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Investigation of the Presence of Drugstore Beetles within Celotex Assemblies in Radioactive Material Packagings

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ABSTRACT

During normal operations at the Department of Energy's Hanford Site in Hanford, WA, drugstore beetles, (*Stegobium paniceum* (L.) Coleoptera: Anobiidae), were found within the fiberboard subassemblies of two 9975 Shipping Packages. Initial indications were that the beetles were feeding on the CelotexTM assemblies within the package. CelotexTM fiberboard is used in numerous radioactive material packages serving as both a thermal insulator and an impact absorber for both normal conditions of transport and hypothetical accident conditions. The Department of Energy's Packaging Certification Program (EM-63) directed a thorough investigation to determine if the drugstore beetles were causing damage that would be detrimental to the safety performance of the CelotexTM. The Savannah River National Laboratory is conducting the investigation with entomological expertise provided by Clemson University. The two empty 9975 shipping packages were transferred to the Savannah River National Laboratory in the fall of 2007. This paper will provide details and results of the ongoing investigation.

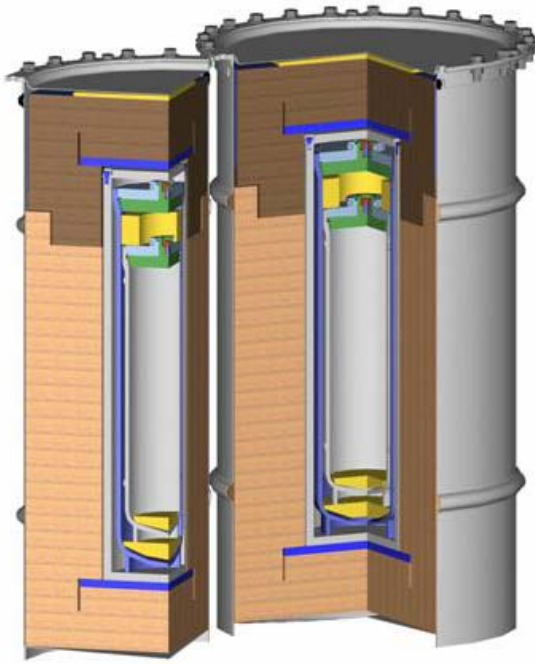
INTRODUCTION

The Model 9975 is a Type B radioactive material (RAM) shipping package designed and certified to meet the standards and requirements specified in the Code of Federal Regulations, 10 CFR 71 ^[1]. The 9975 design incorporates an outer stainless steel drum, CelotexTM fiberboard, a lead shield, and double containment through nested high-integrity containment vessels. Two 9975 packages were discovered to have beetles subsisting within the CelotexTM fiberboard assemblies. It is postulated that over long periods of time the beetles could consume enough of the fiberboard such that the CelotexTM could not perform its intended safety design function.

BACKGROUND

Package Background

During unloading operations at the Plutonium Fabrication Plant at the Hanford Site, two 9975 Shipping Packages were found to contain live insects that were later identified by Dr. Robert Bellinger of Clemson University as drugstore beetles, (*Stegobium paniceum* (L.) Coleoptera: Anobiidae) ^[2]. These beetles are found worldwide and are small, resilient insects that can survive with very little moisture while consuming a wide range of foods. The beetles were thought to be consuming the CelotexTM within the 9975. The CelotexTM performs a function within the 9975 Shipping Package as a thermal barrier during normal conditions of transport as well as during hypothetical accident conditions. Additionally, the CelotexTM serves as a shock absorber in the package.



Model 9975 Shipping Package



9975 Lower Celotex™ Assembly

Drugstore Beetle (Stegobium paniceum (L.))

Beetles (Order Coleoptera) are the largest group of animals and are believed to represent one fifth of all known living organisms and one fourth of all animals. Drugstore beetles, as they are known in the U.S., are in the beetle family Anobiidae, which contains about 460 species, many of which are associated with stored products. Drugstore beetles are common, cosmopolitan, and infest on an extremely wide range of plant-based materials, but also a human mummy, and will bore through wood, tin foil and lead sheathing. They earned their name by feeding on dried plant pharmaceuticals and drugs, including strychnine. In much of the world, and especially in the former British Empire, they are known as biscuit beetles, again earning their title. Drugstore beetle tends to reinfest its food source and all metamorphic stages – eggs, larvae (grubs), pupae (non-feeding resting stage), and adults, can be found together in large numbers ^[3,4,5].



Drugstore Beetle on Celotex™ Assembly
(ink pen at left for reference)

DISCUSSION

Test Plan and Relocation of Packages

A test plan was developed for an investigation to determine the damage being caused by the drugstore beetle on Celotex™ material. The Department of Energy's Packaging Certification Program (EM-63) is funding the investigation and the Savannah River National Laboratory (SRNL) is serving as the principal investigator. Clemson University is providing the support of an entomological expert. The two packages were shipped from the Hanford Site to the Savannah River Site (SRS) on September 26, 2007 in order to begin the investigation.

Computed Tomography

During the October 2007 a computed tomography (CT) unit was set-up for use in developing digital images of the Celotex™ from one of the 9975 Shipping Packages. A functional test was performed on a control specimen made by drilling holes into a non-infested piece of Celotex™ and placing it into a package similar to the 9975. This functional test was performed to determine if the bore holes made by the beetles could be detected without opening the package. Knowing if a package contained beetles would be helpful in preventing the spread of the beetles and removing potentially damaged packages from service. The test showed that drilled holes with diameters of 66 mils were capable of being detected by the CT scan. Having this information and determining by measurement that the beetle holes could be as large as 60 mils, it was decided that 9975 Shipping Package 02662 would be placed into the CT unit for examination for beetle bore holes.

The CT scan of package 02662 began on October 31, 2007. The package was removed from the unit on November 8, 2007 and the Nondestructive Analysis/Nondestructive Examination (NDA/NDE) organization within SRNL began to compile the data for image reconstruction. The lead shield within the 9975 produces large interferences when taking x-ray images of the package. After examining the image reconstructions and looking in the areas that were known to have beetle bore holes, the NDA/NDE group was unable to definitively identify any beetle bore holes. The CT scan did, however, confirm that the beetles were not consuming Celotex™ within concentrated areas of the 9975 Shipping Package. This was determined by observation of a smooth density gradient within the entire package seen in the CT images.

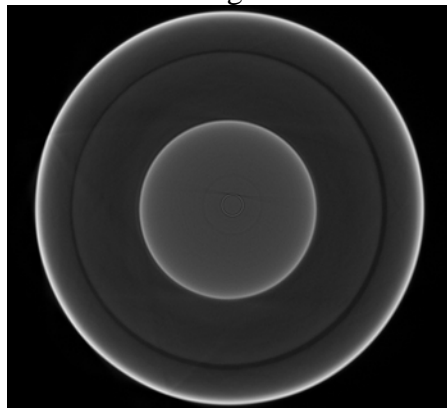


Image Generated from the CT Scan Performed on Package 02662

Initial Opening of the Packages at SRNL

It was decided in the development of the test plan that one of the packages containing drugstore beetles was going to be opened, disassembled, and destructively examined in order to determine the effects of the beetles on the package. The second package was going to be used to “grow” the beetle population in a favorable environment so that the effects of continued use of an infested package could be determined. The package being used to “grow” the population will be opened initially to establish a baseline on the damage to the Celotex™ and then on regular intervals to determine additional damage on the Celotex™.

On December 4, 2007, both of the packages were brought into the SRNL facility and placed into a specially designed hut. The hut was utilized to prevent the spread of the beetles into areas housing in-use 9975 Shipping Packages not containing beetles. Dr. Bellinger was present at SRNL on December 5, 2007 to witness and to provide input and expertise during the opening of the two 9975s containing beetles.

9975 02711

—This package is being used to “grow” the beetle population and was opened first.

The package was opened and the lid, thermal blanket, and top of the upper Celotex™ subassembly were examined. Small traces of beetle excrement were noticed on the air shield on the upper Celotex™ subassembly. The upper Celotex™ subassembly was removed and the top of the lower Celotex™ subassembly as well as the entire top surface of the upper Celotex™ subassembly were examined. There were quite a few beetle bore holes in the Celotex™ and glue layers bonding the layers of Celotex™ in the region around the interface between the two Celotex™ subassemblies. Lead carbonate was observed on the lead shield. A dusting of lead carbonate was observed on the top of the aluminum cover plate that bolts onto the top of the lead shield. Pictures of the package disassembly were taken to document the damage to the Celotex™, and the package was then reassembled and closed. Three or four live beetles were seen crawling inside of the package.

9975 02662

—This package is being used for destructive examination and is the package that was sent to the CT unit.

The package was opened and the lid, thermal blanket, and the top of the upper Celotex™ subassembly were examined. Numerous traces of beetle excrement were noticed on the air shield on the upper Celotex™ subassembly and some traces of beetle excrement were noticed on the bottom of the package lid. No traces of excrement were noticed on any exterior surface of the package thus providing evidence to suggest that the beetles have not been crawling out of the package. The upper Celotex™ subassembly was removed and the top of the lower Celotex™ subassembly as well as the entire top surface of the upper Celotex™ subassembly were examined. There were numerous beetle bore holes seen on the sides of the upper Celotex™ subassembly and on the internal face of the lower Celotex™ subassembly. It was discovered that there was a concentration of bore holes at the glue layers bonding the layers of Celotex™. Lead carbonate was observed on the lead shield. A dusting of lead carbonate was observed on the top of the aluminum cover plate that bolts onto the top of the lead shield. The aluminum cover plate was

removed and there was also a dusting of lead carbonate on the top of the secondary containment vessel (SCV). No evidence of beetle activity was seen on any of the surfaces inside the lead shield (SS lead liner, SCV, and the bottom of the aluminum cover plate). The SCV (containing the primary containment vessel (PCV)) was removed from the package and then the lead liner was removed. There was no evidence of beetle activity on the external surface of the lead liner. Finally the lower Celotex™ assembly was removed and examined. The lower Celotex™ assembly contained numerous bore holes on the external of the assembly and there was a large amount of frass (beetle excrement) left inside the package. The frass was collected so that it could be weighed and the volume determined in order to calculate its density. There was no evidence of any live beetles within the package or the Celotex™. It is hypothesized by Dr. Bellinger that the very high radiation field seen during the CT scan is most likely what caused the beetle population to die.



Drugstore Beetle Bore Holes in Celotex™ Lower Subassembly

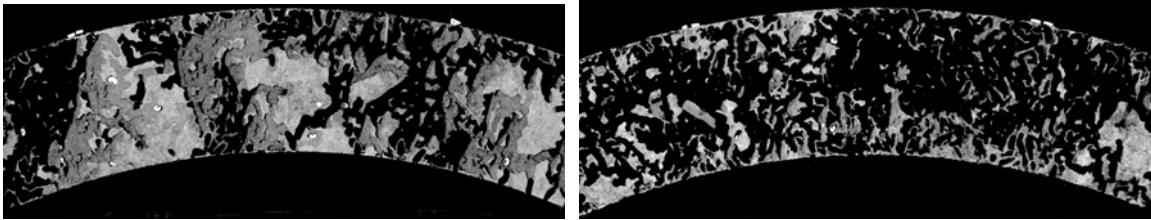
Test Results

Dimensions were taken on the Celotex™ from package 02662 and it was weighed in order to determine if the bulk density of the Celotex™ had been affected by the presence of the drugstore beetles. The density of the Celotex™ assemblies was 17.5 lbs/ft³. This density is within the range listed in the 9975 SARP. The density of the frass was calculated to also be 17.5 lbs/ft³.

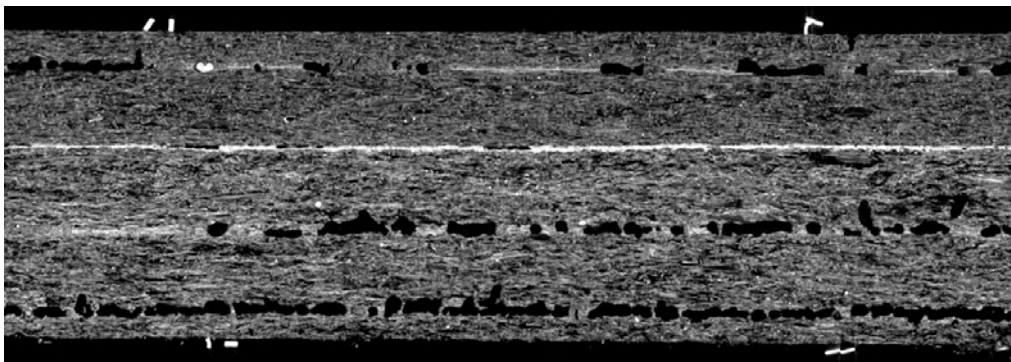
The Celotex™ from package 02662 was placed into an environmental chamber to be chilled to 20°F. Chilling the Celotex™ assemblies ensures that any drugstore beetles possibly surviving the radiation of the CT scan are killed. The Celotex™ was then sectioned and tested for compression strength, heat capacity, and thermal conductivity. The results of these tests were all within the SARP design parameters for the Celotex™ materials [6,7]. The SCV and PCV were also examined to determine if there are any detrimental effects resulting from the drugstore beetles. This data will be compared to that from other 9975 Shipping Packages that have been destructively examined.

Computed Tomography of a Slice of Celotex™

A small slice, approximately 6 inches long, was cut out of the lower Celotex™ subassembly from package 02662 and a CT scan was performed on it. The results of the CT scan showed that the beetles are selectively consuming the glue layers between the Celotex™ layers and are only boring through the Celotex™ to locate the glue layers. Since off-gassing of the glue is hypothesized as one initiator for formation of lead carbonate, investigations are underway to determine if the increased surface area of exposed glue to the atmosphere inside of the package has any effect on the rate of lead carbonate production and what by-products, if any, are being produced by the beetles biologically processing the glue. The images below show damage at two glue boundary layers between the Celotex™ layers.



These additional images show a visible light image of the side of the Celotex™ as well as a reconstruction of the same portion using CT.



Additional Opening of 9975 02711

Package 02711 was opened again on May 21, 2008 for a second examination. Differences in the amount of damage to the Celotex™ within the package were minimal, however there was a significant growth of the beetle population as approximately two

dozen live beetles were seen crawling inside of the package and many dead beetles were found on top of the upper and lower Celotex™ subassemblies. There was a slight increase in the amount of lead carbonate formed on the lead shield.



02711 Upper Celotex™ Assembly 12/07



02711 Upper Celotex™ Assembly 05/08

CONCLUSIONS AND FUTURE TESTING

The investigation shows that the Celotex™ has not been damaged to an extent such that it could not perform its intended safety function. Future examination and testing of 9975 02711 will provide additional insight into the effects, over time, of the drugstore beetle on fiberboard assemblies. Clemson University entomologists will obtain live specimens of the beetles and, through experimentation, will determine the by-products the beetles create from the consumption of the Celotex™ as well as the glue.

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