Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

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UNDERSTANDING AGING IN THE 9975 SHIPPING PACKAGE

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ABSTRACT

Unlike other facilities across the Department of Energy (DOE) Complex, the Savannah River Site (SRS) K-Area Complex (KAC) stores nuclear materials inside a 9975 shipping package because of the robust nature of the package to survive facility accidents and fire events. The 9975 is credited for containment, criticality prevention, impact resistance and thermal resistance. A thorough surveillance program has been in place for more than a decade to monitor the material performance and degradation in order establish a basis for the service life and the need for repackaging 9975 shipping packages in KAC. The surveillance approach is a combination of NDE/DE field surveillance as well as laboratory testing and aging studies. The field surveillance NDE techniques include (e.g. visual inspections, leak checks, dimensional measurements as well as weight and thermal measurements). A limited number of 9975s also undergo a more in-depth examination and destructive testing of some components to provide additional assurance that adequate material properties are maintained. The laboratory testing examines the 9975 material components (e.g. O-rings and fiberboard) at the bounding storage conditions and monitor material properties and functional performance over time. The lab tests are designed to accelerate material aging to monitor and trend properties in order to lead the actual field conditions. After almost fifteen years of storage, a number of items have started to show evidence of degradation. The most significant item to experience a performance change is the fiberboard which is changing not only due to aging but also because of the thermal load inside the package. This report serves to document and understand the as found conditions of the fiberboard and other elements of the 9975 shipping package used for long term storage of nuclear materials. Since many of the components of the 9975 are used in other types of shipping packages as well, the understanding of the aging properties can be applied to other types of packages.

INTRODUCTION

The model 9975 transportation package has been certified by the United States DOE for shipment of type B radioactive and fissile materials in accordance with Part 71, Title 10 Code of Federal Regulations (CFR), or 10 CFR 71, Packaging and Transportation of Radioactive Materials. The package is composed of a 35 gallon stainless overpack drum with a bolted flange closure. The insulation is Celotex® cane or softwood fiberboard surrounding a nominal ½” thick lead shielding cylinder. Inside the shielding are two nested stainless steel containment vessels with double O-ring seals that designed in accordance with Section III, Subsection NB of the ASME Code.

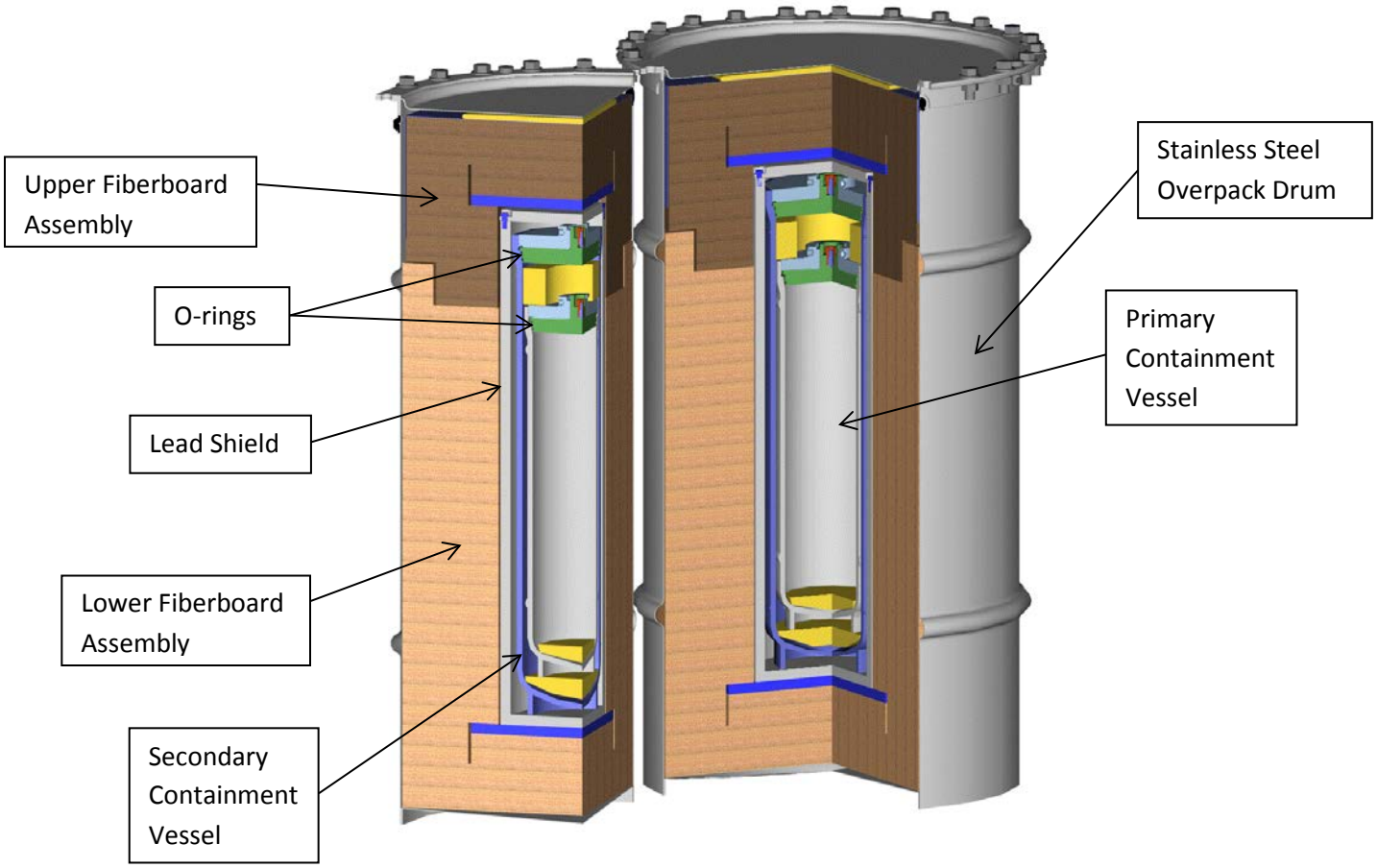

Figure 1: 9975 Cut-away

Thousands of these 9975s are in use for not only transportation, but also interim storage of nuclear materials. The robust design provides containment, criticality and fire resistance to protect nuclear materials during storage at the KAC. Initially, KAC was predicted to be a ten year storage facility, but in 2017 the initial shipping packages received will have reached a 15 year storage life. A long term surveillance program at SRS was established for the 9975 shipping package and for the 3013 container stored inside the shipping package. This program provides non-destructive examination (NDE) field surveillances and laboratory aging studies. In addition, each year one shipping package undergoes more in-depth examination and destructive testing of select components. The long term behavior of the packaging components is fully evaluated to ensure the continued safe storage of materials.

DISCUSSION

With over ten years of field surveillance based on a random selection and recent more focused selections using Engineering judgement, aging elements have been identified. In addition early on, bounding laboratory studies identified problem areas for specific components. Here is a breakdown of surveillance results and laboratory testing by shipping package component:

O-rings

A leak check is performed on the primary containment vessel (PCV) and secondary containment vessel (SCV) O-ring seals prior to opening the shipping packages in the KAC to provide evidence that the seal performance has not changed since the time of packaging. The leak check is conducted using the same 9975 post load leak check procedure, used at the time of packaging, which simultaneously tests the pressure boundary on both the upper and lower O-rings. Only a few cases have been identified were the PCV or SCV did not pass the leak check. In each case the inner most O-ring was impacted by foreign objects or a twist during installation. The outer most O-ring is credited for leak-tightness, and no failures have been identified at this location. In every case, the O-rings are removed and measured before being sent to the lab for further analysis.

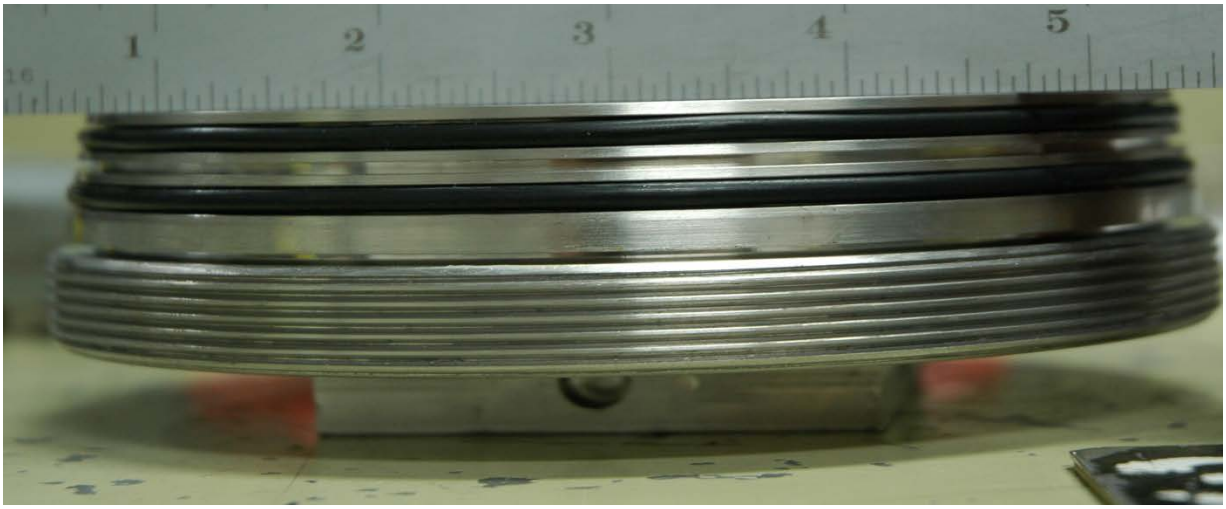

Figure 2: Twist found on Inner O-ring(Upper one)

A series of experiments to monitor the performance of Viton® GLT and GLT-S O-rings (Parker Seal compound V0835-75 and VM835-75) used in the 9975 package under simulated KAC conditions has been ongoing at the Savannah River National Laboratory (SRNL) since 2004. Seventy mock-ups of the 9975 PCV were assembled with GLT O-rings and exposed to nominal and bounding conditions expected in the KAC facility, including environmental parameters of temperature, humidity, radiation dose, and O-ring lubrication. They were leak-tested initially and have been tested periodically thereafter to determine if they meet the criterion of leak-tightness outlined in ANSI standard N14.5-97. The aging temperatures ranged from 200 to 450 °F. An additional fourteen mockups were added in 2008 for the GLT-S O-rings [1].

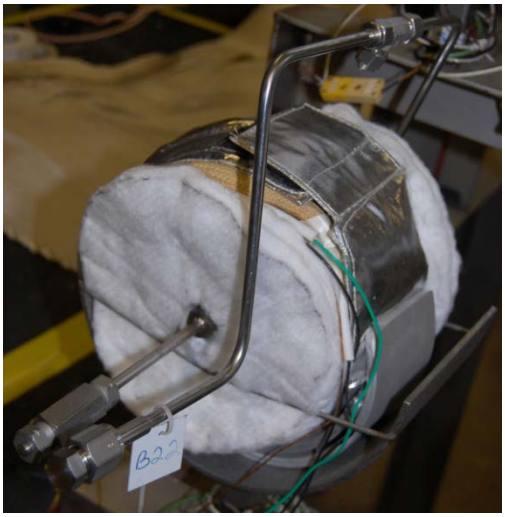

Figure 3: Assembled, insulated mock-up PCV in aging storage rack

High temperature aging continues on a total of 23 GLT O-ring fixtures and 6 GLT-S fixtures. All of the GLT fixtures conditioning at 200 and 270 °F have remained leak tight at room temperature, and all of the GLT-S O-ring fixtures conditioning at 200 and 250°F have remained leak tight at room temperature [1]. Two hundred degrees Fahrenheit is considered a bounding temperature for a 19 watt item stored in KAC.

In addition, predictive models have been developed using compression stress relaxation (CSR) tests to quantify the expected O-ring service lifetime at actual storage conditions. CSR is an industry standard method for evaluating seal performance. Accelerated aging work at elevated has been underway. O-rings are being aged at temperatures of 175 - 400°F and periodically tested to measure their decreasing rebound force. The collective data were used to develop a predictive model for the extrapolation of CSR behavior relevant to the service temperatures (≤ 156 °F). O-ring performance is defined by the leak-tightness, per ANSI N14.5-97 at room temperature. The leak-tightness is related to the retention of the mechanical properties of the polymer. The minimum counter-force for the 9975 seal has not been established, but it is believed to be quite low because of the static design. The predictive models indicate a service life of approximately 37 years for the Viton GLT O-rings, and the service life for the GLT-S O-rings is significantly longer [2].

O-ring dimensions are obtained in the field and again in the laboratory to monitor O-ring compression set over time. The results provide evidence to show that there is no noticeable degradation in the 9975 O-ring seal performance due to the extended storage operations in KAC.

Lead Shielding

Corrosion of the lead shield was discovered early during annual maintenance on the 9975 shipping packages. It was theorized that the white coating on the lead was the result of acetic acid emissions from organic materials used in the fabrication of the 9975 shipping package. Cellulose in the fiberboard is a known source of acetic acid, but other organics exist such as the polyvinyl acetate (PVAc) glue which is used to fabricate the fiberboard assemblies and room temperature vulcanizing (RTV) sealant which is used to secure the stainless steel air shield to the upper fiberboard assembly. Based on laboratory testing, the PVAc was determined to be the most aggressive due to its proximity in the design of the fiberboard.

In addition, the initial integrity of the organic assembly is assumed to play a large role in the corrosion response. Because the PVAc and the RTV off-gas acetic acid as they cure, the degree of curing controls the ability of these materials to resist hydrolysis and the consequent release of acetic acid [3].

The corrosion rate of 2 mpy measured in the experiments is considered to bound the packaging storage conditions. Measured corrosion from stored packages has not been found to exceed this criterion [4].

Figure 4: Lead Carbonate visible on Outer Surface of Lead Shield

Fiberboard

The 9975 overpack is fabricated from cane or softwood fiberboard. By far the most significant changes within the 9975 have occurred within the fiberboard insulation referred to as Celotex®. This material is manufactured as a building material and does not exhibit the degree of uniformity or consistency that might be expected for materials used in safety-related applications. In spite of the variations, the overall assembly delivers bulk properties sufficient to meet the functional requirements.

As expected, a significant difference in strength is observed depending on the material orientation, moisture level and temperature. In general, fiberboard conditioned at higher temperatures and/or higher humidity will be weakened by those conditions. Some of the properties (but not all) are restored after the material returns to a less severe environment. The moisture content of the as-manufactured fiberboard is less than 10 wt% (ASTM Standard C208-95, “Standard Specification for Cellulosic Fiber Insulating Board”, ASTM International, 1995). During manufacturing of the assemblies, the fiberboard layers are laminated with a water based glue (PVAc) which provides a modest increase in the moisture content. Since most 9975 shipping packages were manufactured, loaded with a modest heat load and placed in storage in a relatively short timeframe, it is likely that most remained close to their initial fiberboard moisture value. This is supported by the destructive examination (DE) from the surveillance program for which typical fiberboard moisture content ranges from about 9 – 13 wt% [5].

Baseline testing revealed that the fiberboard samples conditioned at 100% relative humidity developed mold in as little as two weeks at ambient temperature [6]. Field surveillance has observed mold in eleven cases [7].

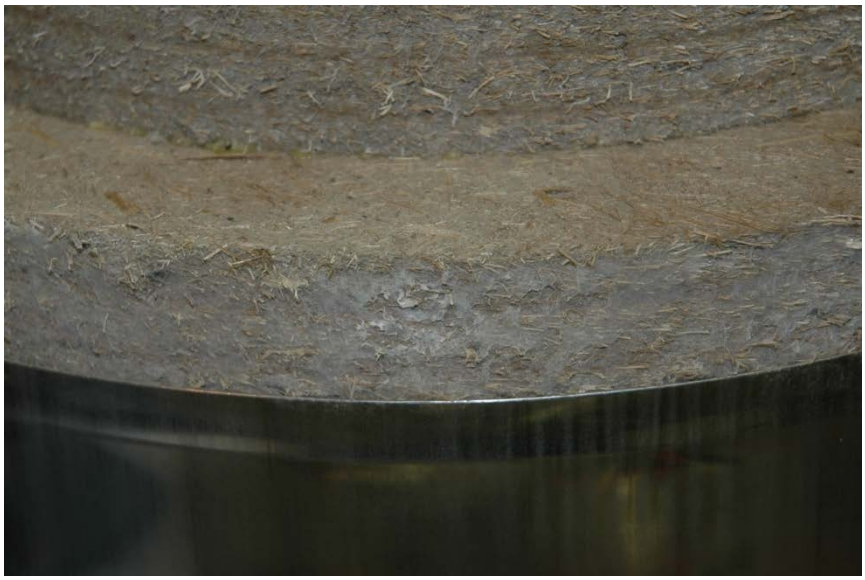

Figure 5: White Mold on Edge of Upper Fiberboard Assembly

More extensive mold was found during inspections of certain lower fiberboard assemblies. The 9975 SARP requires the verification of <1" axial gap at the top of the package. Whenever this criterion is exceeded, the lower assembly is removed for further inspection.

Figure 6: Lower Assembly Removed for Inspection

While almost any package can fail the axial gap criterion, significant change to the axial gap is due to the accumulation of excess moisture at the bottom of the overpack drum which results in a degradation of fiberboard properties. Property changes are either immediate, reversible changes due to moisture content or long term irreversible changes due to degradation. From laboratory testing and field surveillance, a high heat load within the package results in a thermal gradient across the fiberboard. When this occurs, moisture within the fiberboard will preferentially redistribute to the cooler regions and create a counter-gradient in relative humidity. This can result in moisture condensing/accumulating around the overpack drum, supporting the growth of mold and permanent degradation of the bottom layers of fiberboard. The weight of the fiberboard assembly and the internal components compresses the fiberboard and increases

the axial gap. The measurement of the axial gap provides a convenient screening tool for significant moisture at the bottom of the package.

Figure 7: Mold and Moisture on Bottom of Lower Fiberboard Assembly

From DE measurements, this moisture gradient can persist for months after the heat load is removed. Fortunately, the overall assembly retains its physical properties except in the limited region at the bottom [8].

Stainless Steel Overpack Drum

Limited corrosion has been identified on five drums opened for surveillance. In each case, there was significant moisture redistribution inside the package from the heat load. As a result, moisture was condensing inside the drum and/or accumulating at the bottom of the drum.

Figure 8: Condensate and mold inside Overpack Lid

This moisture can create mold and staining inside the overpack drum or on the air shield of the upper fiberboard assembly. In limited cases there was minor surface corrosion inside the overpack Drum.

Figure 9: Corrosion/Staining inside the Overpack Drum

Because the fiberboard contains chlorides, it is theorized that the saturated fiberboard leaches chlorides into the bottom chime of the drum which is not water tight. As a result visible staining/corrosion has been found adjacent to stitch welds on the outside of the shipping package. The regions near the stitch welds are likely more susceptible to corrosion compared to the adjacent base metal. During DE of the 9975 overpack drum, it was determined that corrosion was heaviest in the weld metal and the corrosion had breached a single wall thickness thru the cross section [8]. It is likely that the presence of corrosion at the bottom chime is a strong indicator of moisture accumulation in the bottom of the fiberboard.

Figure 10: Corrosion at the stitch weld on bottom chime

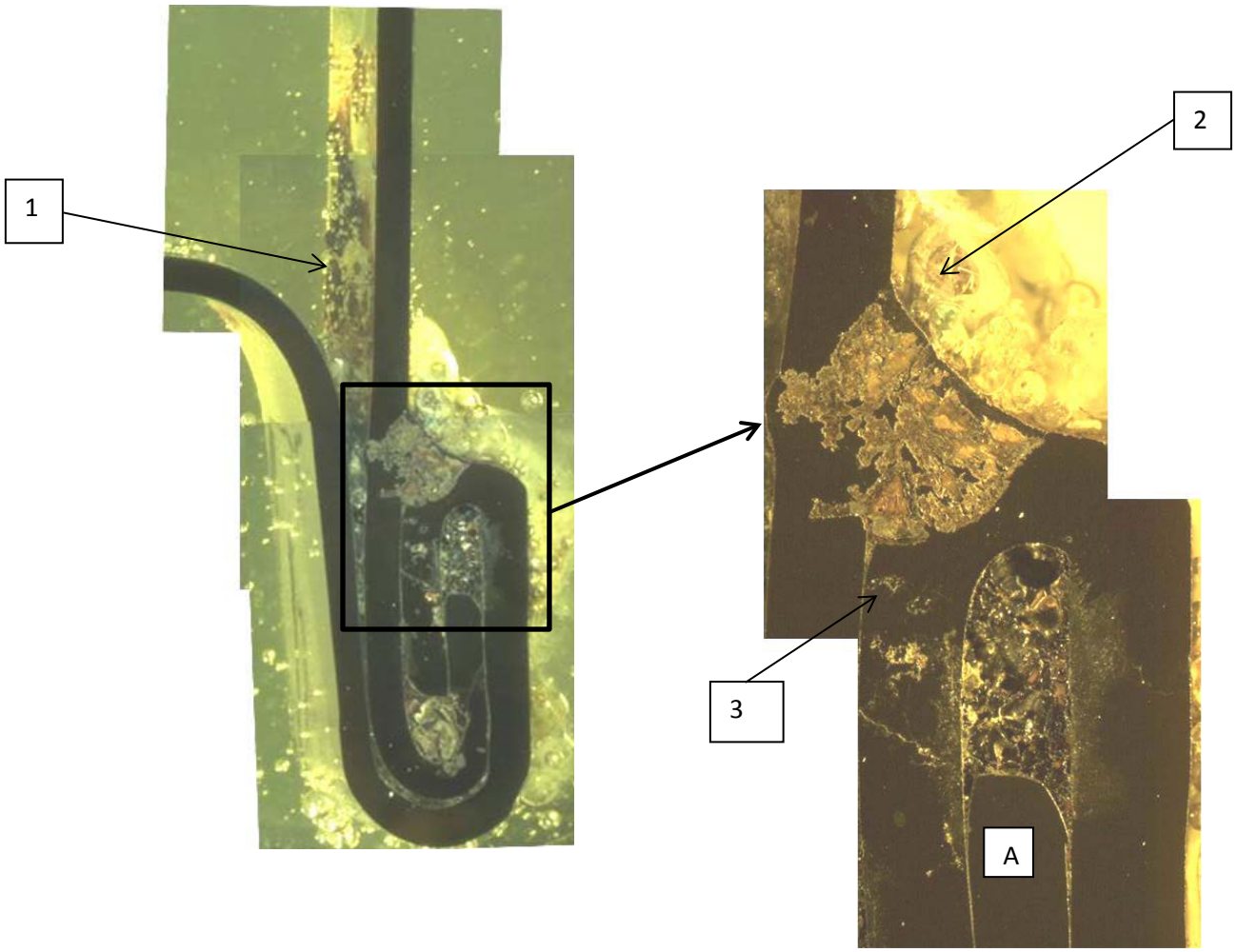

Figure 11: Cross section of bottom chime showing corrosion/scale on interior of drum (1), general/ pitting corrosion at stitch weld (2) and cracking (3) highlighted in close-up A.

SCV and PCV

No abnormal conditions have been noted from surveillance or examination of the containment vessels. This is the expected result without any payload failures within the package.

CONCLUSION

A thorough surveillance program has been in place for more than a decade to monitor the material performance and degradation in order to establish a basis for the service life and the need for repackaging 9975 shipping packages in KAC. The surveillance approach is a combination of NDE/DE field surveillance as well as laboratory testing and aging studies. After almost fifteen years of storage, a number of items have started to show evidence of degradation. The most significant item to experience a performance change is the fiberboard which is changing not only due to aging but also because of the

thermal load inside the package. The degradation of the fiberboard can be impactive to the integrity of the overpack drum. All of these conditions are being evaluated using KAC thermal and structural models to ensure continued safe storage of materials [9]. This report serves to document and understand the as-found conditions of the fiberboard and other elements of the 9975 shipping package used for long term storage of nuclear materials. Since many of the components of the 9975 are used in other types of shipping packages as well, the understanding of the aging properties can be applied to other types of packages.

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