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Implementing the DOE M 441.1-1 Nuclear Materials Packaging Manual at Lawrence Livermore National Laboratory

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Background

Following implementation of the DOE 3013 long term storage standard, discussion began on how nuclear materials are packaged for interim storage at Department of Energy (DOE) and National Nuclear Security Administration (NNSA) sites. In 2005 the Defense Nuclear Facility Safety Board (DNFSB) issued a recommendation that DOE develop requirements for interim storage of nuclear materials. In response to this recommendation DOE developed the Nuclear Material Packaging Manual DOE Manual 441.1-1 (DOE, 2008).

This Nuclear Material Packaging Manual covers nuclear materials that are stored outside engineered contamination barriers. It is concerned about materials

> "whose composition and quantity create the potential for an airborne contamination hazard that could result in a facility worker receiving an internal radiation dose in excess of 5 rem CEDE. Nuclear materials of this type (i.e., that could become an airborne hazard upon package failure) with a total quantity in a storage package exceeding the A2 thresholds established in 49 CFR § 173.435, Table of A1 and A2 values for radionuclides, are subject to the specific container requirements of this Manual. "

This paper discusses LLNL's implementation of the Nuclear Material Packaging Manual.

Lawrence Livermore National Laboratory (LLNL) Background

LLNL has a long history of safely using inexpensive and disposable containers for short term packaging of nuclear materials. To assure worker safety LLNL employs the following systems for short term packaging of nuclear materials: multiple packaging barriers, Fissile Material Handler training and response, visual inspection during MC&A activities, Personal Protection Equipment, and Continuous Air Monitors. However, these current packaging systems are not fully compliant with DOE Manual 441.1-1. LLNL has produced a plan to achieve full compliance.

LLNL has just recently completed a major reduction in the nuclear material inventory at LLNL in order to transition from a Security Category I to a Security Category III site. It was determined that implementation of the DOE M441.1-1 would be delayed until LLNL was operating as a Security Category III site. This approach was considered to have the least safety risk to workers since most nuclear material was destined to be processed and packaged for off-site shipment. Thus eliminating the need to handle and package the nuclear material more than once. A more important consideration is that the DOE M441.1-1 compliant overpack containers were not approved or available until this year.

Prioritization

LLNL has about 700 items in the Plutonium Facility vaults that are within scope of the Manual. Each of these items were assigned a risk score to assure that those packages that had the highest risk to the workers were repackaged first. This was done by using a modification of the "Methodology for Determining Repackaging Needs and Prioritization of Repackaging Nuclear Materials" (DOE, 2007).

Risk is the combination of Consequence and Probability of Failure:

Risk = Consequence * Probability of Failure

The consequence is what the worker would be exposed to if the container fails. And the probability of failure is what the chances that the container would fail. For this analysis it is hard to determine probabilities of container failure so the analysis is done on a relative scale for each of the factors that affect container failure.

The risk factor is computed using the following equation:

R = [Health Factor]*[Sum(Material Factors{M1-M4}*Container Factors{C1-C4})]*
[Container Integrity {C5}]*[Age Factor]

The factors that determine the risk to the worker include:

a) Health Factor

This is the consequence part of the risk equation. The Health Factor is determined by the radioactive material content of the item. Each isotope has a different risk to the worker depending upon the radioactive dose the isotope emits and how it is eliminated from the body. This information is incorporated in determining the A2 factor in 49 CFR § 173.435. The health factor is determined by computing the sum of fractions:

$$Effective\ A2 = \sum \frac{Amount_x}{A2_x}$$

Where the $Amount_x$ is the amount of isotope x and $A2_x$ is the value of A2 for isotope x from 49 CFR § 173.435. The units of Amount and A2 should be the same.

The Effective A2 value was used to determine the Health Factor:

Table 1

Effective A2 Value	Health Factor Score
<20*A2	1
20*A2 to 200*A2	2
200*A2 to 10,000*A2	10
>10,000*A2	20

b) Material factors

Material factors are one of the components that determine the chances of container failure. It is based on the characteristics of the material and how they would interact with the container. The other component that determines the chances of container failure is the container properties which are discussed below. That is why the second factor of the equation is a sum of Material Factors and Container Factors. The Material Factors are:

M1) pyrophoricity, explosion sensitive or flammable,
M2) gas Generating, Oxidative Expansion, and/or has moisture,
M3) corrosivity, solutions, and/or incompatible materials, and
M4) radiation Decay and Heat Generation.

Characteristics M1, M2, and M3 are given a score from 0, 2 or 5 with:

0 being no potential,
2 low potential, and
5 being high potential.

M4 are scored as follows:

Low Heat/Radiation Field Generation (Specific Activity $<1 \times 10^{-1}$ Ci/g)	1,
Mid Heat/Radiation Field Generation (Specific Activity between 1×10^{-1} and 1 Ci/g)	2, and
High Heat/Radiation Field Generation (Specific Activity $>1 \times 10^{1}$ Ci/g)	5.

c) Container Factors

The container has factors that correspond to the Material Factors. This is basically how well does the container withstand the various concerns that the material would cause. There is also a 5th Container Factor that is Drop Vulnerability. The container factors are:

C1 – Reaction to air: Sealing Mechanism,
C2 – Pressure Generation: Venting and/or Expansion Mechanism,
C3 – Corrosion Resistance: Resistance to reaction byproducts, gases, corrosion, etc,
C4 – Resistance to heat and radiation field: Material of construction resistance to radiation and/or heat, and
C5 – Drop Vulnerability.

Each of these characteristics are given a score from 1, 3, or 5 with:

Good resistance	1,
Fair resistance	3, and
Poor resistance	5.

d) Age Factor
This factor is to include the concern that the older the item is the more likely it will fail. The Age Factors are determined as following:

Table 2

Age (yrs)	Score
0 to <5	1
5 to <10	2
10 to <20	5
>20	10

For a particular item all of the factors are evaluated and the R factor is computed. Then materials are binned into risk groups. The risk groups are:

Table 3

Risk Group	R
Very High	>10000
High	1000-10000
Medium	100-1000
Low	<100

A couple examples for LLNL material are:

Table 4

Material	Packaging	Age	M1	M2	M3	M4	C1	C2	C3	C4	C5	Age	R'
Salts	Sealed Quart/ Sealed Juice	0-10 yrs	0	2	5	2	3	1	5	1	3	2	174
Salts	Paint Can/ Slip Lid	0-10 yrs	0	2	5	2	3	1	5	1	5	2	290
Oxides	Sealed Quart/ Sealed Juice	0-10 yrs	0	5	0	2	3	1	5	1	3	2	42
Metals	Sealed Quart/ Sealed Juice	0-10 yrs	2	5	2	2	3	1	1	1	3	2	9
Note: The R' score is without the Health Factor													

A December 2012 analysis resulted in the following number of containers by risk score at LLNL.

Low	412
Medium	266
High	13
Total	691

The 13 containers that were given a risk score of high were repackaged. LLNL had no containers in the very high risk group.

Technical Basis

In selecting a packaging system that would work for LLNL the first consideration was that the packaging system must meet the requirements of the Manual. These requirements include:

a) multiple container can be combined to create an acceptable package,
b) packaging System shall be tested by a drop test,
c) seal must last the design life of the package or be replaced as part of the package maintenance,
d) container should be leak tested to meet the requirements,
e) sealed container must withstand the pressure,
f) vented container must be filtered to the requirements, and
g) surveillance program must be developed to monitor the packages for premature failure.

Using these requirements we developed packaging systems for various materials. In July 2007, LLNL looked into different packaging options to meet the Manual requirements. The systems we looked at included using double-welded containers (similar to a DOE-STD-3013 container) or our current packaging of rigid container/double bag/crimp sealed containers.

The double welded container is a very robust system but it was also costly with an estimated cost to implement of $10M and additional high costs to repackage as material is used for programmatic missions. The other option was to use the LLNL double rigid crimp sealed containers that are leak tested. This was estimated to require $3.7M for implementation.

A third option was developed by Los Alamos National Laboratory (LANL) that consists of placing existing nuclear material packages into engineered and tested SAVY containers. In 2010, LANL has completed their work on SAVY4000 containers (LANL, 2010). Although more expensive than the second option, the elimination of leak testing decreases operational costs. This container was developed by LANL and has been reviewed by NA-17. NA-17 also reviews shipping package Safety Analysis Reports for Packaging (SARPs). The SAVY containers come in a number of sizes:

Table 5

Size	Overall OD (inches)	Overall Height (inches)	Inner OD (inches)	Usable Inner Height (inches)	Gross Weight (lb)	Tare Weight(lb)	Payload Max Weight (lb)
1 QT	4.770	5.980	3.670	4.38	22	3.32	18.68
3 QT	6.550	7.950	5.450	6.76	33	5.62	27.38
5 QT	7.700	9.950	6.600	8.76	40	7.40	32.60
8 QT	8.850	11.450	7.750	10.26	44	9.31	34.69
12 QT	10.000	13.950	8.900	12.76	49	11.92	37.08
5 GAL	11.750	15.665	10.250	14.06	55	18.81	36.19
10 GAL	15.469	17.635	13.969	15.87	88	26.13	61.87

LLNL has procured and has begun using the 1, 3, and 5 Quart sizes.

The inner package consists of a sealed food pack configuration which is a rigid container that is bagged out of the glove box and then sealed in a crimp sealed food pack can. The use of the crimp sealed inner can maintains an inert atmosphere for metals and salts that would react with air or moisture in the air. If the food pack container were to fail the outer vented SAVY4000 container would prevent release of material.

A number of other controls have been initiated to ensure that the inner cans remain intact. These include:

a) salts will be packaged under inert gas atmosphere,
b) oxides will be calcined at 750C before packaging for storage or they will be stored in vented containers,
c) containers for metal items will have sufficient volume for oxidative expansion, and
d) slip-lids will be eliminated.

Implementation

We have two categories of material currently stored in the vaults. They are programmatic material and waste material. The programmatic materials are items for ongoing programs. The waste materials are nuclear material slated for waste that has high nuclear material content and was generated as a result of disposal of programmatic material. It is being held in the vaults while a glove box is being set up for processing those items into waste drums.

We have completed the quality assurance on the SAVY containers and are placing them into service. Once they are placed in service, programmatic material in the vault will be repackaged in the SAVY4000 containers.

Current plans

In Fiscal Year 2013 (FY13), LLNL has developed and approved DOE M 441.1-1 compliance Quality Assurance (QA), surveillance, and worker use procedures for the SAVY 4000 containers. The containers on site have been QA'd. We have begun risk reduction of the stored materials by repacking them into SAVY4000 containers. We have repacked all of the high hazard items and have begun the implementation of all SAVY 4000 container use. As part of this process, we will periodically reevaluate the materials per the risk ranking analysis to assure that the highest risk items are in proper packaging. We plan to complete the next official risk ranking by December 31, 2013. The results of this risk ranking will be reported to DOE.

References:

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