to evaluate existing packages. The prioritization provides a means to focus on the most hazardous items as well as providing a means to develop an implementation plan for repackaging that employs a graded approach based on an objective measure of relative risk to the facility workers.

Approach

The purpose of the prioritization methodology is to provide a means of evaluating the packaging of stored nuclear material across the complex that results in a measure of the relative risk posed by the item. The risk is an estimate of the potential consequences of a container breach that results in a release of the material and the probability of that occurring. The receptors are the facility workers who may be impacted by such a release.

With this prioritization methodology, the sites and the complex can focus resources on corrective actions, such as repackaging of the material, to reduce or minimize the potential risks posed by the containers. In many cases, the material may be suitably packaged and this methodology provides a measure of the adequacy of the packaging.

The methodology is based on an understanding of the properties of the nuclear material and those characteristics that could increase the consequences or probability of a release. With a clear understanding of the material characteristics, one can estimate the challenges the containment system must endure to adequately contain the material. Material with a high specific radioactivity and/or a particular physical state can pose an increased risk to the worker. For example, a finely divided powder presents a greater dispersion consequence than a solid metallic object. Other material characteristics of interest are those that would promote, or increase the probability of a container breach, such as corrosivity or radiolytic decomposition of organic polymers

The characteristics of the containment system (packaging) can be evaluated. Various materials of construction, sealing/venting systems, and design issues must be considered. Often multiple layers of containment are employed to adequately address the multiple challenges posed by the material. Likewise, additional containment may be employed for handling and transfer during the packaging process to enable attainment of ALARA goals at the facility level.

<u>Dose Consequence Model (Y Axis of Chart in Appendix C)</u>

A dose consequence model is used to address the potential hazard source term (S) 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), i.e. the radioactive material in the container, the respirable release fraction (RRF), and a leak path factor (LPF) which is a 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 Respirable Release Fraction (RRF) is composed of the Damage Ratio (DR), which is the fraction of the MAR that can be released, the Airborne Release Fraction (ARF), how much gets into the air and the Respirable Fraction (RF) , what fraction of the airborne release is small enough particles to enter and stay in a persons lungs.

The Acronyms used above are listed on a previous page. They are based upon the discussion and calculations which may be found in LA-UR-05-3864. A more detailed discussion of the 5 factor formula, its basis, use and acronyms used for release calculations can be found in DOE-HDBK-3010-94.

For example, a solid metallic object with no fines or dust associated with the object would have an ARF and RF of zero and therefore, an RRF of zero. As a result, the object presents an essentially zero source term for a containment breach scenario. On the other hand, a gas 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. Values for DR, ARF, RF and RRF are listed in Appendix A, by IDES, using example data.

The source term (S) 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. Appendix B has DCFs for selected materials. The DCF has the units of rem CEDE/g. From this information, a dose consequence can be calculated for each container or class of materials. This can be plotted on the Y Axis.

Container Failure Probability Model (X Axis of Chart in Appendix C) **(Option 1)**

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

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 relative probability of failure per year is then computed using the following relationship:

(3) $F = I \bullet C$

where: F is the Failure Probability of a Package
I is called the Reactivity Index and
C is 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
$I = (I1 = \text{corrosivity}, I2 = \text{pressure}, I3 = \text{pyrophoricity}, I4 = \text{oxidative expansion})$

I5 is a placeholder = 1 (so that we aren't trying to multiply by 0)

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 oxidative expansion is great. Each of the reactivity indices is generated from the IDES database at a given site, as determined by subject matter experts (personnel who are familiar with the processes, packaging and material at the site).

Vulnerability Index (C)

The Vulnerability Index (C) 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.
C = (C1 = corrosivity, C2 = pressure, C3 = pyrophoricity, C4 = oxidative expansion, C5 = radiolysis)

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

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

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

The Failure Probability (F) 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, the total Vulnerability Index (C_T) of all packages, and that is calculated as a product which is 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,

$C_T = Ci \times Co$
$C_T = (0,1,0,2,3) \times (1,2,0,0,1)$
$C_T = (0x1, 1x2, 0x0, 2x0, 3x1)$
$C_T = (0 , 2 , 0 , 0 , 3)$

Thus, C_T would be the C that would be dotted with I in the above equation, $F = I \bullet C$:

$F = I \bullet C_T$
$F = (0, 1, 2, 3, 1) \bullet (0, 2, 0, 0, 3)$
$F = (0x0 + 1x2 + 2x0 + 3x0 + 1x3)$
$F = (0 + 2 + 0 + 0 + 3)$
$F = 5$

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

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

(4) Risk (R) = Dose x F x T

Ideally, perfect knowledge of packaging would allow relevant assignment of values for F, because relevant values for C would be known (as drawn from equation $F= I \bullet C$ and to the extent that can be accurately determined). However, with imperfect, or no knowledge of packaging status, a default value for C of (1,1,1,1,1) can be assigned until the knowledge of packaging details is determined through appropriate surveillance or repackaging activities. With the assignment of C = (1,1,1,1,1), F will equal I. Therefore, in the following analysis, C is assumed to be 1, and I is substituted for F.

The sum of the Reactivity Indices (I_{total}) determined for selected packages ranged from 0 to about 7.52 (in the LANL risk prioritization model). In order to normalize the range from 0 to 1, each Reactivity Index sum (I_{total}) was divided by 7.52 (i.e., I_{max}), yielding, in general, the normalized I (I_{norm}).

(5) $I_{norm} = I_{total} / I_{max}$

Also, 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_{norm}

(6) $R = \text{Dose} \times (I_{norm}) \times T$ (standard equation)

(7) $R = \text{Dose} \times (I_{norm} \times (I_{norm} \times T))$ (equation modified to reflect compounding effect of time and reactivity index)

(8) $R = \text{Dose} \times (I_{norm})^2 \times T$

A scatter-plot of Dose vs. $(I_{norm})^2 \times T$ 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 accommodate 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

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

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.

Discussion and Model Evaluation

In general, it is recognized that the model is based upon quantitative calculations for the dose, and experience from surveillance data and engineering knowledge for the failure probability. 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 can easily accommodate insights derived from package inspections and surveillance. Another key benefit of an automated nature of this methodology is that it provides a tool to examine the relative importance of various input parameters and thus provides for expedient sensitivity analyses.

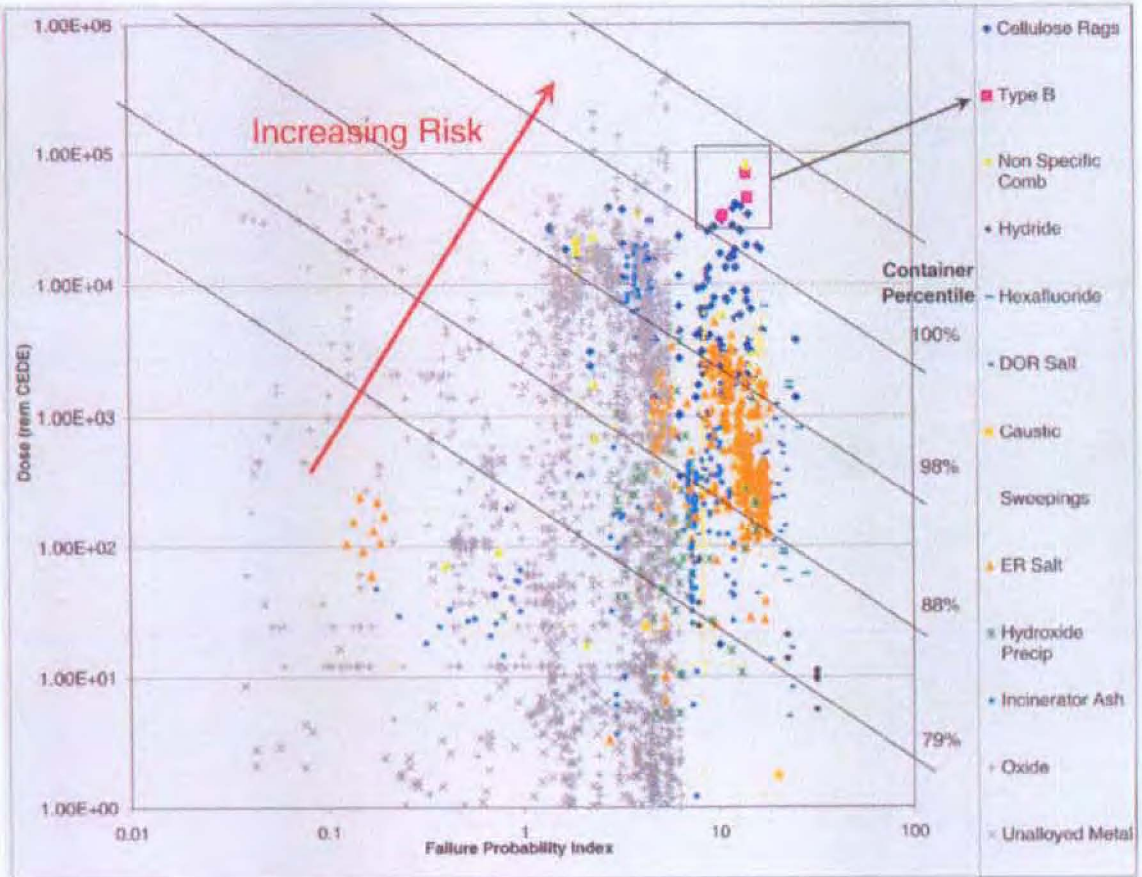

Figure 1. Container Failure Probability

Container Failure Probability Model (X Axis of Chart in Appendix C)(Option 2)

This is another model, which management can use, to provide a relatively simple 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. This model for the X Axis, along with the potential dose associated with a package failure calculated using the Dose Consequence Model for the Y Axis, can be used to create a chart similar to Figure 1 and estimate the repackaging priority.

(9) $RP = 1/CR \times T$

Where: RP = Repackaging Priority
T = time package has been in storage, in years

CR = Container robustness

And:

(10) CR = A + B + C + D + E + F + G + H + I

If the package consists of more than one container, evaluate the most robust container, using the following parameters:

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
2 Liquid
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 (for sealed packages only)

10	Dry/ inert atmosphere
5	Ambient Conditions
3	Unknown
0	Wet atmosphere or wet material

I = Potential for Radiolytic Damage

10	Low
5	Medium
3	Unknown
0	High

The container robustness (CR) is the sum of the numbers. The higher the CR number, the safer the package. Therefore, 1/CR, which equals the Repackaging Priority, is lower and there is a lower priority to repackage the material.

As an example, if we had a solid metallic piece of U-235 with no fines, oiled to prevent corrosion, stored in a cross-taped stainless steel slip lid can for 10 years, using the simple model in option 2 the following calculation might result:

A = 10	Type of container material is stainless steel
B = 5	Type of container closure is slip lid top, taped
C = 5	Vented without filter - slip lid top, taped
D = 5	Single container
E = 10	Monolithic Metal/ solid
F = 10	Other Material – none
G = 10	Non-corrosive since it is oiled
H = N/A	Since container not sealed
I = 10	Potential for radiolytic damage is low

$$
\begin{aligned}
CR &= 65 \\
RP &= 1/CR \times T \\
&= 1/65 \times 10 \\
&= 0.015 \times 10 \\
RP &= 0.15
\end{aligned}
$$

Assuming the Repackaging Priority (RP) is approximately equal to the Failure Probability Index as shown on the Scatter Plot in Figure 1, then:

(11) Failure Probability $F \sim RP = 1/CR \times T$

Assuming the Source Term (S) in the above example is essentially zero, since the activity involved with the U-235 is not readily respirable, the result with equation 11 would fall on the X Axis at 0.15 on Figure 1.

Conclusions

The methods outlined in this report estimate the relative risks of individual, or classes, of packaged Nuclear Materials. The methodologies consider both characteristics of the material and the package. The relative risk determination is a useful management tool to prioritize repackaging or disposition activities based on the potential exposure dose and failure probability of the package. A consistent approach also permits evaluation and prioritization across the DOE sites and acknowledges various site-specific packaging approaches. Either option is used with the Appendix C to determine which packages are excluded from repackaging and which packages are in scope and assist in determining the priority for repackaging, based upon worker risk.

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

IDES	Description	Physical Characteristic	*DR*	*ARF*	*RF*	*RRF*
TBD	Metal Monolith – ^{235}U	large pieces, <0.1% fines, passivated	0.001	1.0E-04	0.1	1.0E-08
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

IDES	Description	Physical Characteristic	*DR*	*ARF*	*RF*	*RRF*
M74	Alloyed Metal - ^{238}Pu	large pieces, < 10% fines in bottom	0.01	2.0E-03	0.3	6.0E-06
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*	rem CEDE/g *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.

Appendix C
Definition of "In-scope" Packages for DNFSB 2005-1 Repackaging Effort