



Blast Pendulum Testing of Milliken Tegriss Panels

by Donald J. Grosch, Erick J. Sagebiel, and Hal Eleazer

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January 2008

prepared by

**Southwest Research Institute
San Antonio, Texas**

and

**Milliken & Company
Spartanburg, South Carolina**

under contract

W911NF-07-2-0074

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14. ABSTRACT Milliken contracted Southwest Research Institute¹ (SwRI¹) to conduct blast pendulum tests on various panels. The blast pendulum allows one to investigate a material's capability of mitigating sample deformation and bulk structural loading that result from "close-in"² blast loading. The methodology is based upon placing a sample in a semi-rigid frame. The frame is supported by large supports that are free to rotate about a fixed position. Based upon the angular motion, the momentum transferred into the sample can be determined. The pendulum is most useful for looking at plate coatings which hopefully can reduce the plate deformation and the overall momentum transferred into a structure. SwRI conducted a total of four tests on September 5, 2007, using the blast pendulum at its remote site near Yancey, Texas. A representative from Milliken witnessed each test. None of the tests resulted in perforation of the target assembly, and their swing angles and deflections were considerably less than those of a baseline 3/8-inch mild steel target performed the next day (47.2-degree maximum swing with 4.53-inch maximum plate deflection) versus the best Milliken combination that showed a 41.8-degree maximum swing with 2.64-inch maximum plate deflection. ¹ Southwest Research Institute and SwRI are registered trademarks of Southwest Research Institute. ² The term "close-in" means within 10 to 20 meters.				
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1. Overview

Milliken & Company contracted Southwest Research Institute (SwRI) to conduct blast pendulum tests on various panels. The blast pendulum allows one to investigate a material's capability of mitigating sample deformation and bulk structural loading that result from "close-in"¹ blast loading. The methodology is based upon placing a sample in a semi-rigid frame which is supported by large supports that are free to rotate about a fixed position. Based upon the angular motion, the momentum transferred into the sample can be determined. The pendulum is most useful for looking at plate coatings which hopefully can reduce the plate deformation and the overall momentum transferred into a structure. SwRI conducted a total of four tests on 5 September 2007, using the blast pendulum at its remote site near Yancey, Texas. A representative from Milliken witnessed each test.

2. Test Fixture

The test fixture is a large pendulum (see figures 1 and 2) onto which panels are clamped for testing. The pendulum accepts 30- by 30-inch panels, which are clamped between front and rear frame plates, each of which is fabricated from 2-inch-thick steel. Sixteen 1-inch bolts are used to clamp the two frame plates together and secure the test panel (the bolts are on the outside of the panel so no through-holes are required). The front frame has a 26-inch-square opening through which the panel is explosively loaded, while the rear frame has a 24-inch-diameter round hole through which the panel can deform or rupture. When the charge is detonated, the test panel is loaded and then deflects and transfers the load into the rest of the pendulum. The overall motion of the pendulum is recorded with high-speed video to capture the maximum swing angle. The panel deflection/rupture and the resulting swing angle can be compared to other materials loaded during similar conditions for a direct performance comparison.

¹Close-in means within 10 to 20 meters.

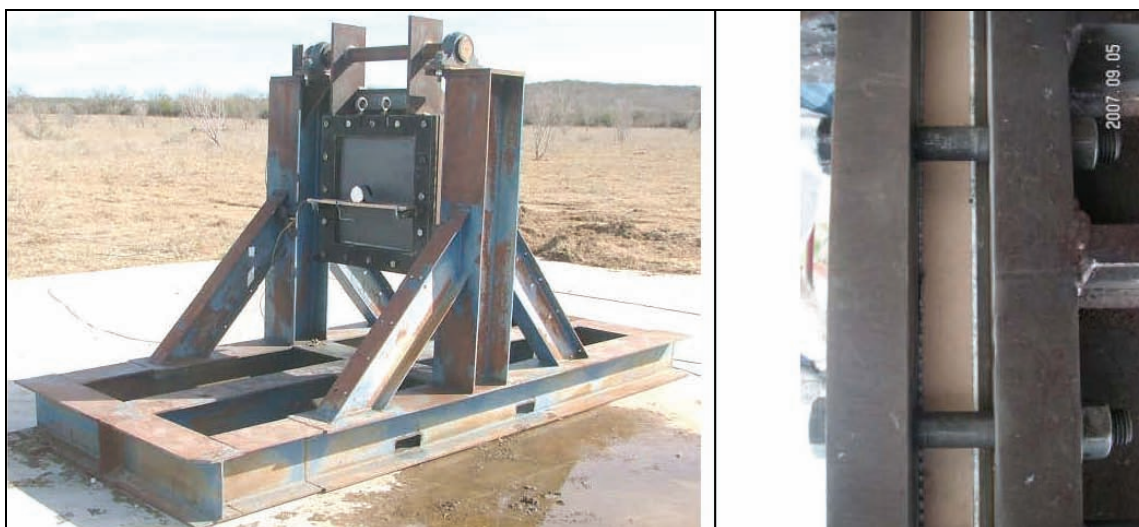


Figure 1. Blast pendulum fixture and edge view showing panel clamping.

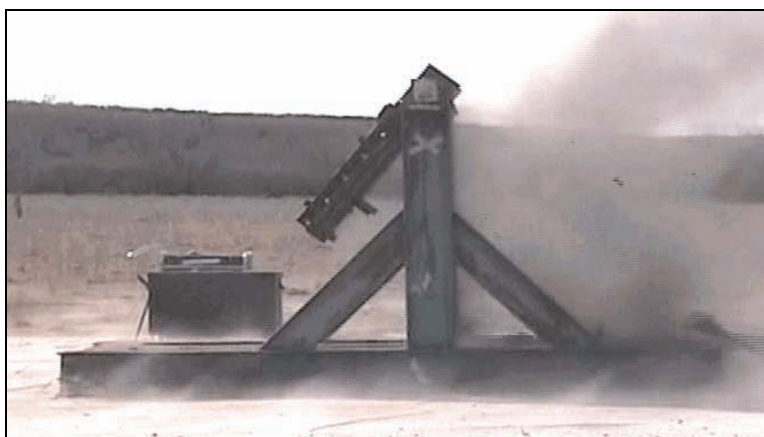


Figure 2. Picture of blast pendulum swinging after shot.

3. Explosive Charge

These tests were conducted with a bare Composition C-4 charge with a weight of 2.09 pounds and a cylindrical shape with a length-to-diameter (l/d) ratio of 0.72. This resulted in a 4-inch-diameter charge with a height of 2.88 inches. The charge was positioned “end on” to the sample, and it was center detonated on the far end of the charge (see figure 3). The stand-off distance (from the closest edge of the charge to the near face of the test panel) varied and is listed in table 1.



Figure 3. Photo of charge on fixture.

Table 1. Test results

Test	Target Description	Maximum Swing (degrees)	Maximum Plate Deflection (inches)	Comments
1	AM General Target 2.09 lb C4 charge 3-15/16-in. standoff 0.157-in. 46177 steel 0.25-in. 6061-T6 aluminum 0.25-in. 6061-T6 aluminum 1.0-in. Tegriss ^a panel with aluminum skins	43.7	3.16	Steel plate has a 6-in.-dia. dent area, no cracks; 0.25-in. aluminum plate 1 has a 7-in.-dia. dent and a 7-in. crack; 0.25-in. aluminum plate 2 has a 7-in.-dia. dent and a 10-in. x 7-in. crack area; the Tegriss panel has a 9-in. x 5-in. crack area on the impact side and no cracks on the back side.
2	Milliken/C-foam target 2.09-lb C4 charge 3.5-in. standoff 0.157-in. steel 1.0-in. Tegriss panel with aluminum skins 1.50-in. C-foam 1.0-in. Tegriss panel with aluminum skins	46.2	3.29	Steel plate has an 8-in.-dia. dent and no cracks; the 1 Tegriss panel has an 8-in.-dia. dent and a 3.5-in. x 0.5-in. through crack; the C-Foam panel has a 20-in.-dia. dent area and a 2-in.-dia. hole; the 2 Tegriss panel has no cracks on either surface.
3	Milliken low temp 2.09-lb C4 charge 3-7/8-in. standoff 0.157-in. steel 0.37-in. Tegriss with aluminum skins 1.25-in. low temp Tegriss 0.375-in. mild steel	41.8	2.64	Steel plate has a 6-in.-dia. dent and a 3-in. x 1.5-in. hole; the 0.37-in. Tegriss panel has a 6-in.-dia. dent and a 3-in. x 1.5-in. hole; the low temp Tegriss panel has a 6.5-in.-dia. dent and a 3-in. hole; the 3/8-in. mild steel has no cracks.
4	Milliken special panel 2.09-lb C4 charge 3-7/8-in. Standoff 0.157-in. steel 0.37-in. Tegriss with aluminum skins 1.20-in. special Tegriss 0.375-in. mild steel	42.0	2.50	Steel plate has a 6.5-in.-dia. dent with no cracks; the 0.37-in. Tegriss panel has a 6-in.-dia. dent and a 1.5-in. x 1-in. hole; the special Tegriss panel has a 6-in.-dia. dent and a 3.5-in. x 1.5-in. hole; the 3/8-in. mild steel has no cracks.

^aTegriss is a revolutionary 100% PP thermoplastic composite with excellent impact resistance and stiffness as well as a lightweight composition. Tegriss is based on a patent-pending technology which creates a highly engineered polypropylene tape yarn with a highly drawn core for strength properties within a lower melt polymer matrix for composite processing.

4. Instrumentation

A Phantom² V7 high-speed video camera was positioned normal to the back surface of the pendulum uprights to observe the pendulum swing. A regular-speed video camera was positioned in a similar manner as a backup. The measured swing angles are provided in table 1.

5. Test Results

A summary of the tests is shown in table 1. The maximum swing angle was measured from the high-speed video to within ± 0.5 inch. The maximum plate deflection was measured by an SwRI quality assurance (QA) inspector using a coordinate measuring machine. The QA inspector scanned the center of the plate in both directions. The data from these scans are shown in figures 4 through 7. The maximum deflection values are provided in table 1. Photographs of each test are provided in appendix A.

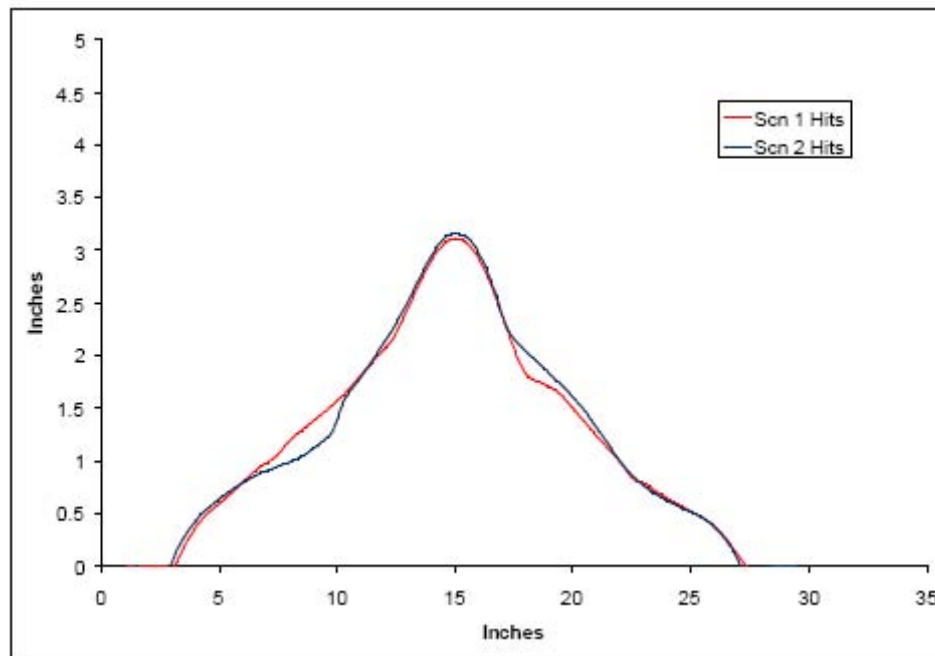


Figure 4. Plate deflection data for test 1.

²Phantom is a registered trademark of ViSiON Research, Inc.

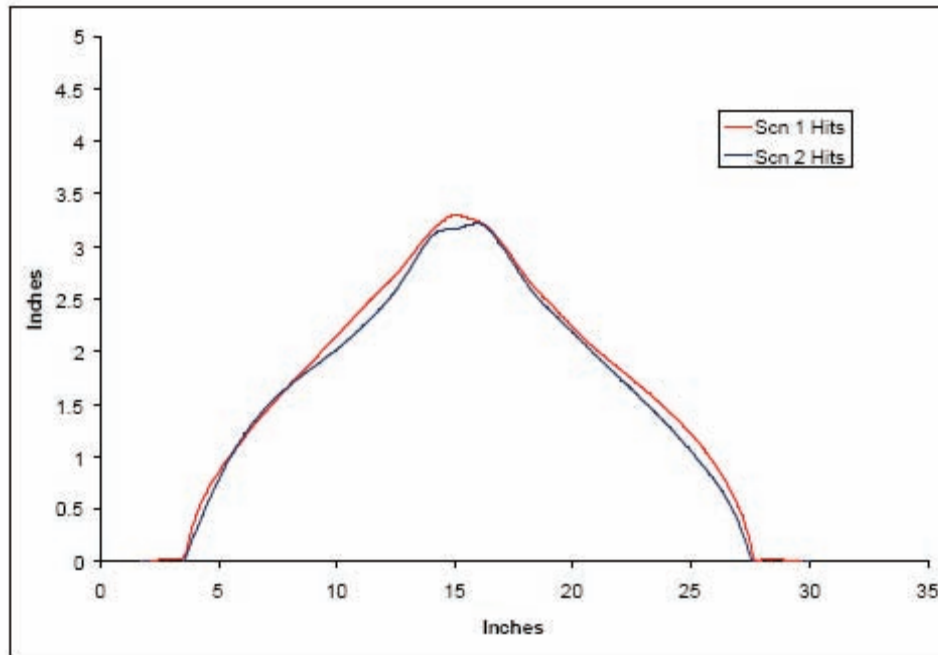


Figure 5. Plate deflection data for test 2.

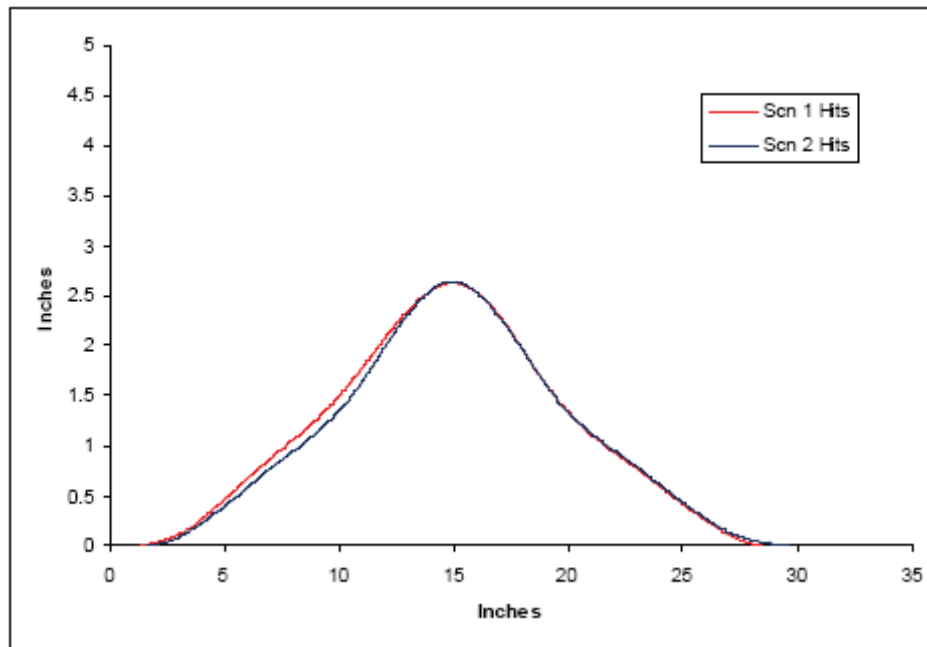


Figure 6. Plate deflection data for test 3.

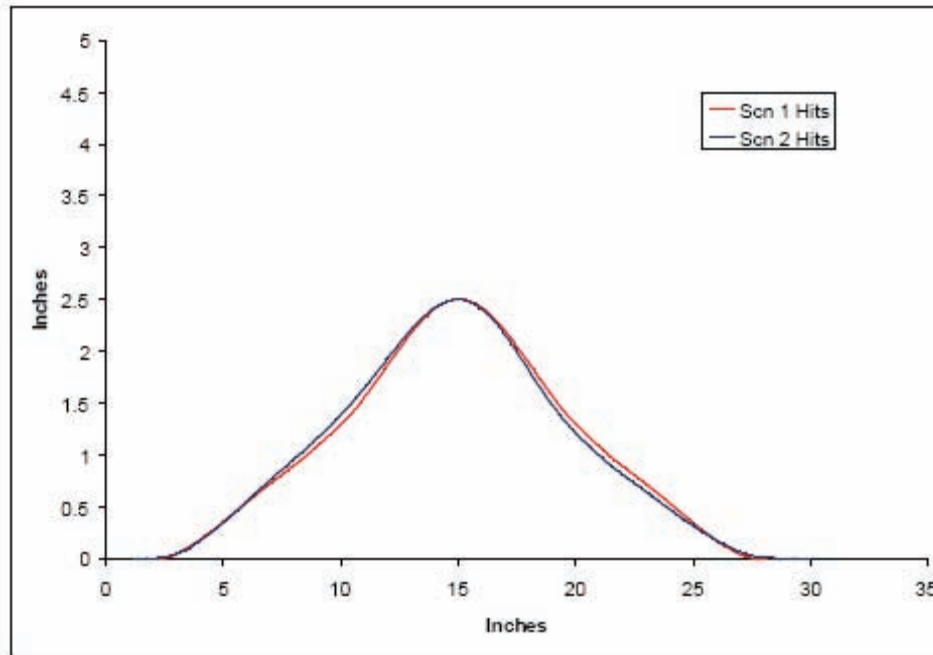


Figure 7. Plate deflection data for test 4.

6. Summary

Four pendulum blast tests were performed on panels provided by Milliken. None of the tests resulted in a perforation of the target assembly, and their swing angles and deflections were considerably less than those of a baseline 3/8-inch mild steel target performed the next day (47.2-degree maximum swing with 4.53-inch maximum plate deflection).

Appendix A. Test Photographs



Test 1 Post-Test



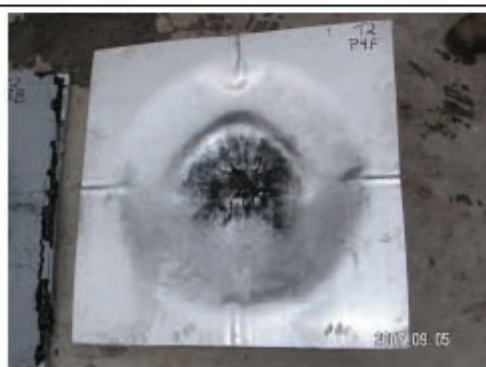
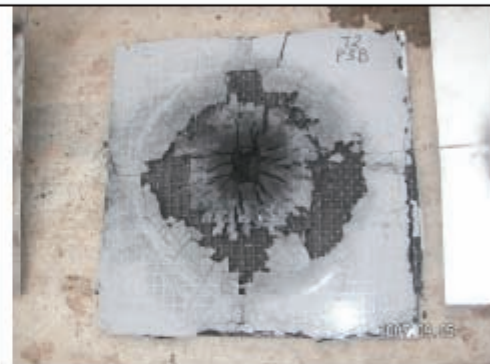
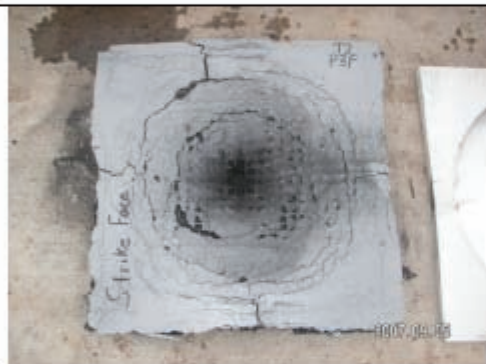
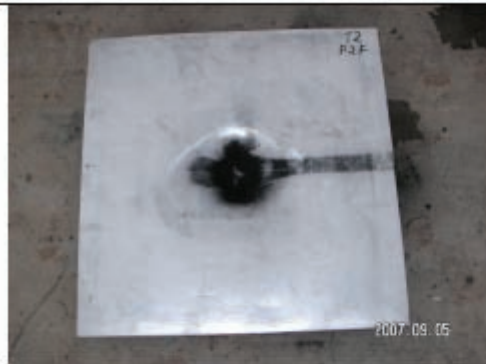
Test 2 Pre-Test



Test 2 Post-Test



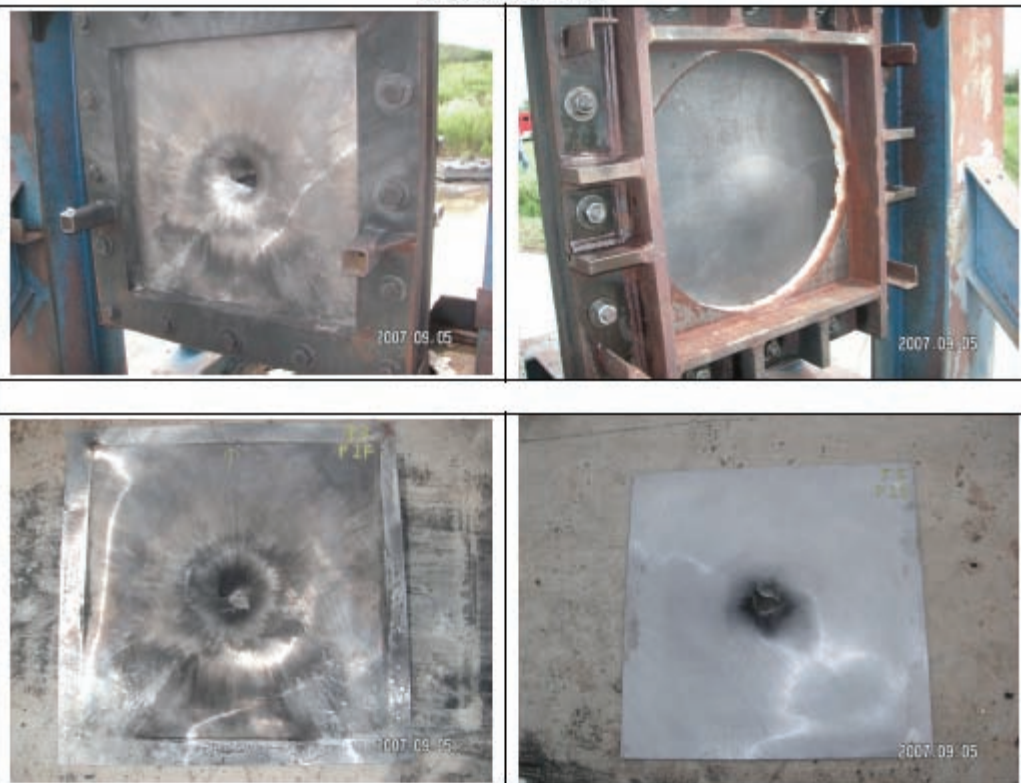
Test 2 Post-Test



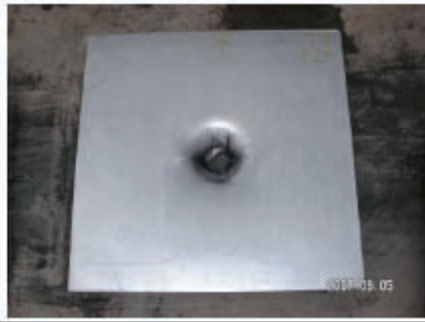
Test 3 Pre-Test



Test 3 Post-Test



Test 3 Post-Test



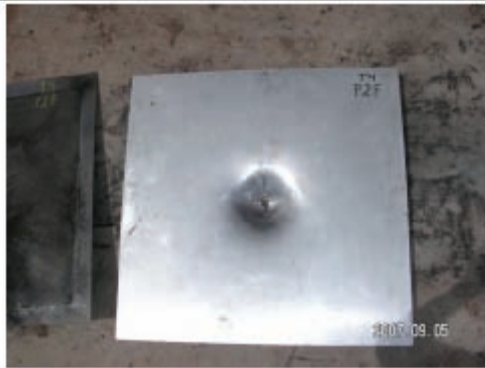
Test 4 Pre-Test



Test 4 Post-Test



Test 4 Post-Test



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