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OAK RIDGE Y-12 PLANT

MARTIN MARIETTA

Engineering Division
Mechanical Design Department

PACKAGING MATERIALS PROPERTIES DATA

M. S. Walker

JANUARY 1991 .

Prepared for the
Y-12 Plant Program Management
Packaging Group

Prepared by the
Engineering Division
Y-12 Mechanical Design Department
Oak Ridge, Tennessee 37831-8202
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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MASTER

PREFACE

In the process of preparing and reviewing a series of Safety Analysis Reports for Packaging, a need was determined for detailed compression versus deflection data for the energy absorbing materials used in the packages. Data for this property is required for package use at ambient temperature and at -40°C (-40°F). In addition, data was collected and is reported for a temperature of 66°C (150°F) to simulate conditions which may be attained during hot weather shipments where solar heating of the containers may occur.

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1. ABSTRACT

Several energy absorbing materials are used in nuclear weapons component shipping containers recently designed for the Y-12 Plant Program Management Packaging Group. As a part of the independent review procedure leading to Certificates of Compliance, the U.S. Department of Energy Technical Safety Review Panels requested compression versus deflection data on these materials. This report is a compilation of that data.

2. INTRODUCTION

Energy absorbing materials are used in nuclear weapons component shipping containers to protect the components shipped and the inner container from damage in both normal and accident conditions. The containers designed for the Y-12 Plant Program Management Packaging Group have been physically tested at full scale in accordance with the applicable regulations, Title 10, Code of Federal Regulations, Part 71. The energy absorbing materials performed satisfactorily in these tests. Safety Analysis Reports for Packing (SARPs) have been prepared for six containers designated DT-18, DT-19, DT-20, DT-21, DT-22, and DT-23. After review by the Department of Energy, Certificates of Compliance have been issued for most of these containers, authorizing their use for shipment of nuclear materials.

As part of the Department of Energy review process, the SARPs are reviewed by a Technical Safety Review Panel (TSRP). Each container may be reviewed several times--once for each content loading. In the process of performing these reviews, members of the TSRP perform independent analyses of the containers. Although the SARPs contain information on the materials of construction, the TSRPs have requested that the Y-12 Plant Program Management Packaging Group perform additional testing of the energy absorbing materials to characterize its behavior in use. Specifically, the TSRPs asked for compression force versus deflection data for use in calculating energy absorbance. They requested that the data be taken at temperatures from -40°C (-40°F), room temperature, and at the maximum temperature anticipated in normal transport. This temperature was estimated to be 66°C (150°F) for purposes of these tests, to simulate the effect of solar heating in a 38°C (100°F) ambient shipping environment. Detailed temperature requirements are delineated in 10 CFR 71.71.

3. DESCRIPTION OF MATERIALS TESTED

Four energy absorbing materials were tested. Two of the materials are used to surround an inner container and protect it from external damage. The other two materials are used inside the inner container to protect it from damage by the content.

The materials used outside the inner container are plywood and Celotex[®]. These materials are laminated together to provide the support structure for the inner container. Plywood is used principally to provide load distribution and reinforcement at points where handling causes additional wear and tear. It is also used at the ends of the inner container where sharp corners might penetrate through the Celotex[®] in an accident. The majority of the external energy absorbing material is Celotex[®], which also performs a thermal insulation role.

The Celotex[®] is a cellulosic fiber insulation board which is specified by ASTM C-208, as Roof Insulating Board. An additional requirement limits the acceptable density to $0.256 \pm 0.03 \text{ g/cm}^3$ ($16 \pm 2 \text{ lb/ft}^3$). The material is manufactured in felted layers 12.7 mm (0.5 in.) thick which are laminated at the vendor's factory into sheets up to 50.8 mm (2 in.) thick. The samples for these tests were 50.8 mm (2 in.) cubes cut from factory laminated stock. Compression versus deflection tests were conducted both normal and parallel to these laminations to account for any anisotropic behavior.

The plywood used in these containers is fir plywood of A-C grade. Thicknesses used are 6.35 mm (.25 in.), 12.7 mm (.50 in.), and 19.05 mm (.75 in.). In order to use consistent sample sizes for all materials, 50.8 mm (2 in.) cubes were laminated from 12.7 mm (.50 in.) sheet. The adhesive used for lamination was the same adhesive used to laminate the layers of Celotex[®] and plywood in the actual containers. This adhesive is TYPE W BLACK MAGIC[®] by the Miracle Adhesive Corporation. Compression versus deflection tests were conducted both normal and parallel to the laminations to account for any anisotropic behavior.

The first of the two materials used for energy absorption inside the inner container is FP-236 foam. This is a medium density flexible polyurethane foam. It is made by the reaction of two components in a closed mold. The raw material is manufactured by the Flexible Products Corporation. The foam parts are molded at the Y-12 Plant. Part density is controlled to the range of 0.24-0.29 g/cc (15-18 lb/ft³) during the molding process. The parts used for these tests were fabricated by molding a 50.8 mm (2 in.) thick sheet of foam, which was then cut up into 50.8 mm (2 in.) cubes. Where the foam contacts the mold surface, a smooth, relatively non-porous, thin skin of material is formed. Each cube has two sides with this skin. Parts on the perimeter of the sheet, where skin is formed on three sides, were discarded. Compression versus deflection tests were conducted both normal and parallel to the mold skin in order to account for any anisotropic behavior.

The second material used inside the inner containers is a cast single component solid polyurethane, INDPOL^(R) Monothane^(R). The resin for this material is manufactured by the SYNAIR Corporation. The parts used in the containers are cast and oven cured at the Y-12 Plant. The material used has a specified Shore A durometer of 40. The samples were manufactured by casting a bar 50.8 mm (2 in.) square by length. This bar was then cut into 50.8 mm (2 in.) cubes for testing. Where the polyurethane is exposed to the air during the oven cure (the top surface of the bar), a dark discolored skin forms. One surface of each cube had this skin. Actual parts cast in molds would have this skin on the top surface as cast. Compression versus deflection tests were conducted both normal and parallel to the skin surface in order to account for any anisotropic behavior.

All materials tested were taken from Y-12 Plant production stores. Multiple samples were tested for each material in each orientation and at each temperature. The samples were all taken from one lot of each material.

4. TEST METHODS

Samples were tested in accordance with ASTM C165, Procedure A. The testing machine was a 55 KIP MTS Tensile Test Machine with Model 880 load frame. This is a closed loop servo hydraulic machine and is equipped with Model 458 electronics. The machine is also equipped with a Thermotron environmental chamber which allows the samples to be tested at reduced and elevated temperatures. When operating at non-ambient temperatures, samples were placed in the chamber and allowed to stabilize before testing. Crosshead speed was set at 0.04 mm/s (0.1 in./min). The samples were compressed to either 90 percent compression, until the material failed to support an increase in compression force, or until the load on the machine reached 222.4 kN (50,000 lb). Sample size was reduced from the ASTM C165, Procedure A, recommendation of 203 mm (8 in.) square to 50.8 mm (2 in.) square in order to achieve higher deformations without exceeding the test machine load capacity. The reduced size is the minimum allowable for the procedure.

Samples were not laterally constrained during compression. One surface plate was fixed perpendicular to the machine loading axis. The other surface plate was self-aligning, suspended by a spherical bearing. Only the plywood specimens tested normal to the laminations showed significant tendencies to compress nonuniformly. In the tests conducted at 66°C (150°F), the laminations tended to slip at high loads, caused by nonuniform compression. Plywood is not laminated into 50.8 mm (2 in.) thicknesses in the actual containers.

Compression vs. Deflection
Celotex, Sample #1, Temperature -39.8 F
Sample Size 1.91" Thick x 2.01" x 1.98"
Load Perpendicular to Laminations

Compression vs. Deflection
Celotex, Sample #2, Temperature -40.7 F
Sample Size 1.93" Thick x 2.02" x 2.00"
Load Perpendicular to Laminations

Compression vs. Deflection
Celotex, Sample #3, Temperature -40.3 F
Sample Size 1.93" Thick x 2.01" x 2.01"
Load Perpendicular to Laminations

Compression vs. Deflection
Celotex, Sample #31, Temperature 73.4 F
Sample Size 1.94" Thick x 1.99" x 2.02"
Load Perpendicular to Laminations

Compression vs. Deflection
Celotex, Sample #5, Temperature 73.4 F
Sample Size 1.90" Thick x 2.01" x 2.01"
Load Perpendicular to Laminations

Compression vs. Deflection
Celotex, Sample #6, Temperature 73.4 F
Sample Size 1.90" Thick x 2.01" x 1.99"
Load Perpendicular to Laminations

Compression vs. Deflection
Celotex, Sample #30, Temperature 150.1 F
Sample Size 1.93" Thick x 2.01" x 2.01"
Load Perpendicular to Laminations

Compression vs. Deflection
Celotex, Sample #8, Temperature 149.5 F
Sample Size 1.94" Thick x 2.17" x 1.99"
Load Perpendicular to Laminations

Compression vs. Deflection
Celotex, Sample #9, Temperature 150.6 F
Sample Size 1.93" Thick x 2.01" x 2.00"
Load Perpendicular to Laminations

Compression vs. Deflection
Celotex, Sample #10, Temperature -42.0 F
Sample Size 2.00" Thick x 1.92" x 2.02"
Load Parallel to Laminations

Compression vs. Deflection
Celotex, Sample #11, Temperature -39.5 F
Sample Size 2.00" Thick x 1.92" x 2.02"
Load Parallel to Laminations

Compression vs. Deflection
Celotex, Sample #12, Temperature -40.0 F
Sample Size 2.01" Thick x 1.92" x 2.00"
Load Parallel to Laminations

Compression vs. Deflection
Celotex, Sample #13, Temperature 73.4 F
Sample Size 2.00" Thick x 1.93" x 1.99"
Load Parallel to Laminations

Compression vs. Deflection
Celotex, Sample #14, Temperature 73.4 F
Sample Size 1.99" Thick x 1.94" x 2.01"
Load Parallel to Laminations

Compression vs. Deflection
Celotex, Sample #15, Temperature 73.4 F
Sample Size 2.00" Thick x 1.93" x 2.00"
Load Parallel to Laminations

Compression vs. Deflection
Celotex, Sample #16, Temperature 150.5 F
Sample Size 2.02" Thick x 1.93" x 2.00"
Load Parallel to Laminations

Compression vs. Deflection
Celotex, Sample #17, Temperature 149.0 F
Sample Size 2.00" Thick x 1.94" x 2.01"
Load Parallel to Laminations

Compression vs. Deflection
Celotex, Sample #18, Temperature 148.8 F
Sample Size 2.00" Thick x 1.90" x 2.02"
Load Parallel to Laminations

Compression vs. Deflection
Plywood, Sample #1, Temperature -39.3 F
Sample Size 2.00" Thick x 2.02" x 2.00"
Load Perpendicular to Laminations

Compression vs. Deflection
Plywood, Sample #2, Temperature -39.7 F
Sample Size 2.00" Thick x 2.03" x 2.00"
Load Perpendicular to Laminations

Compression vs. Deflection
Plywood, Sample #3, Temperature -40.8 F
Sample Size 1.99" Thick x 2.03" x 2.00"
Load Perpendicular to Laminations

Compression vs. Deflection
Plywood, Sample #5, Temperature 73.4 F
Sample Size 2.00" Thick x 2.03" x 2.00"
Load Perpendicular to Laminations

Compression vs. Deflection
Plywood, Sample #6, Temperature 73.4 F
Sample Size 1.99" Thick x 2.03" x 1.99"
Load Perpendicular to Laminations

Compression vs. Deflection
Plywood, Sample #19, Temperature 73.0 F
Sample Size 1.98" Thick x 2.03" x 2.00"
Load Perpendicular to Laminations

Compression vs. Deflection
Plywood, Sample #7, Temperature 150.2 F
Sample Size 1.99" Thick x 2.04" x 1.98"
Load Perpendicular to Laminations

Compression vs. Deflection
Plywood, Sample #8, Temperature 150.3 F
Sample Size 2.00" Thick x 2.02" x 2.00"
Load Perpendicular to Laminations

Compression vs. Deflection
Plywood, Sample #9, Temperature 150.5 F
Sample Size 1.99" Thick x 2.02" x 2.00"
Load Perpendicular to Laminations

Compression vs. Deflection
Plywood, Sample #10, Temperature -38.5 F
Sample Size 1.99" Thick x 2.03" x 1.99"
Load Parallel to Laminations

Compression vs. Deflection
Plywood, Sample #11, Temperature -40.0 F
Sample Size 2.00" Thick x 2.03" x 1.99"
Load Parallel to Laminations

Compression vs. Deflection
Plywood, Sample #12, Temperature -39.0 F
Sample Size 1.99" Thick x 2.02" x 2.00"
Load Parallel to Laminations

Compression vs. Deflection
Plywood, Sample #13, Temperature 73.4 F
Sample Size 1.99" Thick x 2.03" x 2.00"
Load Parallel to Laminations

Compression vs. Deflection
Plywood, Sample #14, Temperature 73.4 F
Sample Size 2.00" Thick x 2.02" x 2.00"
Load Parallel to Laminations

Compression vs. Deflection
Plywood, Sample #15, Temperature 73.4 F
Sample Size 2.00" Thick x 2.02" x 2.00"
Load Parallel to Laminations

Compression vs. Deflection
Plywood, Sample #16, Temperature 150.5 F
Sample Size 2.00" Thick x 2.03" x 1.99"
Load Parallel to Laminations

Compression vs. Deflection
Plywood, Sample #17, Temperature 149.5 F
Sample Size 2.00" Thick x 2.03" x 1.99"
Load Parallel to Laminations

Compression vs. Deflection
Plywood, Sample #18, Temperature 148.8 F
Sample Size 2.00" Thick x 2.03" x 2.00"
Load Parallel to Laminations

Compression vs. Deflection
FP-236 Foam, Sample #19, Temp. -40.1 F
Sample Size 1.94" Thick x 1.97" x 1.94"
Load Perpendicular to Skin

Compression vs. Deflection
FP-236 Foam, Sample #20, Temp. -40.0 F
Sample Size 1.94" Thick x 2.00" x 1.93"
Load Perpendicular to Skin

Compression vs. Deflection
FP-236 Foam, Sample #21, Temp. -40.8 F
Sample Size 1.97" Thick x 1.94" x 2.04"
Load Perpendicular to Skin

Compression vs. Deflection
FP-236 Foam, Sample #22, Temp. 72.5 F
Sample Size 1.96" Thick x 1.94" x 2.02"
Load Perpendicular to Skin

Compression vs. Deflection
FP-236 Foam, Sample #23, Temp. 72.5 F
Sample Size 1.97" Thick x 2.02" x 1.94"
Load Perpendicular to Skin

Compression vs. Deflection
FP-236 Foam, Sample #24, Temp. 72.5 F
Sample Size 1.95" Thick x 1.94" x 2.06"
Load Perpendicular to Skin

Compression vs. Deflection
FP-236 Foam, Sample #25, Temp. 150.3 F
Sample Size 1.90" Thick x 1.95" x 2.02"
Load Perpendicular to Skin

Compression vs. Deflection
FP-236 Foam, Sample #26, Temp. 149.3 F
Sample Size 1.94" Thick x 1.96" x 2.01"
Load Perpendicular to Skin

Compression vs. Deflection
FP-236 Foam, Sample #27, Temp. 150.2 F
Sample Size 1.92" Thick x 2.00" x 1.95"
Load Perpendicular to Skin

Compression vs. Deflection
FP-236 Foam, Sample #28, Temp. -40.6 F
Sample Size 1.96" Thick x 2.03" x 1.88"
Load Parallel to Skin

Compression vs. Deflection
FP-236 Foam, Sample #29, Temp. -41.0 F
Sample Size 1.95" Thick x 1.98" x 1.89"
Load Parallel to Skin

Compression vs. Deflection
FP-236 Foam, Sample #30, Temp. -40.7 F
Sample Size 2.05" Thick x 1.95" x 1.94"
Load Parallel to Skin

Compression vs. Deflection
FP-236 Foam, Sample #31, Temp. 72.5 F
Sample Size 1.95" Thick x 2.03" x 1.95"
Load Parallel to Skin

Compression vs. Deflection
FP-236 Foam, Sample #32, Temp. 72.5 F
Sample Size 1.96" Thick x 1.97" x 2.02"
Load Parallel to Skin

Compression vs. Deflection
FP-236 Foam, Sample #33, Temp. 72.5 F
Sample Size 1.96" Thick x 1.97" x 2.02"
Load Parallel to Skin

Compression vs. Deflection
FP-236 Foam, Sample #34, Temp. 150.3 F
Sample Size 1.95" Thick x 1.88" x 1.96"
Load Parallel to Skin

Compression vs. Deflection
FP-236 Foam, Sample #35, Temp. 150.2 F
Sample Size 2.00" Thick x 1.96" x 1.92"
Load Parallel to Skin

Compression vs. Deflection
FP-236 Foam, Sample #36, Temp. 149.9 F
Sample Size 2.03" Thick x 1.95" x 1.96"
Load Parallel to Skin

Compression vs. Deflection
Monothane, Sample #37-1, Temp. -39.5 F
Sample Size 1.92" Thick x 2.01" x 1.97"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #38-2, Temp. -40.3 F
Sample Size 1.90" Thick x 2.06" x 2.01"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #39-3, Temp. -40.0 F
Sample Size 1.92" Thick x 1.95" x 2.04"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #40-4, Temp. 72.0 F
Sample Size 1.91" Thick x 1.97" x 1.98"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #41-5, Temp. 72.0 F
Sample Size 1.92" Thick x 1.97" x 1.99"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #42-6, Temp. 72.0 F
Sample Size 1.91" Thick x 1.99" x 2.04"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #43-7, Temp. 150.2 F
Sample Size 1.89" Thick x 1.99" x 2.00"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #44-8 Temp. 149.6 F
Sample Size 1.93" Thick x 2.07" x 2.00"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #45-9 Temp. 150.0 F
Sample Size 1.88" Thick x 2.07" x 1.97"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #46-10 Temp. -39.5 F
Sample Size 1.97" Thick x 2.01" x 1.92"
Load Parallel to Skin

Compression vs. Deflection
Monothane, Sample #47-11 Temp. -39.8 F
Sample Size 1.98" Thick x 2.06" x 1.89"
Load Parallel to Skin

Compression vs. Deflection
Monothane, Sample #48-12 Temp. -39.6 F
Sample Size 1.99" Thick x 1.96" x 1.90"
Load Parallel to Skin

Compression vs. Deflection
Monothane, Sample #49-13, Temp. 72.5 F
Sample Size 1.96" Thick x 2.00" x 1.91"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #50-14, Temp. 72.5 F
Sample Size 2.01" Thick x 1.98" x 1.91"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #51-15, Temp. 72.5 F
Sample Size 1.97" Thick x 2.08" x 1.89"
Load Perpendicular to Skin

Compression vs. Deflection
Monothane, Sample #52-16 Temp. 150.1 F
Sample Size 1.97" Thick x 2.01" x 1.92"
Load Parallel to Skin

Compression vs. Deflection
Monothane, Sample #53-17 Temp. 150.0 F
Sample Size 1.99" Thick x 1.99" x 1.93"
Load Parallel to Skin

Compression vs. Deflection
Monothane, Sample #54-18 Temp. 150.0 F
Sample Size 2.03" Thick x 2.03" x 1.88"
Load Parallel to Skin

END

**DATE
FILMED**

12/27/91