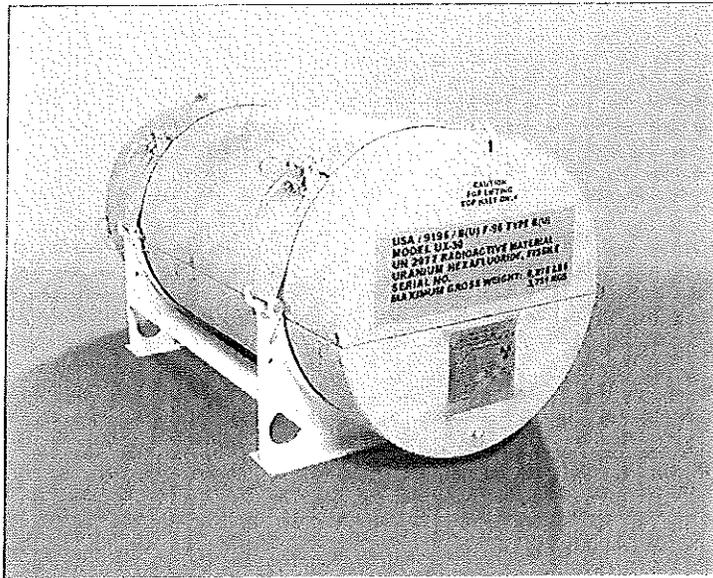




UX-30 PERFORMANCE TESTING SUMMARY REPORT

Revision 0



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1.0 Introduction

The UX-30 Overpack is licensed for domestic use in the US by the Nuclear Regulatory Commission (NRC) under Certificate of Compliance No. 9196, USA/9196/B(U)F-96 for the transport of unirradiated or reprocessed uranium in the form of UF₆.

Multiple regulatory drop tests have been performed on full-scale UX-30 overpacks with both 30B and 30C compliant cylinders. The testing performed in these tests was performed to address specific questions raised in a Request for Additional Information (RAI) issued by the French Competent Authority, ASN, regarding UX-30 validation, USA/9196/B(U)F-96. The testing is used to:

- Demonstrate the effectiveness of the UX-30 at -40°C (-40°F) and at the maximum evaluated internal cylinder temperature of 62.94°C (145.3°F).
- Demonstrate the leak tightness of the cylinder's plug during the prescribed 1 m and 9 m drop tests.
- Evaluate the consequences of any outer shell damage resulting from the prescribed 1 m puncture and 9 m drop tests and the possible effect on the polyurethane foam and the UX-30 thermal analysis.
- Evaluate the consequences of any polyurethane foam deformation resulting from the prescribed drop tests and the possible effect on the UX-30 thermal analysis.
- Evaluate the consequences of any outer shell damage resulting from the UX-30 transport cradle during the prescribed 9 m drop test.
- Demonstrate the effectiveness UX-30 closure system during the prescribed 9 m drop test.

1.1 General Approach

Five separate Drop Tests (two Puncture and three Free Drop Tests) were performed. Each test used a full-scale production unit UX-30 overpack along with a full size ANSI compliant Model 30B cylinder (the same overpack and cylinder were used for two or more tests) as the Test Unit. One of the free drop tests included attaching the UX-30 transport cradle to the Test Unit. All testing was performed with a cylinder containing sufficient material (steel shot) to properly simulate payload mass. In all five tests, the cylinder sustained no deformation and was shown to meet the required leak criteria after being subjected to three 30-foot drops and two 40-inch puncture tests.

1.2 Test Pad

The test pad used was designed to simulate an unyielding surface.

- Reinforced Concrete 3,000 psi: Type I Portland cement with maximum aggregate size of 25 mm (1 inch)
- Concrete reinforced with ASTM A-615 Gr. 60 steel rebar
- Pad Dimensions: 2,438 mm wide x 7,315 mm long x 1,372 mm thick (8' x 24' x 4'-6")
- Pad Weight: approximately 129,600 pounds (exclusive of a 1-1/4" thick A36 carbon steel plate covering the pad).
- Weight Ratio of Test Pad to Test Unit: greater than 10:1 (129,600/8,300).

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1.3 Cylinder Preparation

Two 30 inch (model 30B) uranium hexafluoride cylinders were used for free drop testing. The cylinders were verified to be compliant with ANSI N14.1 and fabricated in accordance with Section VIII, Division I of the American Society of Mechanical Engineers Boiler and Pressure Code and were ASME Code Stamped. The 30B Cylinders were loaded with over 5,400 lbs of steel shot, 400 lbs more than the maximum allowable payload weight. Prior to the test, the UX-30 and cylinders were visually inspected for damage, including dents, creases, weld flaws, and corrosion.

After adding the steel shot and prior to drop testing, each 30B cylinder was pressurized with helium to a pressure of 16.7 psia. Each cylinder was placed into a test chamber and the chamber evacuated to approximately 100 milli-Torr. An integrated helium leak test was performed on the cylinder per ANSI N14.5-1997 (test sensitivity of at least 5×10^{-8} ref-cm³/sec). Each cylinder was verified to have a measured leak rate of less than 1×10^{-7} cm³/sec.

1.4 Test Unit Heating and Cooling (See photos Heating & Cooling Enclosure)

To perform the elevated temperature tests, the Test Unit (Cylinder and Overpack) was placed inside of a large reinforced wooden structure covered with insulating material. The Test Unit was heated until all temperature labels read greater than 63°C (145°F).

To perform the reduced temperature tests, the Test Unit (Cylinder and Overpack) was placed inside of a large reinforced wooden structure covered with insulating material. Cooling of the Test Unit was accomplished by introducing liquid nitrogen through holes within the structure. The Test Unit was cooled until all temperature labels read less than -40°C (-40°F).

2.0 Drop Test Observations

2.1 Free Drop No. 1: *Side Drop onto UX-30 Cradle*

A free drop slap down (See Fig. 1) was performed with Test Unit 1 through a distance of 9 m (30 ft) onto the test pad, striking the surface in a position for which maximum damage is expected.

Overpack orientation: Horizontal with Test Unit 1 Parting Plane axis at 7° to the drop test pad, bottom half down with transport cradle attached in its normal orientation for transport.

Cylinder type and orientation: Model 30B with its plug end down (normal orientation for transport) so as to be nearest to contact point from the transport cradle.

Test Unit Temperature: Minimum of 62.94°C (145.3°F).

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The test was performed at an elevated temperature condition, since foam strength decreases with increasing temperature, yielding maximum foam deformation and maximum outer shell damage. After the drop, Test Unit 1 was removed from the cradle. The following observations were made (see photos Drop Test 1-1 through 1-7):

- The overpack remained closed and the parting plane gap remained within tolerance.
- Nine of 10 locking pins remained engaged. One locking pin at the plug end of the overpack sheared.
- There were no observed tears in the package.
- The lower half of the overpack deformed in the shape of the cradle supports, but did not tear. The deformation on the plug end of the overpack, making initial contact, measured approximately 44 mm (1-3/4 inches) deep. The deformation on the opposite end of the overpack (slap-down end) was approximately 51 mm (2 inches) deep.

2.2 Free Drop No. 2 – Puncture Test

A free drop (See Figure 2) of Test Unit 2 was performed through a distance of 1 m (40 in) onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on the test pad with a drop angle that maximized the damage to the shell of the overpack.

Overpack orientation: Center of Gravity over cylinder plug, with Test Unit 2 Parting Plane axis at 17° to the pin. Initial contact of puncture bar was on the Test Unit 2 end plate, ~9 inches from the corner of the overpack.

Model 30B Cylinder orientation: Plug end down (normal orientation for transport) so as to be nearest to the contact point from the puncture bar.

Test Unit Temperature: Minimum of 62.94°C (145.3°F).

The test was performed at an elevated temperature condition, since foam strength decreases with increasing temperature, yielding maximum foam deformation and maximum outer shell damage. After the drop, the following observations were made (see photos Drop Test 2-1 through 2-4):

- The overpack remained closed and the parting plane gap remained within tolerance.
- All 10 locking pins remained engaged.
- The puncture pin indented the package outer skin at an angle with plug end of the overpack. The maximum depth of the indent was 76 mm (3 inches). The elongated indent was approximately 178 mm (7 inches) wide.
- All welds remained intact, and, with the exception of the puncture pin tear, the package outer skin was not breached.

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2.3 Free Drop No. 3 – Center of Gravity over Cylinder Plug

A free drop (See Figure 3) of Test Unit 2 (second sequential drop of this unit) through a distance of 9 m (30 ft) onto the test pad, striking the surface in a position for which maximum damage is expected.

Overpack orientation: Center of Gravity over cylinder plug, with the Test Unit Parting Plane axis at 17° to the drop test pad.

Model 30B Cylinder orientation: Plug end down (normal orientation for transport) so as to be nearest to contact point from the drop test pad.

Test Unit Temperature: Minimum of 62.94°C (145.3°F).

The test was performed at an elevated temperature condition, since foam strength decreases with increasing temperature, yielding maximum foam deformation and maximum outer shell damage. After the drop, the following observations were made (see photos Drop Test 3-1 through 3-6):

- The overpack remained closed and the parting plane gap remained within tolerance.
- All 10 locking pins remained engaged.
- There was deformation of the outer skin at the plug end of the overpack along the area of impact with the test pad. The maximum deformation was approximately 100 mm (4 inches).
- As a result of the impact, the outer skin compressed the foam in the area of the puncture pin indent such that indent depth was reduced to a maximum of 25 mm (1 inch).
- All welds remained intact, and, with the exception of the puncture pin tear, the package outer skin was not breached.

2.4 Free Drop No. 4 – Side Drop onto UX-30 Closure Pins

A free drop (See Figure 4) of Test Unit 1 (second sequential drop of this unit) through a distance of 9 m (30 ft) onto the test pad, striking the surface in a position for which maximum damage is expected.

Overpack orientation: Horizontal with Test Unit 1 Parting Plane axis rotated 90° from normal condition of transport such that closure pins will make contact with drop test pad.

Model 30B Cylinder orientation: Plug end down (cylinder was rotated within the UX-30 90° from its normal orientation for transport) so as to have the plug nearest to contact point from the drop test pad.

Test Unit Temperature: Maximum of -40°C (-40°F).

The test was performed at a reduced temperature condition, since maximum foam strength occurs at the minimum temperature condition, since foam strength increases with decreasing

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temperature. Maximum structural effects due to impact reaction loading are generally expected at minimum temperature conditions, where loads will be greatest relative to closure component structural strength. The following observations were made after the drop (see photos Drop Test 4-1 through 4-7):

- The overpack remained closed and the parting plane gap remained within tolerance at the valve end of the overpack. At the plug end of the overpack the parting plane separated slightly in the area where the locking pin had sheared in Free Drop No. 1, measuring approximately 16 mm (5/8 inch). The gap decreased down to within tolerance at the opposite end of the overpack. The gap was on the side of the overpack 180° away from the side of the overpack that impacted the test pad.
- Nine of 10 locking pins remained engaged. The one locking pin at the very end of the overpack which sheared in Free Drop No. 1 was not replaced for this test.
- There was deformation and some buckling of the outer skin of the overpack along the parting plane which impacted the test pad.
- There were no observed tears in the package.

2.5 Free Drop No. 5 – Center of Gravity over Parting Plane

A free drop (See Figure 5) of Test Unit 1 (third sequential drop of this unit) through a distance of 1 m (40 in) onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on the test pad, with a drop angle that maximizes the damage to the shell of the overpack caused by Free Drop No. 4.

Overpack orientation: Impact orientation (Center of Gravity over parting plane) was determined following Drop Test No. 4.

Model 30B Cylinder orientation: As oriented for Drop Test No. 4.

Test Unit Temperature: Ambient.

The test was performed at ambient temperature condition. The following observations were made after the drop (see photos Drop Test 5-1 through 5-5):

- The overpack remained closed and the parting plane gap remained within tolerance at the valve end of the overpack, except at the area of contact with the steel bar that deformed the skin at the parting plane. The parting plane at the plug end of the overpack did not change from Free Drop No. 4.
- Nine of 10 locking pins remained engaged. The one locking pin at the very end of the overpack which sheared in Free Drop No. 1 was not replaced for this test.
- The puncture pin indented the package outer skin at an angle with valve end of the overpack. One side of the indent penetrated to a depth of approximately 51 mm (2 inches) and the other side to a maximum depth of 114 mm (4.5 inches). The elongated indent was approximately 178 mm (7 inches) wide.
- All welds remained intact, and, with the exception of the puncture pin tear, the package outer skin was not breached.

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2.6 Post Drop Test Inspections and Testing

Following completion of the drop tests, the cylinders were removed from the overpacks and inspected. Test Unit 2 was wedged closed and had to be pried open (see Test Unit 2 – Post Drop Test photos). There was no discernible damage to the interior of Test Unit 1 or Test Unit 2 UX-30 overpacks or to either of the 30B cylinders from any of the drop tests. Glazing material applied to the end of the cylinder plug showed no deformation, indicating that the plug did not contact the inner shell of the UX-30 at any time during the testing.

Following the overpack and cylinder inspections, both cylinders were leak tested and the post-drop test measured integrated leakage rates were 4.3×10^{-7} atm-cc/sec. and 6.3×10^{-8} atm-cc/sec. The damage sustained to the UX-30s was consistent with previous drop tests for the same model, and no damage was sustained by the Test Units from any of the drop tests which would compromise the package's ability to meet the requirements of 10 CFR 71.

3.0 Thermal

The effect of the hypothetical accident fire event is examined in Section 3.5 of the UX-30 Safety Analysis Report (SAR). The results of the UX-30 fire test scenario and associated thermal analysis models, used to correct for deviations between test conditions and initial conditions required for the hypothetical accident, are discussed in detail in Appendix 3.6.3 of the UX-30 Safety Analysis Report (SAR).

The drop tests addressed in this report show that the effect of these drops is a local crushing of the foam, and possible rupture of the impact limiter skin. The puncture drop tests also show the crushing of the foam and rupture of the skin in the vicinity of the impact location. The local crushing of the foam during the drop and puncture tests will increase the foam density. The effect of the local density increase of the foam is addressed in Section 3.5.3 of the SAR.

The rupture of the impact limiter skin after the drop and puncture tests may minimally expose the polyurethane foam material to the fire. However, the polyurethane fire retardant characteristics will mitigate the effect of the direct exposure to fire due to formation of intumescent char. The following is a quote from the General Plastics sales brochure.

“The primary fire retardant mechanism of FR-3700 is the production of an intumescent char when thermally degraded. The foam acts much like the small pallets children light on the fourth of July which grows a long worm when burning. The intumescent char has the ability to seal large voids which could be caused by the impact damage. The char also provides a secondary thermal barrier which breaks down very slowly at 2000 to 2200°F.”

Tests performed by General Plastics where the open face of a foam filled 5-gallon bucket is exposed to direct fire show the formation of the char that prevents the fire from extending into the underlying foam. These tests also indicate that for the 1 1/4” foam thickness in the test, the effect of 30-minute fire has a minimal effect on the end opposite the exposed end.

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These tests were performed for various density foams and it was shown that the effectiveness of the foam is enhanced with the increasing foam density. With 7.8 – 9.8 lb/ft³ foam nominal density and a nominal thickness of 6 inches in the UX-30 overpack, the effect of exposure of a small portion of foam due to rupture during the drop and puncture test will not have a significant effect on the impact limiter performance during the fire.

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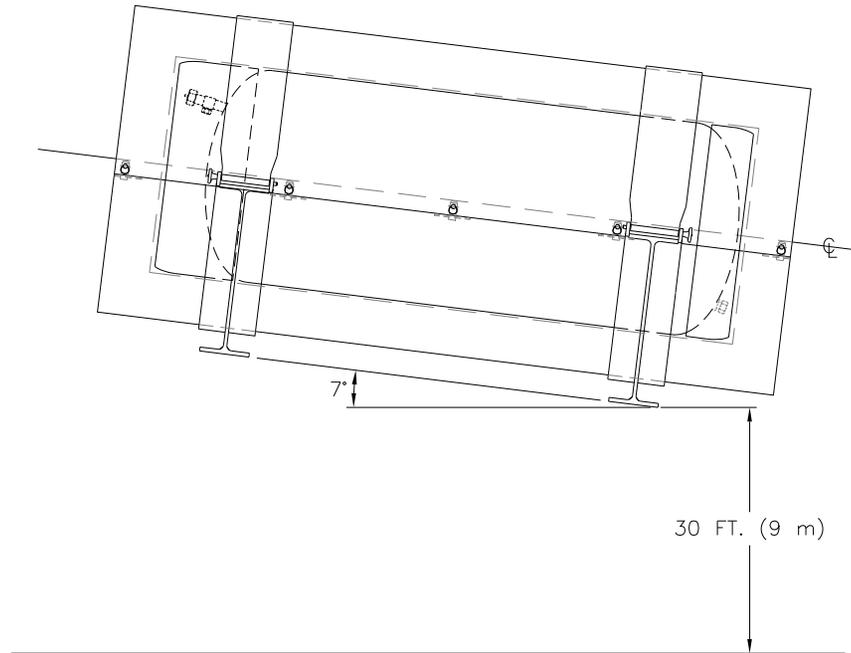


FIGURE 1

30 Foot Drop – *Slap Down onto UX-30 Cradle*

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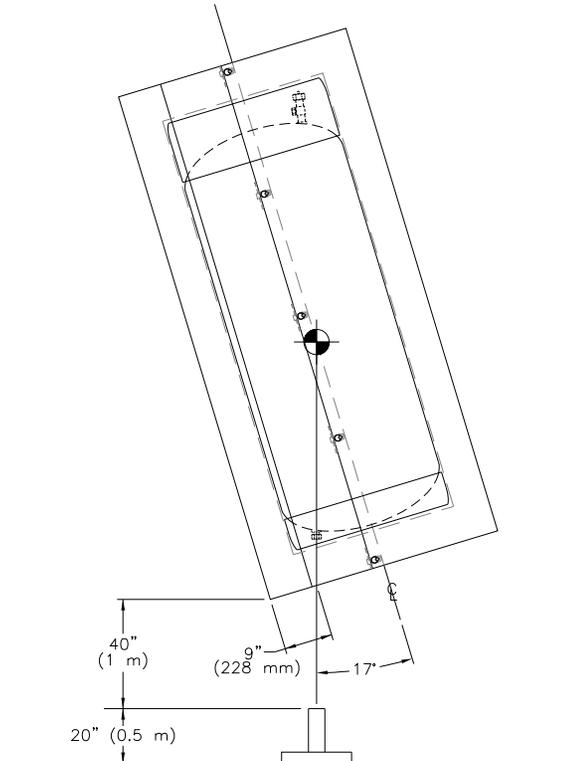


FIGURE 2

Puncture – *CG over 30B cylinder plug*
Pin below plug

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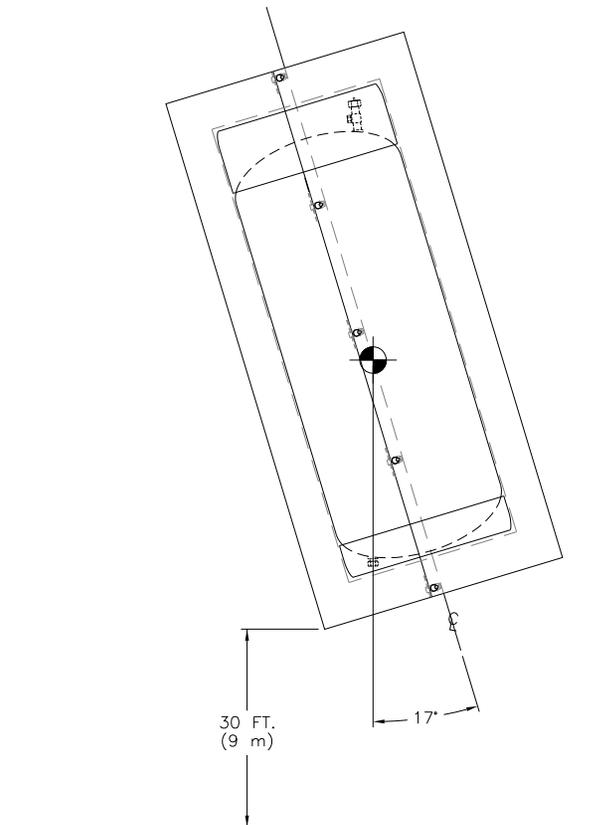


FIGURE 3

30 Foot Drop - *CG over 30B cylinder plug*
Plug end down

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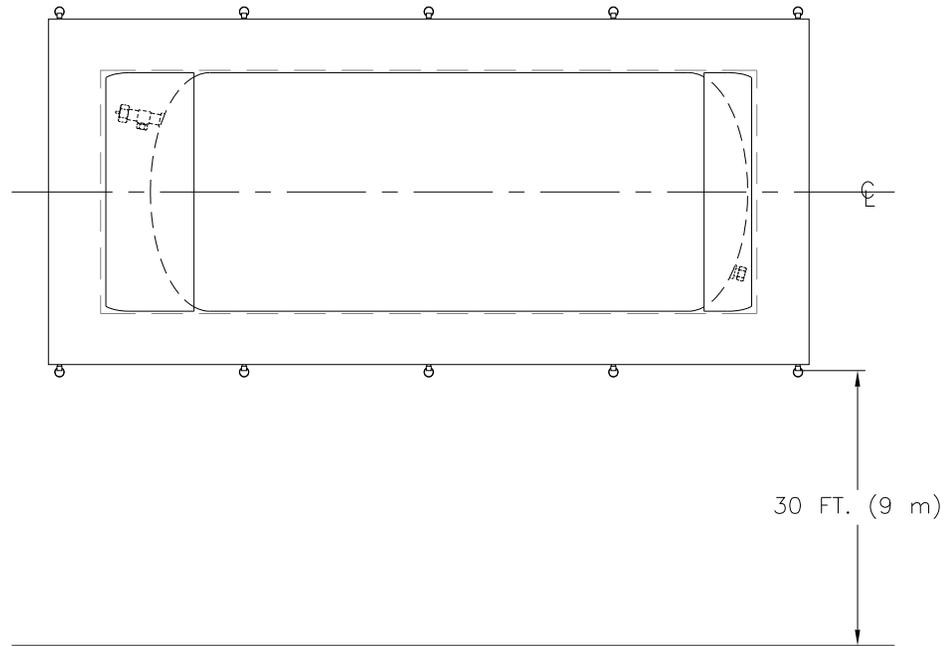


FIGURE 4

30 Foot Drop - *Side Drop onto UX-30 Closure Pins*

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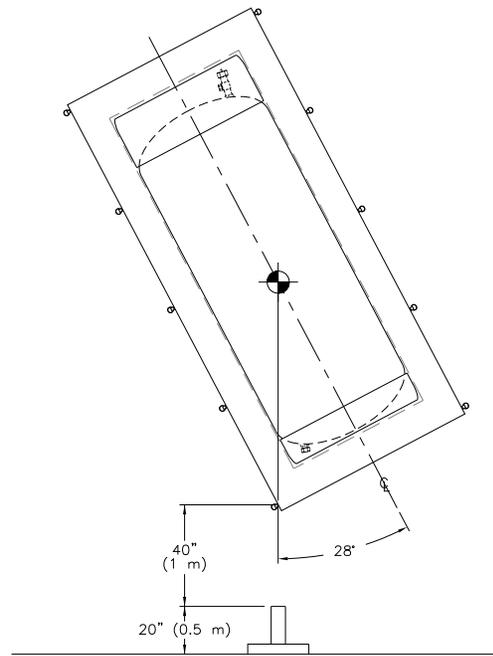


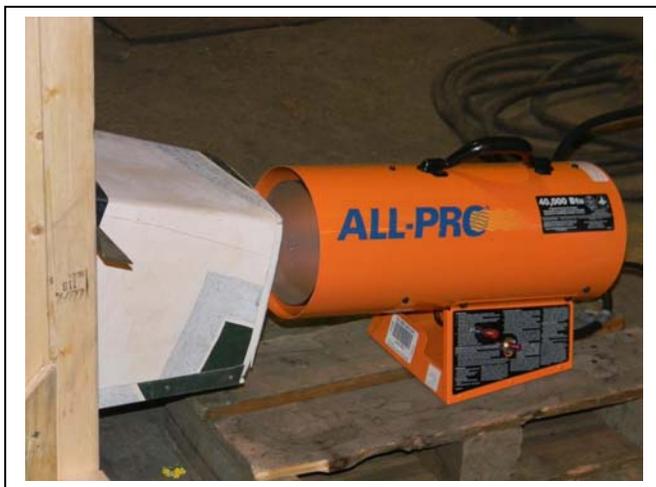
FIGURE 5

Puncture – *CG over Parting Plane*

PHOTOS

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HEATING/COOLING ENCLOSURE



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CYLINDER LEAK TEST CHAMBER



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TEST 1



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Drop Test 1 - 3



Drop Test 1 - 4

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TEST 2



UX-30 PERFORMANCE TESTING SUMMARY REPORT



Drop Test 2 - 3



Drop Test 2 - 4

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TEST 3



Drop Test 3 - 1



Drop Test 3 - 2



Drop Test 3 - 3

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Drop Test 3 - 4



Drop Test 3 - 5



Drop Test 3 - 6

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TEST 4



Drop Test 4 - 1



Drop Test 4 - 2



Drop Test 4 - 3



Drop Test 4 - 4

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Drop Test 4 - 5



Drop Test 4 - 6



Drop Test 4 - 7

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TEST 5



Drop Test 5 - 1



Drop Test 5 - 2



Drop Test 5 - 3

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Test Unit 2 – POST DROP TESTS



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