Rail Strength Tests for Time of Flight (TOF) Trays

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One-Rail Tests - *Two-Rail Test* - *End-Rail Test*

Introduction
The Time of Flight detectors of the STAR experiment at RHIC (Relativistic Heavy Ion Collider) are contained in 120 aluminum trays[1] that border the cylindrical STAR detector. A mounting system for these trays consist of a single rail of length[1] 181" ± 0.06" (Fig. 1) and two "feet" that attach along the length of a tray (Fig. 2, Fig. 8 bottom left). When fully loaded with equipment, the trays will weigh approximately 75 lbs.

Each foot is attached to the tray via 15 rivets spaced 8" apart, excepting the three rivets on either end of the tray, which are spaced 0.5" and 5" apart (Fig. 4, top left). These rivets are rated to have a tensile strength of 100 lbs. and a shearing strength of 150 lbs. Since the trays will be positioned in virtually all angles around the detector, these rails will have to endure strain from any angle, the maximum strain being at 180° (hanging on both rails) and 90° (on one rail). Theoretically, they should be able to hold 2250 lbs. on its side and 3000 lbs. while hanging (since two rails will be carrying the load).

Tests will be performed at these angles to ensure that the railing system (namely the feet) are sufficient to secure the trays. Measurements of the foot spacing and height (Fig. 2) were taken before and after each test to check for possible deformation at each rivet. Since the two rivets on each end were spaced only 0.5" apart, only the inner rivet was measured (Fig. 4, top left). For the tests, the lid was reinforced with aluminum tape to ensure the tray itself would not break. The feet themselves were completely unassisted for the tests. A beam of double-sided unistrut was attached to the backside of the rail to allow for hooks and mounts so the whole apparatus could be lifted via a gantry crane. Two nylon slings were fastened to the hooks, and then to the crane hook.

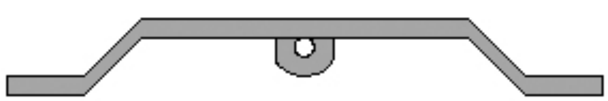


Fig. 1 Rail shown on end. (Rail is not drawn to scale).

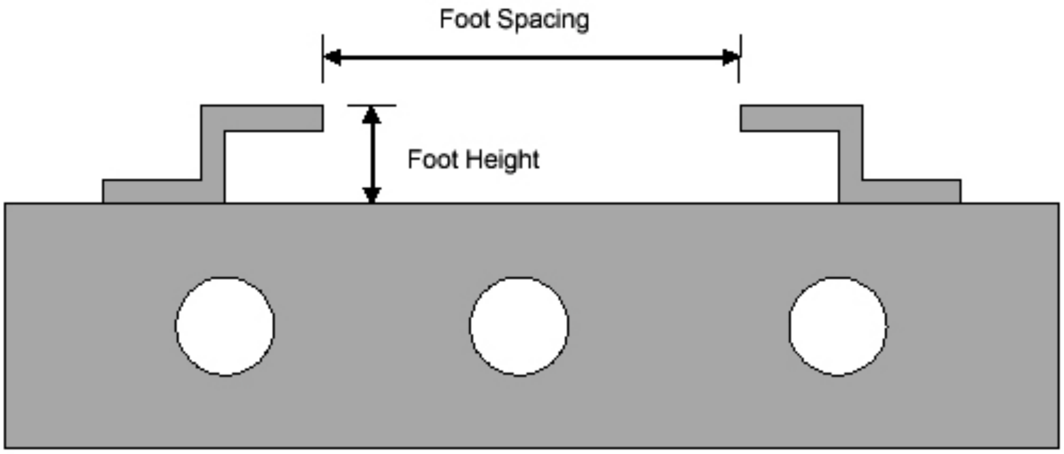


Fig. 2 Tray with rails shown on end. Right rail is on the right side of the tray while looking at the end with the feed holes while the tray is resting feet up. (Tray is not drawn to scale).

One-Rail Tests

The test performed placed a tray at 90 degrees such that it was supported by only one foot. This is equivalent to the trays being held at the 9:00 and 3:00 positions on the STAR detector. Three fifty pound lead weights were positioned in the tray as seen in Figure 3 top left and Figure 4 top right. As seen, firm yellow foam was used as filler between the lead and the tray lid. Cement blocks were placed underneath the tray to allow for loading, and blocks with wood beams on the ends prevented the apparatus from rotating during the test (Fig. 3). Unistrut hooks were attached to the rail to allow for lifting (Fig. 5 bottom left, Fig. 6 bottom right). Two nylon slings were placed around the two hooks and the crane hook (Fig. 3 top left). Note: the terms "right" and "left" rail refer to the left and right foot of the tray relative to the face of the tray where the cables are fed while the tray is resting foot-up.

Right Rail

The unistrut hooks bowed slightly under the strain, but returned to normal when the test was completed. The tray itself made no noises or obvious signs of strain when it was lifted. The rail held for the full time, and did not deform or break.

Before Test

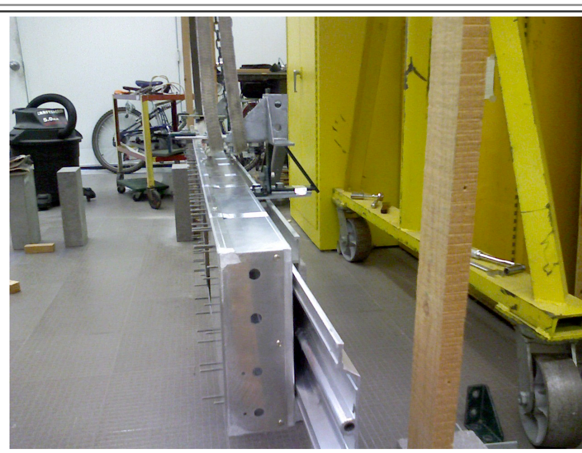


Fig. 3
From top left to bottom right: 1. Tray shown resting on cinder blocks before lift. 2. Long edge of tray before lift. 3. Tray shown immediately after lift. 4. Spacing shown between lifted tray and cement blocks.

After Test

Fig. 4
From top left to bottom right: 1. Close-up of foot and end rivets. 2. Front of tray shown while suspended. 3. Close-up of foot and rivets shown on end. 4. Entire apparatus shown.

Left Rail

This test was performed in the same manner as the right rail test, only for the left foot. Figure 7 shows the deformation as the differences between the measurements of rail height and spacing taken before and after the test for the 13 rivets. Note: the wooden blocks were placed on the lid of the tray so it could be set down on its face without damaging the PEM studs on the lid (Fig. 5 top left).

The unistrut hooks bowed slightly under the strain, but returned to normal when the test was completed. The tray itself made no noises or obvious signs of strain when it was lifted. The rail held for the full time, and did not deform or break.
Average change in rail heights: Right = -0.005 ± 0.011 in. Left = 0.007 ± 0.009 in.
Average change in rail spacing: l = -0.004 ± 0.008 in.

Before

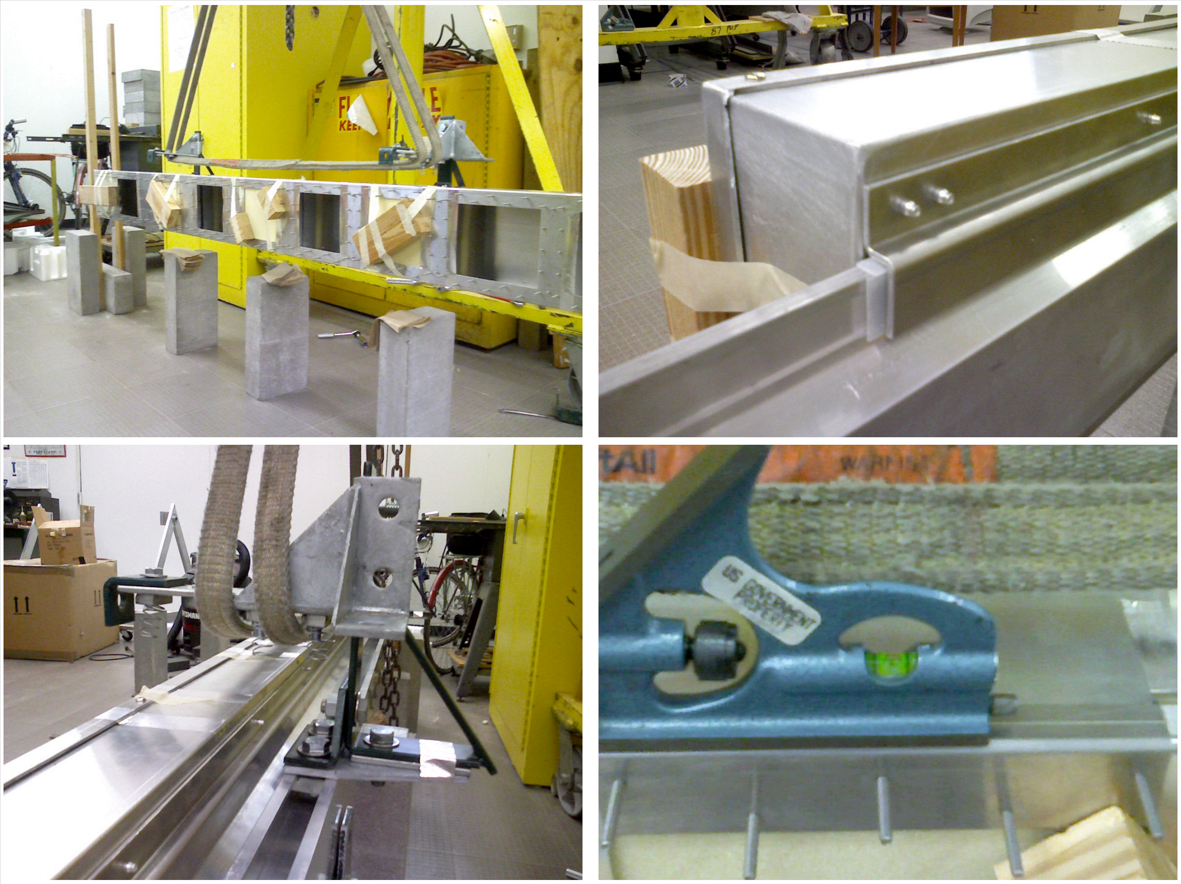


Fig. 5
From top left to bottom right: 1. Apparatus shown lifted. 2. Close-up on the foot. 3. Hooking system shown. 4. Leveling of the tray shown.

After

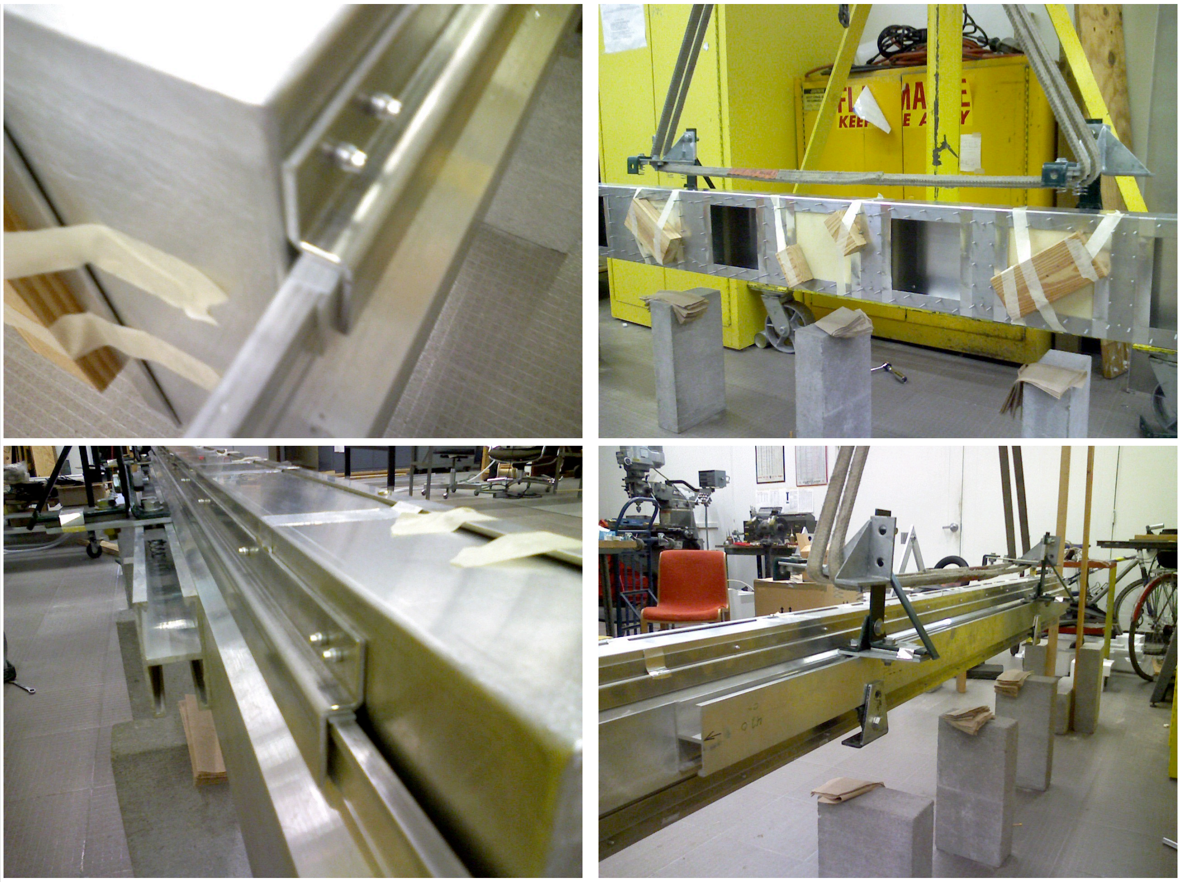


Fig. 6

From top left to bottom right: 1. Close-up of the foot. 2. Tray shown suspended. 3. Close-up of the foot on the opposite side. 4. Backside of the apparatus while lifted.

Rail Dimension Comparison

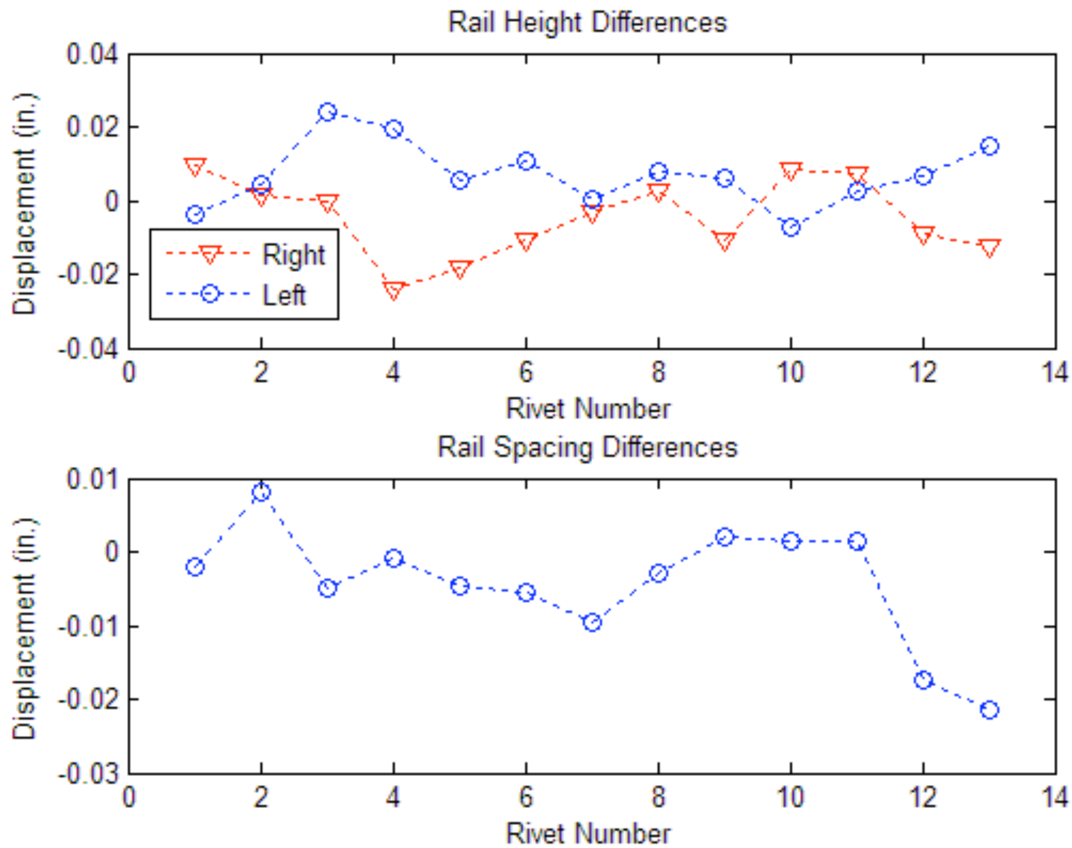


Fig. 7
The top graph shows the difference between the rail heights before and after the test, and the bottom graph shows the difference in rail spacing before and after the test.
Graphing done via MATLAB

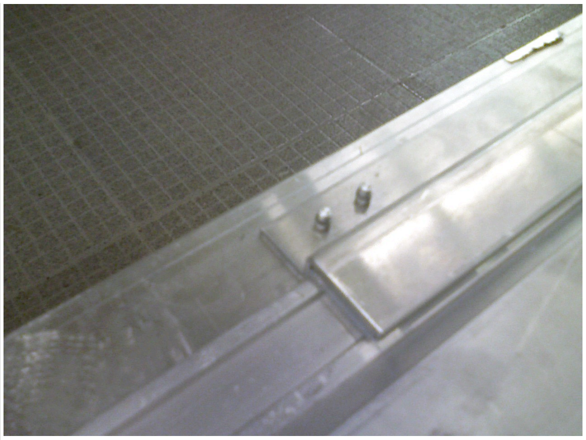
<u>Two-Rail Test</u>
At the 6:00 position on STAR, the TOF tray will essentially be hanging from both of its feet. In this test, small hooks were mounted on a unistrut bar bolted to the back of the mounting rail, and the nylon slings were looped around each of them (Fig. 8 top). Cement blocks were placed on either side of the rail ends to prevent the tray from rotating (Fig. 8). Measurements were taken immediately following the completion of the test.

The tray was suspended for 1.5 hrs. The tray made no sounds or other signs of strain, and the feet held for the full time without deforming or breaking.
Average change in rail heights: Right = .002 ± .007 in. Left = -.003 ± .005 in.
Average change in rail spacing: l = -.215 ± .012 in.
The likely cause for the rail spacing to decrease instead of increase (Fig. 10 bottom) would be that the box itself deformed. The force on the box is along the edge, where the rails are. This may cause the box to sag in the center from the lead, drawing the rails closer together. Therefore, the change is a result of the box deforming and not the rails. The foot height differences seemed to be evenly distributed around 0 (Fig. 10 top).

Before Test

Fig. 8
From top left to bottom right: 1. tray shown rested. 2. Tray lifted with foam blocks underneath as a safety measure. 3. Close-up on the feet. 4. Rail shown on end.

After Test



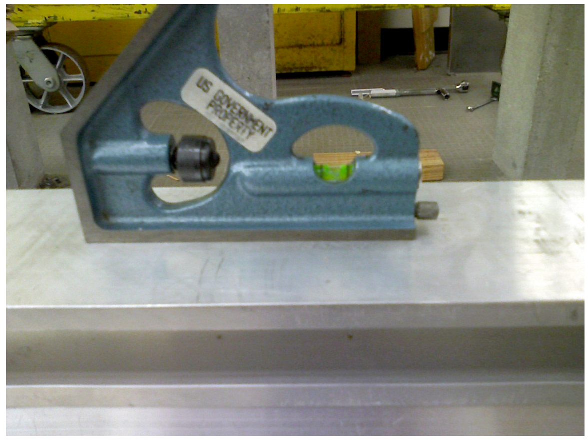


Fig. 9
From top left to bottom right: 1. Close-up of feet. 2. Entire apparatus shown. 3. Close-up of individual foot. 4. Leveling shown.

Rail Dimension Changes Due to the Test

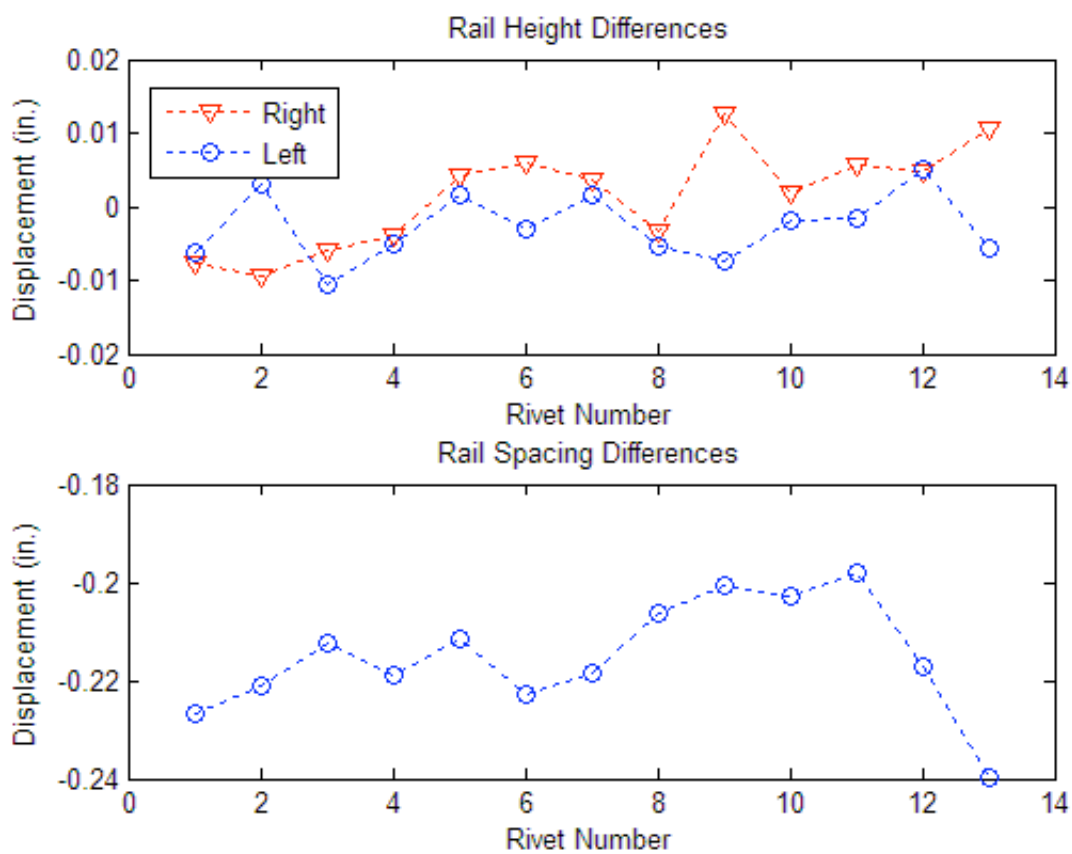


Fig. 10
Note: the terms "right" and "left" rail refer to the left and right foot of the tray relative to the face of the tray where the cables are fed while the tray is resting foot-up.
The top graph shows the difference between the rail heights before and after the test, and the bottom graph shows the difference in rail spacing before and after the test.
Graphing done via MATLAB

End-Rail Test

When these trays are being loaded into STAR, the very end of the feet will have to support much of the tray's weight for a brief time. For this test, the mounting rail was placed 13.5" in on the solid end of the tray. Two weights (100 lbs.) were used, along with the firm yellow foam for padding as before (Fig. 11 top right). These two weights were placed at the solid end (opposite the cable-feed end) of the tray. This end was used because the PEM stud arrangement on the inside allowed us to place the weights closer to the end of the tray. Cement blocks were used to hold up the tray for loading (Fig. 11 bottom right). Once the rail was in place, the crane was used to raise the tray just enough to slide the blocks out leaving only one block supporting the opposite end of the tray, and one other to support the other end of the rail (Fig. 11 top left, Fig. 12 bottom left). The extra support on the opposite end of the tray was to avoid torquing the tray (Fig. 11 bottom left). A nylon strap was wrapped around a unistrut hook in a similar fashion to the two-rail test (Fig. 11 top).

The tray held for a full hour with no deformation or breakage (Fig. 12 top). For this test, the rail spacing change seemed to be in the positive direction and the rail height changes appeared to be more or less eveny distributed about 0 (Fig. 13).
Average change in rail heights: R = -0.003 ± 0.007 in. L = 0.005 ± 0.008 in.
Average change in rail spacing: l = 0.006 ± 0.008 in.

Before

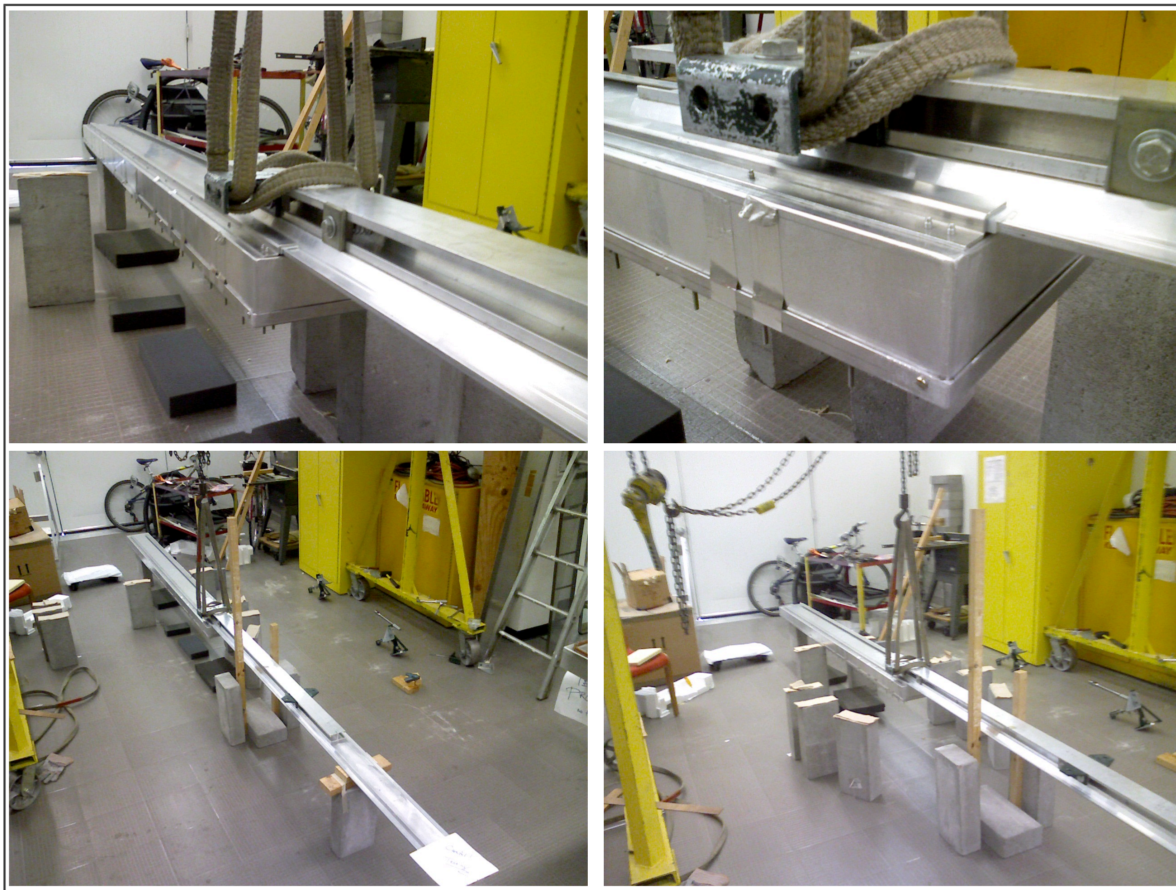


Fig. 11
From top left to bottom right: 1. Connection point shown along rail. 2. Close-up of connection point.

3. Entire apparatus shown (tray at the top, rail at the bottom of the frame). 4. Entire apparatus shown.

After

Fig. 12
From top left to bottom right: 1. Close-up of right foot. 2. Close-up of left foot. 3. Connection point shown. 4. Connection point shown along rail.

Comparison

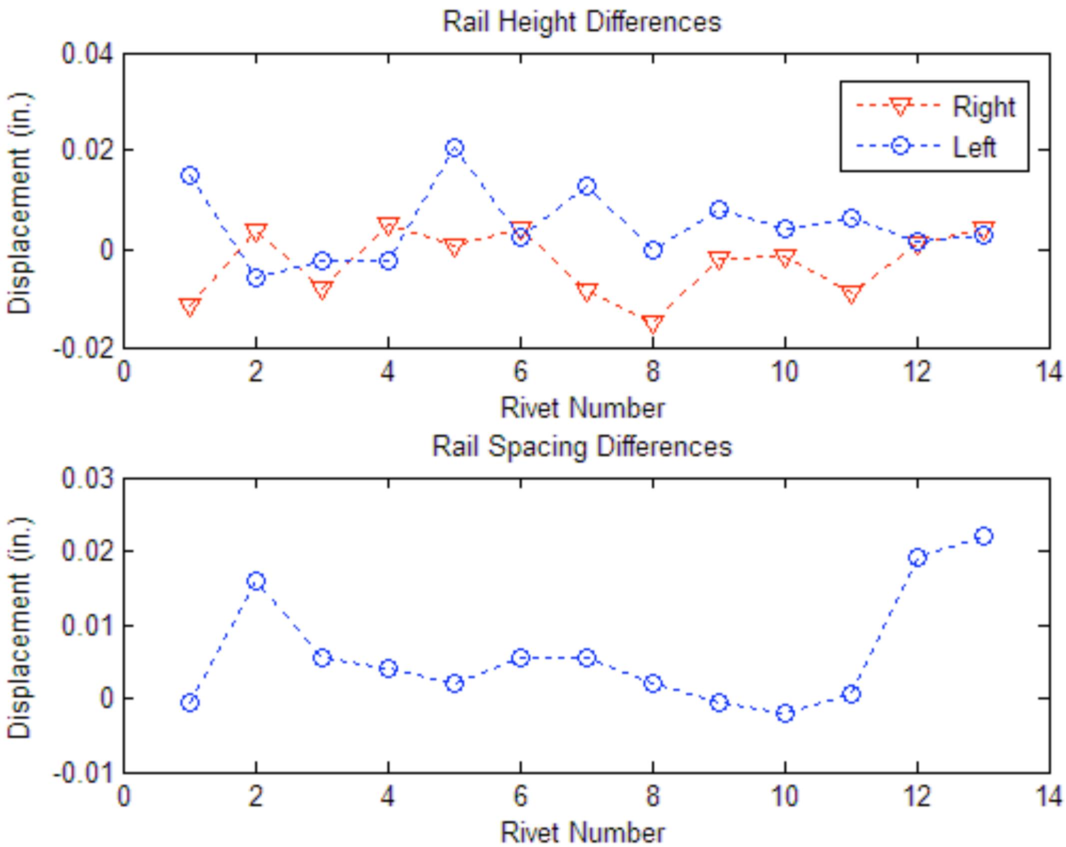


Fig. 13
Note: the terms "right" and "left" rail refer to the left and right foot of the tray relative to the face of the tray where the cables are fed while the tray is resting foot-up.
The top graph shows the difference between the rail heights before and after the test, and the bottom graph shows the difference in rail spacing before and after the test.
Graphing done via MATLAB

References

1. Llope, W. J., and Ralph Brown. "2.1 Dimensions in (R,ϕ)." TOF Tray Mechanical Design Dimensions & Tolerances. 2.