U.S. Department of Transportation
Federal Railroad Administration

Quasi-Static Test on a State-of-the-Art Collision Post and End Post Assembly

Office of Research and Development
Washington, DC 20590

DOT/FRA/ORD-

April 2009
Draft Report

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13. ABSTRACT (Maximum 200 words) This test evaluated the quasi-static method for demonstrating energy absorption and graceful deformation as outlined in the notice of proposed rulemaking for front-end strength of cab cars and multiple unit locomotives. The quasi-static tests were successful and were executed as planned. Minor modifications were made to the design of the end frame assembly as a result of the test on the collision post. The modifications were in the area of the bulkhead plate and shelf, where they attach to the collision and end posts. Changes reduced some of the high stress areas noticed during the collision post test. After review by FRA, indications are that the end frame assembly did meet the requirements of the proposed rulemaking for front end strength of the cab car.				
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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION

Inches	0			1			2			3		4		5
Centimeters	0	1	2	3	4	5	6	7	8	9	10	11	12	13

QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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EXECUTIVE SUMMARY

The Office of Research and Development of the Federal Railroad Administration (FRA) has been conducting research on rail equipment crashworthiness with the approach of reviewing relevant accidents, identifying options for design modifications to improve occupant survivability, and applying analytical tools and testing techniques to assess the effectiveness of such options. As part of this research, computer models have been developed and used to predict the response of passenger rail equipment in different collision scenarios. To assess the accuracy of these computer models, the model predictions have been compared with accident data and component test results. The information learned in the research will be used to develop safety rulemaking requirements for passenger equipment end frame designs.

This test evaluated the quasi-static method for demonstrating energy absorption and graceful deformation as outlined in the notice of proposed rulemaking for front-end strength of cab cars and multiple unit locomotives.

The quasi-static tests were successful and were executed as planned. All data collected was made available to the FRA immediately following the test and is also included by reference and attachment in this report. Minor modifications were made to the design of the end frame assembly as a result of the test on the collision post. The modifications were in the area of the bulkhead plate and shelf, where they attach to the collision and end posts. Changes reduced some of the high stress areas noticed during the collision post test. After review by FRA, indications are that the end frame assembly did meet the requirements of the proposed rulemaking for front end strength of the cab car.

The quasi-static method will be compared with the dynamic method for testing previously performed under this test program. To accomplish this, a previously damaged LIRR (Long Island Rail Road) M1 Budd car was retrofit with a new state-of-the-art end frame for two separate tests. Testing involved controlled loading of both the collision and end posts within the end frame assembly separately, with a single load applied on the respective post using two separate end frame assemblies. Both the collision and end posts were taken to failure with their respective test setup.

Results of the quasi-static testing will be analyzed and compared with the results obtained from the dynamic test conducted on April 16, 2008, for correlations between the two test methods. Testing was performed by TTCI for the FRA at the Transportation Technology Center, Pueblo, Colorado. Data collected from the testing was given to the FRA for review and analysis through the Department of Transportation, Volpe Center.

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1.0 Introduction

The Office of Research and Development of the FRA has been conducting research on rail equipment crashworthiness with the approach of reviewing relevant accidents, identifying options for design modifications to improve occupant survivability, and applying analytical tools and testing techniques to assess the effectiveness of such options. As part of this research, computer models were developed and used to predict the response of passenger rail equipment in different collision scenarios. To assess the accuracy of the computer models, the model predictions were compared with accident data and components test results. The information learned in the research will be used to develop safety rulemaking requirements for passenger equipment end frame designs.

This test used a quasi-static method for demonstrating energy absorption and graceful deformation as outlined in the notice of proposed rulemaking for front-end strength of cab car and multiple unit locomotives. Testing involved controlled loading of both the collision and end posts within the end frame assembly separately, with a single load applied on the respective post using two separate end frame assemblies. Both the collision and end posts were taken to failure with their respective test setup.

Results of the quasi-static testing will be analyzed and compared with the results obtained from the dynamic test conducted on April 16, 2008, for correlations between the two test methods. Testing was performed by TTCI for the FRA at the Transportation Technology Center, Pueblo, Colorado. Data collected from the testing was given to the FRA for review and analysis through the Department of Transportation, Volpe Center.

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2.0 Test Description and Method

The first test required that the collision post of the end frame be loaded using a hydraulic ram, which is supported against a reinforced reaction car. The collision post was then tested to failure. The post must absorb at least 135,000 ft-lb of energy with no more than 10-inch deflection with no complete separation of the post from its support to meet the proposed test requirements. This test was performed on June 25, 2008. The second test was a repeat of the procedure, with the load applied at the end post on a new end frame assembly. The damaged end frame assembly from the collision post quasi-static test was removed from the car, and a new end frame assembly was installed prior to the second test. The end post test was performed on August 13, 2008.

The test was conducted on Track 2 inside the Passenger-Rail Services Building. The LIRR M1 Budd car used for the dynamic collision post impact test was also used for the quasi-static tests. The TTC-reinforced reaction car was coupled to the test car, and a hydraulic ram was placed between the two vehicles, as stated above. The hydraulic ram was placed 30 inches above the buffer beam on the end frame assembly or approximately 82 inches above top of rail. The reaction car brake was set while the hydraulic ram applied force to the collision post. The test car wheels were also blocked to control potential movement. Figure 1 and 2 demonstrate the test setup.

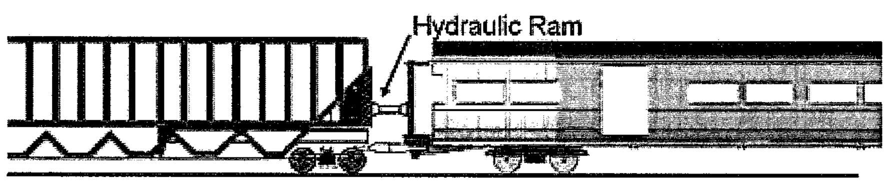

Figure 1. Test Vehicles (Side View)

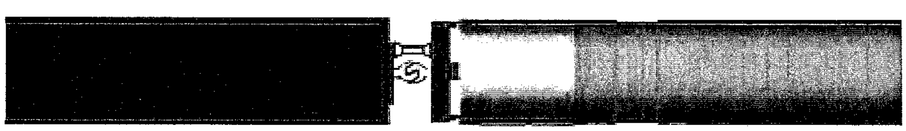

Figure 2. Test Vehicles (Top View), Set on the Collision Post

2.1 End Frame Assembly

New state-of-the-art end-frames were assembled at TTC. Components were fabricated by Zimmerman Metals, Denver, based on a design furnished by the Volpe Center through a contract with TIAX LLC, Cambridge. End frames were the same design as that used for the dynamic test, with the exception that some modifications were performed at the shelf reinforcing channel and bulkhead plate where they attached to the collision and end posts for the end post test. End frame assembly drawings are Number D038-009-010. This report contains a CD of Microsoft PowerPoint format files with progress reports showing the fabrication process of the end assemblies, as reference. See Figure 3 showing the Dynamic Test setup for reference.

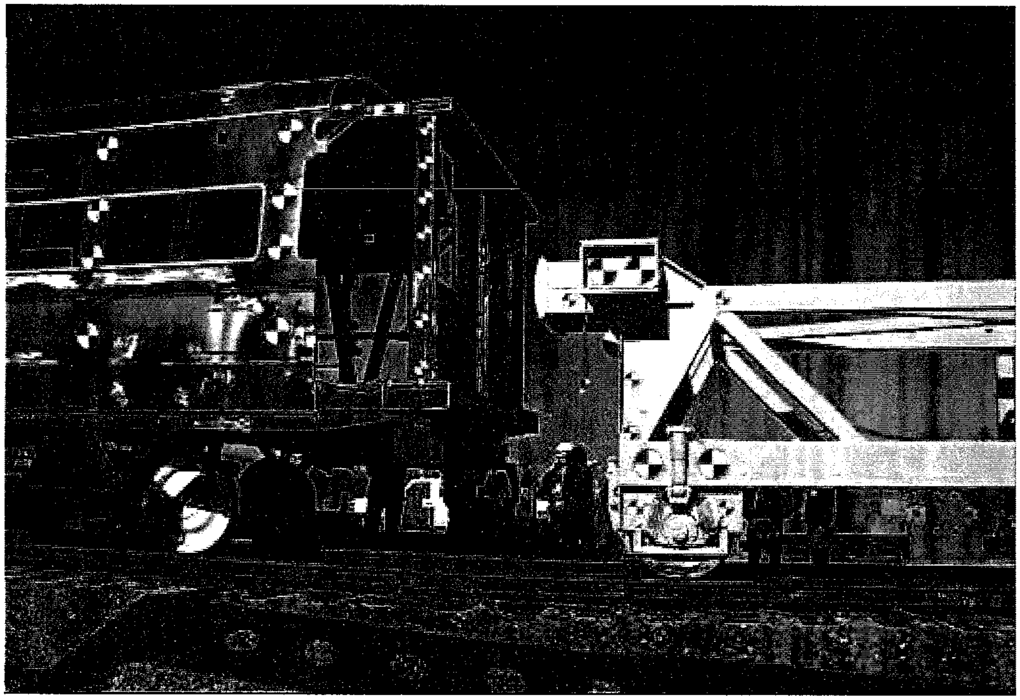

Figure 3. Dynamic Test Setup Collision Post Impact

2.2 Loading Fixture

The 48-inch diameter coil shape used on the impactor cart (see Figure 3) was mounted on the base end of the hydraulic ram as the contact shape against the collision and end posts (Figure 4). The cylinder end has a series of four 100,000-pound load cells sandwiched between the reaction car and the cylinder head to measure force directly in a pin style connection (compression only). A pressure transducer was also installed in the hydraulic line to correlate hydraulic pressure with force applied through the hydraulic ram. A 10,000 pound per square inch rated hydraulic pump was used to provide pressure to the actuator that is rated for a maximum of 1,000,000 pounds force. The ram was suspended in place with an overhead crane to support and hold the ram, should an abrupt failure occur. There was a safety concern that the stored energy in the end frame could release suddenly during the test. Lateral movement of the two cars during loading could also affect the hydraulic ram and make loading of the end frame unstable. As the test post displaces inward, contact is made with the shelf (C-channel) and bulkhead plate assembly, which could impose an eccentric load on the coil shape. Loading on the four load cells was watched for signs of instability. Although the four load cells did show variable loading between the load cells during the test, the system was stable and behaved well over the entire displacement range. A rectangular spacer was placed behind the shim plate to make up the difference between the end frame and the reaction car when the hydraulic cylinder was compressed. This allowed a range of up to 12 inches of displacement before the cylinder was fully extended. The cylinder was then compressed, and a second rectangular spacer was used that was 10 inches longer to extend the displacement range of the test setup.

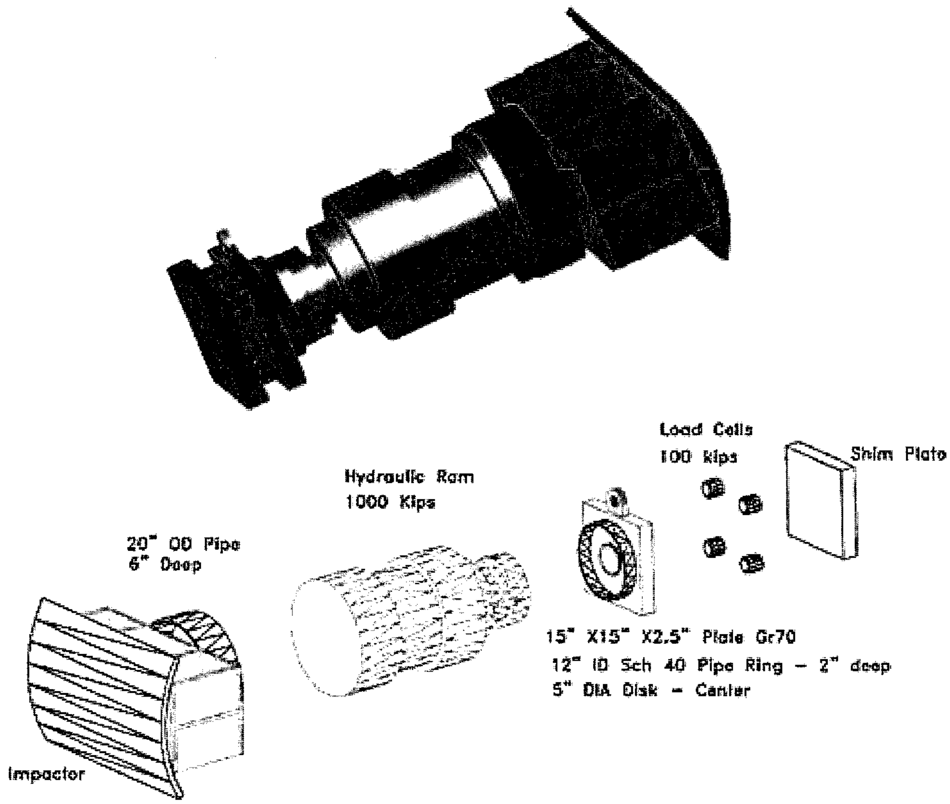

Figure 4. Squeeze (Load) Fixture Detail

The post connection behavior and mode of deformation was measured and observed during the test. The force crush characteristic required to fail the post connection was measured and displayed real time for test observers. Work required to displace the test post can be determined by analysis of the data generated during the tests. This data reduction was performed by the DOT Volpe Center as a separate activity.

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3.0 Measurements

3.1 Load Cells

A load cell array attached to the hydraulic ram cylinder end, as shown in Section 2.2 and Figure 5, was used to measure the force applied to the test post. The load cells are rated for 100,000 pounds, with an over range of 50 percent. A maximum range to 350,000 pounds of force was requested as a test parameter.

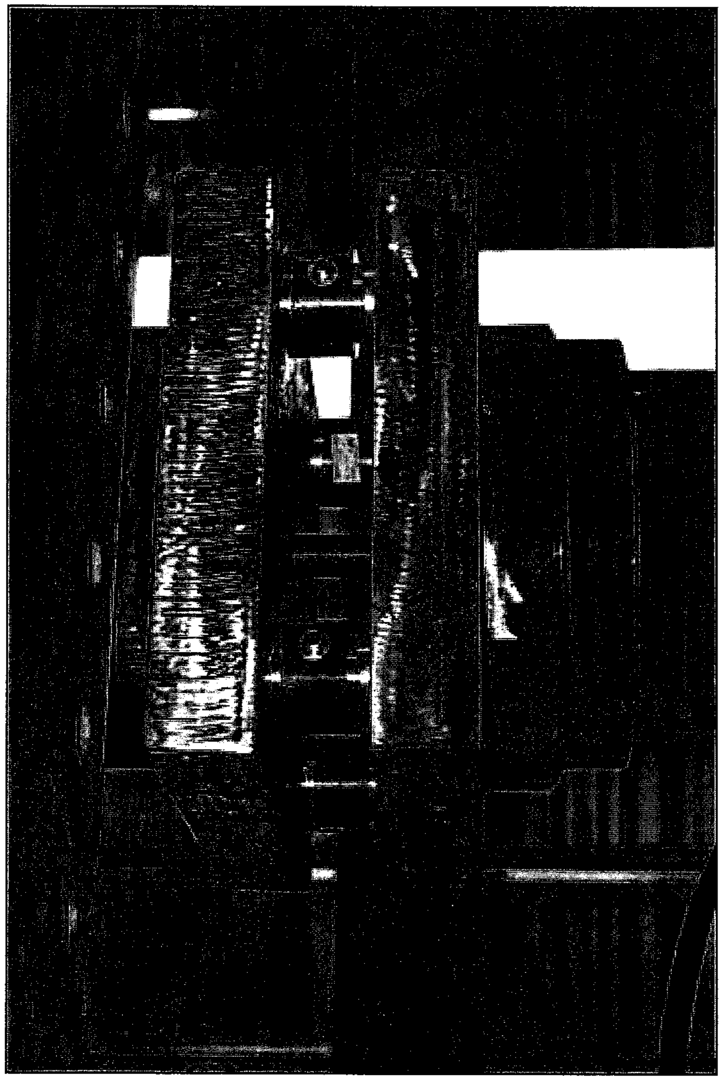


Figure 5. Load Cell Configuration with Hydraulic Ram

Measurements for each load cell were taken real time, recorded, and displayed on a screen to view as the load was applied (Figure 6). This allowed a quick view of eccentric load conditions being applied to the base of the reaction car bearing surface for monitoring purposes. A totalizing load was also displayed adjacent to the individual load cells for observation.

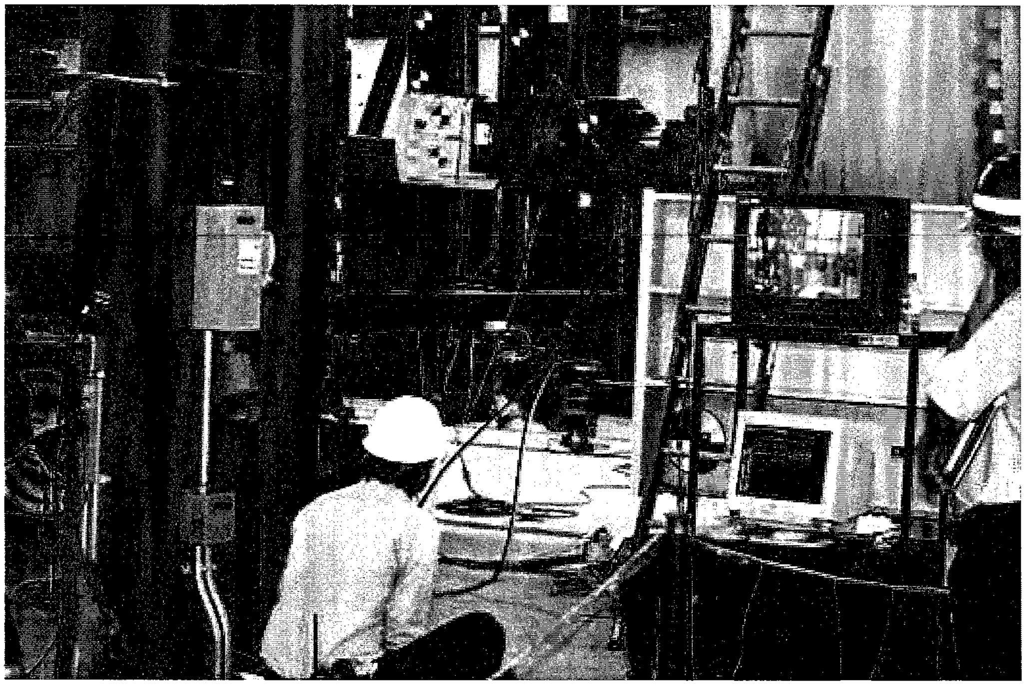


Figure 6. Force Display from Load Cells

3.2 Strains

Twenty-eight strain gages were used to measure the reaction strains on the cab car at locations specified in the Test Implementation Plan (TIP). The locations were on the state-of-the-art end-frame members as well as on the longitudinal members of the original car structure. Strain gage locations were similar for both tests, as Figures 7 and 8 show.

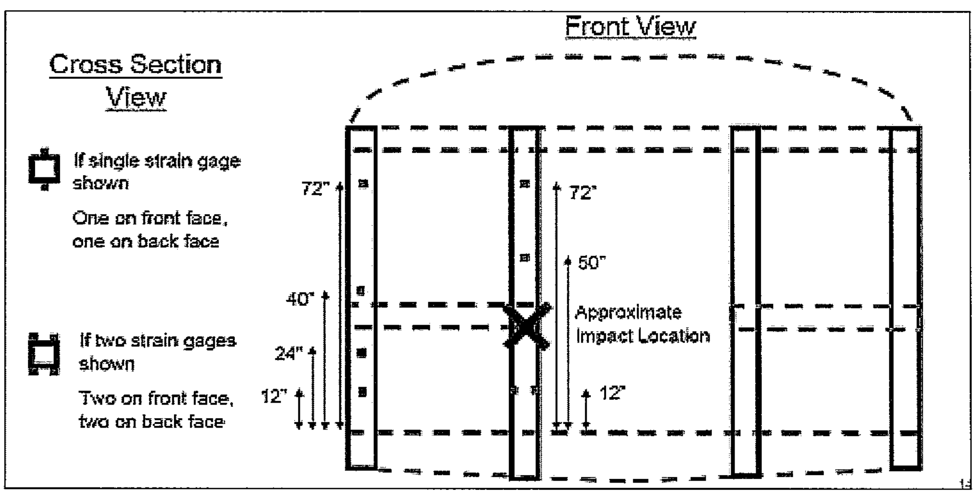


Figure 7. Vertical Member Strain Gage Locations, Collision Post Test

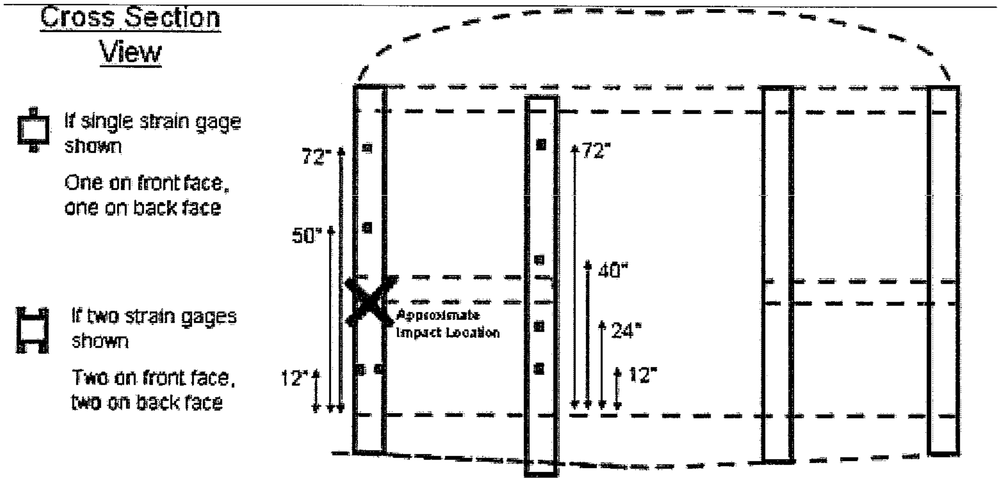


Figure 8. Vertical Member Strain Gage Locations, End Post Test

Strain gages were also in place on the test car support structure for the end frame assembly as Figure 9 shows. This included two strain gages on each side for the roof line support and side sills, with four strain gages on the center sill. Table 1 lists the channel names and orientation of the measurements for the collision post test, with a similar numbering scheme in Table 2 for the end post test.

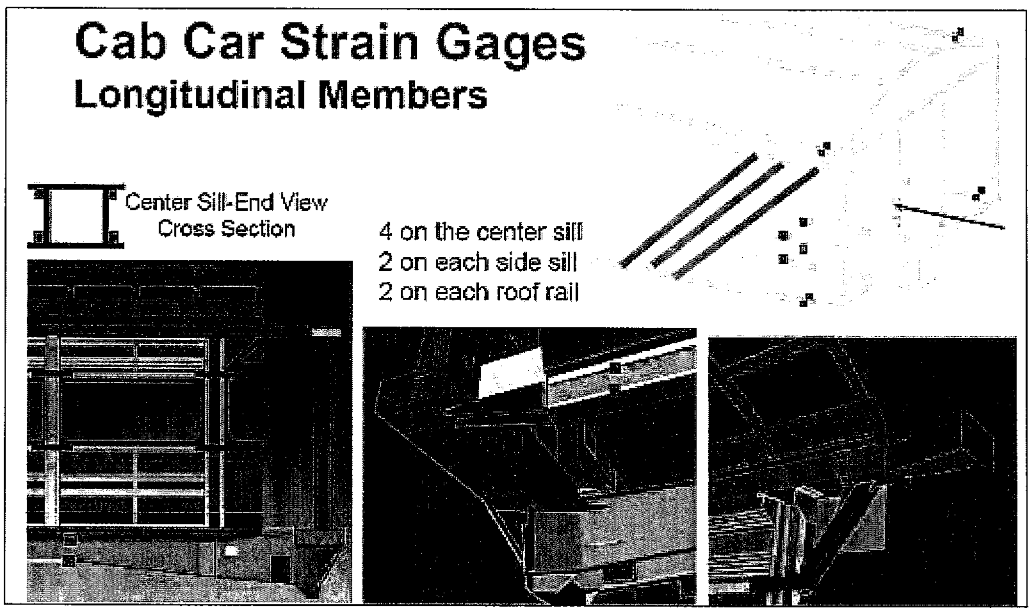


Figure 9. Longitudinal Member Strain Gage Locations

Table 1. Strain Gage Parameters, Collision Post Test

No.	Location	Direction	Data Channel Name
1	Corner Post -12" Front	Vertical	CCORP12F
2	Corner Post -12" Rear	Vertical	CCORP12R
3	Corner Post - 24" Front	Vertical	CCORP24F
4	Corner Post - 24" Rear	Vertical	CCORP24R
5	Corner Post - 40" Front	Vertical	CCORP40F
6	Corner Post - 40" Rear	Vertical	CCORP40R
7	Corner Post - 72" Front	Vertical	CCORP72F
8	Corner Post - 72" Rear	Vertical	CCORP72R
9	Collision Post - 12" Front Right	Vertical	CCOLP12FR
10	Collision Post - 12" Front Left	Vertical	CCOLP12FL
11	Collision Post - 12" Rear Right	Vertical	CCOLP12RR
12	Collision Post - 12" Rear Left	Vertical	CCOLP12RL
13	Collision Post - 50" Front	Vertical	CCOLP50F
14	Collision Post - 50" Rear	Vertical	CCOLP50R
15	Collision Post - 72" Front	Vertical	CCOLP72F
16	Collision Post - 72" Rear	Vertical	CCOLP72R
17	Right Cant Rail Top	Longitudinal	CCRRT
18	Right Cant Rail Bottom	Longitudinal	CCRRB
19	Left Cant Rail Top	Longitudinal	CCRLT
20	Left Cant Rail Bottom	Longitudinal	CCRLB
21	Right Side Sill Top	Longitudinal	CSSRT
22	Right Side Sill Bottom	Longitudinal	CSSRB
23	Left Side Sill Top	Longitudinal	CSSLT
24	Left Side Sill Bottom	Longitudinal	CSSLB
25	Center Sill Top Right	Longitudinal	CCSRT
26	Center Sill Top Left	Longitudinal	CCSLT
27	Center Sill Bottom Right	Longitudinal	CCSRB
28	Center Sill Bottom Left	Longitudinal	CCSLB

Table 2. Strain Gage Parameters, End Post Test

No.	Location	Direction	Data Channel Name
1	Corner Post -12" Front Right	Vertical	CCORP12FR
2	Corner Post -12" Front Left	Vertical	CCORP12FL
3	Corner Post -12" Rear Right	Vertical	CCORP12RR
4	Corner Post - 12" Rear Left	Vertical	CCORP12RL
5	Corner Post - 50" Front	Vertical	CCORP50F
6	Corner Post - 50" Rear	Vertical	CCORP50R
7	Corner Post - 72" Front	Vertical	CCORP72F
8	Corner Post - 72" Rear	Vertical	CCORP72R
9	Collision Post - 12" Front	Vertical	CCOLP12F
10	Collision Post - 12" Rear	Vertical	CCOLP12R
11	Collision Post - 24" Front	Vertical	CCOLP24F
12	Collision Post - 24" Rear	Vertical	CCOLP24R
13	Collision Post - 40" Front	Vertical	CCOLP40F
14	Collision Post - 40" Rear	Vertical	CCOLP40R
15	Collision Post - 72" Front	Vertical	CCOLP72F
16	Collision Post - 72" Rear	Vertical	CCOLP72R
17	Right Cant Rail Top	Longitudinal	CCRRT
18	Right Cant Rail Bottom	Longitudinal	CCRRB
19	Left Cant Rail Top	Longitudinal	CCRLT
20	Left Cant Rail Bottom	Longitudinal	CCRLB
21	Right Side Sill Top	Longitudinal	CSSRT
22	Right Side Sill Bottom	Longitudinal	CSSRB
23	Left Side Sill Top	Longitudinal	CSSLT
24	Left Side Sill Bottom	Longitudinal	CSSLB
25	Center Sill Top Right	Longitudinal	CCSRT
26	Center Sill Top Left	Longitudinal	CCSLT
27	Center Sill Bottom Right	Longitudinal	CCSRB
28	Center Sill Bottom Left	Longitudinal	CCSLB

3.3 Displacements

Five string potentiometers were used to measure the longitudinal displacement on the collision or end posts, respectively, as well as the vertical displacement on the AT plate during the test (Figures 10 and 11). The potentiometers were located at each quarter point and midpoint of the post being tested and from the buffer beam to the AT plate. Figure 12 shows the potentiometers in place on the collision post. A sixth potentiometer was placed across the hydraulic ram to correlate cylinder displacement with force. The naming convention is as given for Table 3 and 4, respectively.

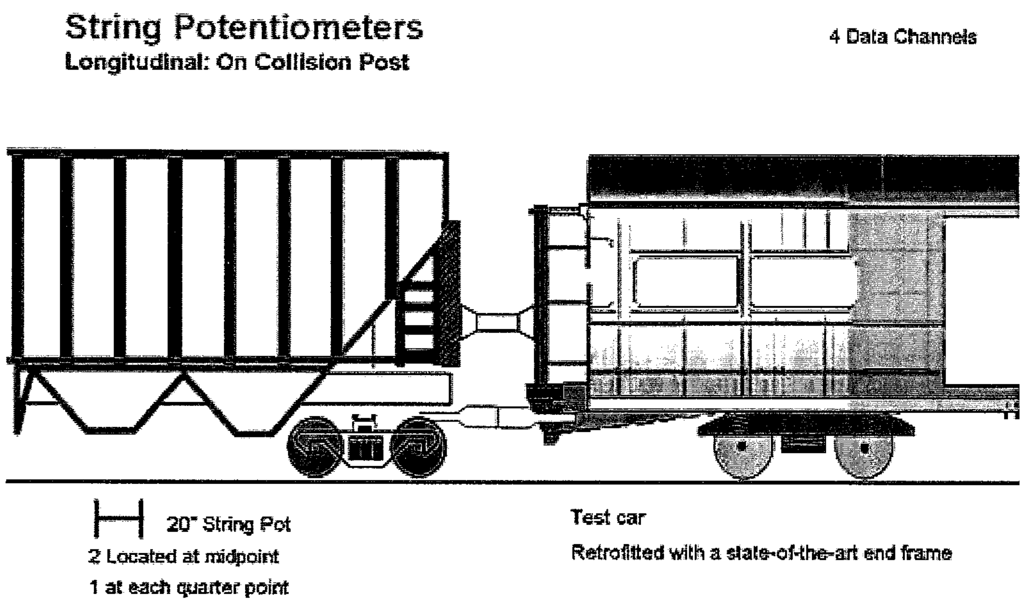


Figure 10. Longitudinal String Potentiometers on the Post Being Tested

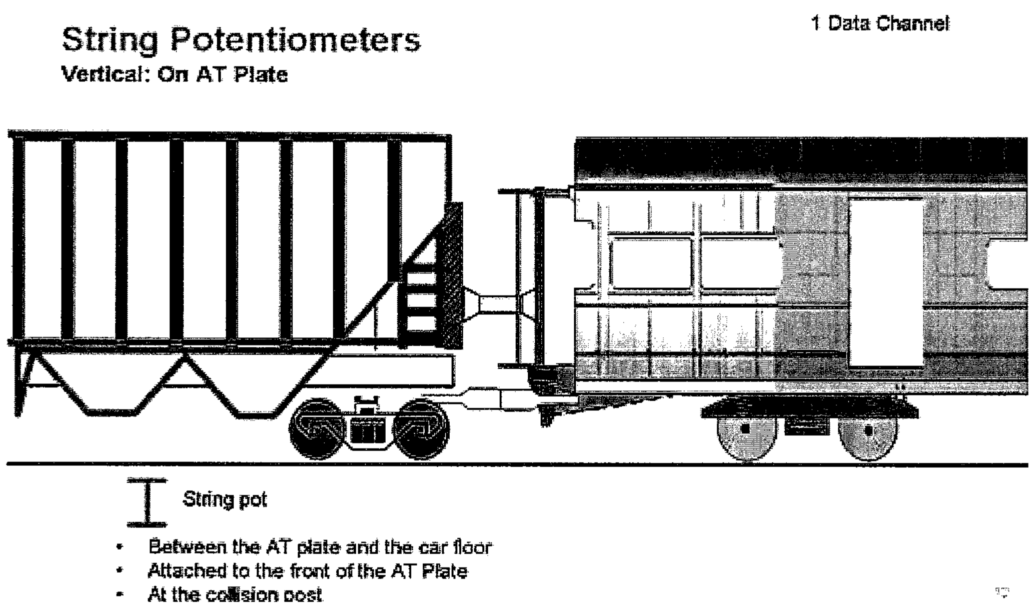


Figure 11. Vertical String Potentiometers on AT Plate

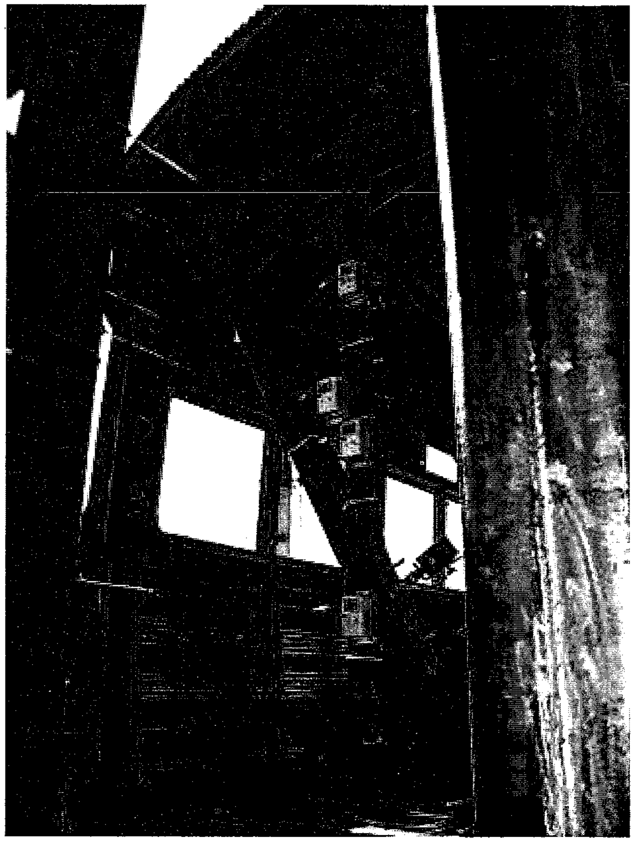


Figure 12. String Potentiometers on Cab Car

Table 3. String Potentiometer Parameters, Collision Post Test

No.	Location	Data Channel Name	Range
1	Bottom Quarter of Collision Post	COLDB	20"
2	Midpoint of Collision Post - Right	COLDMR	20"
3	Midpoint of Collision Post – Left	COLDML	20"
4	Top Quarter of Collision Post	COLDT	20"
5	Between AT plate & car floor	ATDBB	20"
6	Across the hydraulic ram	HDR	20"

Table 4. String Potentiometer Parameters, End Post Test

No.	Location	Data Channel Name	Range
1	Bottom Quarter of Corner Post	CORDB	20"
2	Midpoint of Corner Post – Right	CORDMR	20"
3	Midpoint of Corner Post – Left	CORDML	20"
4	Top Quarter of Corner Post	CORDT	20"
5	Between AT plate & car floor	ATDBB	20"
6	Across the hydraulic ram	HDR	20"

3.4 Data Acquisition

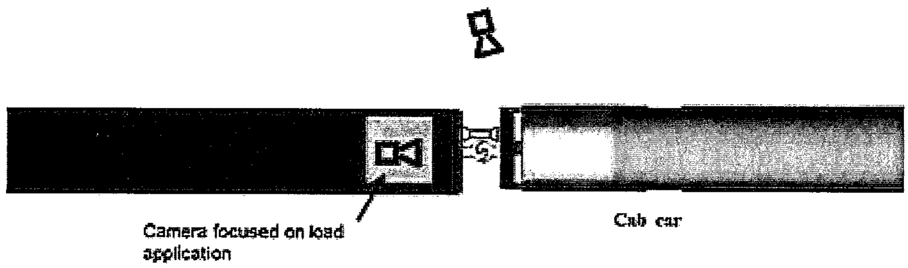
A Megadac data acquisition system model 5414AC was used to provide the analog to digital conversion, recording capability, and signal conditioning needed for the load cells, strains, and displacement transducers. The Megadac data acquisition system is a 16-bit system with user defined sample rates; the signal conditioning provides anti-aliasing filters, differential inputs, and resister calibrations to verify data integrity before and after testing.

Data from each channel was recorded at 100 Hz and synchronized with a time reference of the application of the load on the collision post. A UPS (universal power system) was used in the event of power failure to ensure data integrity while collecting the data.

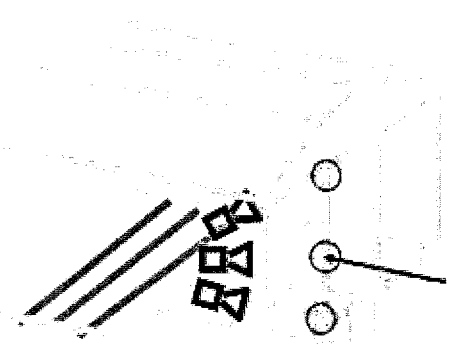
3.5 Video Photography

Five uncompressed digital cameras were used to record modes of deformation during the test. The recording rate was adjusted to provide an anticipated 1 frame of video for 0.01 inch of actuator displacement. The video taken was referenced to a common time reference so that the mode of deformation could be observed after the test.

Targets were placed on the test car and the reaction car to facilitate post-test analysis and to observe the mode of deformation and post connection behavior during the test. The targets were divided into four quadrants with adjacent colors contrasting for good visibility. The distances between the targets, known from pretest measurements, provide distance reference information for the film analysis. The following details in Figure 13 illustrate camera locations and general view for the digital video camera setup on the two tests.

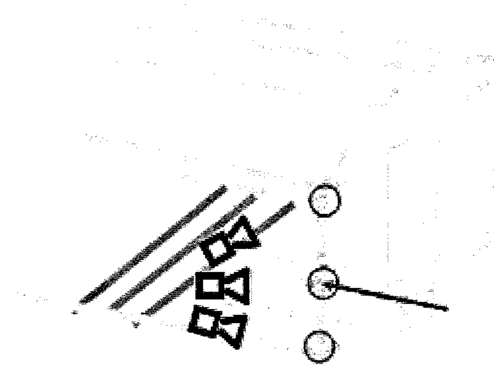


- Three internal cameras
- One camera focused on the roof attachment
- One camera focused on the floor attachment
- One camera focused on the back of the collision post at the loading location



Cameras focused on collision post

- Three internal cameras
- One camera focused on the roof attachment
- One camera focused on the floor attachment
- One camera focused on the back of the corner post at the loading location



Cameras focused on end post

Figure 13. Uncompressed Digital Video Cameras

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4.0 Testing

4.1 General Test Setup

Figures 14 and 15 show the general test setup for each quasi-static test. Figure 6 in Section 3.0 shows the data display used to monitor force being exerted on the test post, along with a visual display of displacement as load was applied. Hydraulic pressure was applied with manual control using a series of bumps with the controls to gradually increase pressure over time. When a loud pop from a fracture was heard, the hydraulic pressure was substantially reduced to remove any remaining potential energy so that the end frame could safely be visually inspected up close.

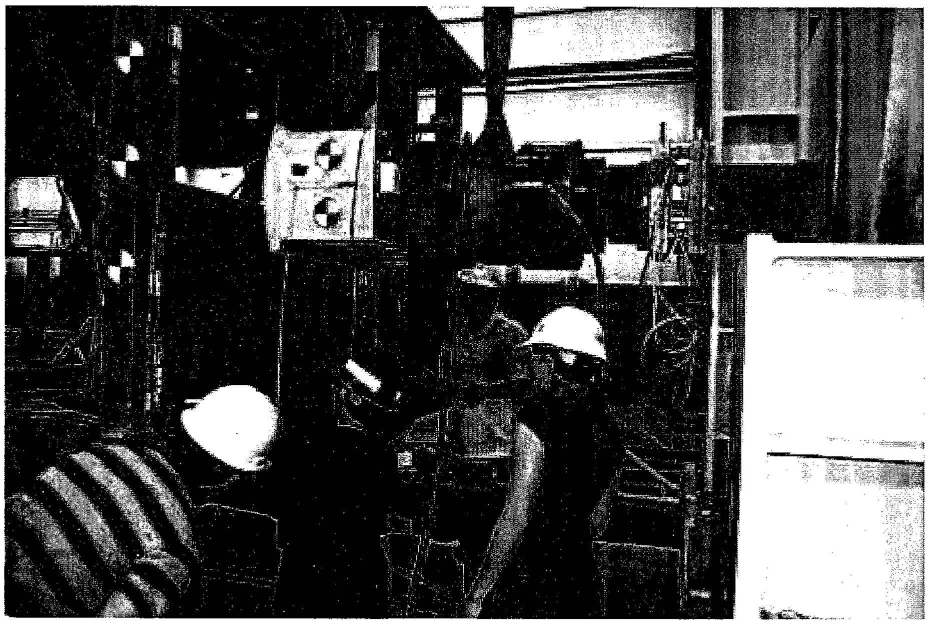

Figure 14. Test Setup for Collision Post Test, Load Positioning

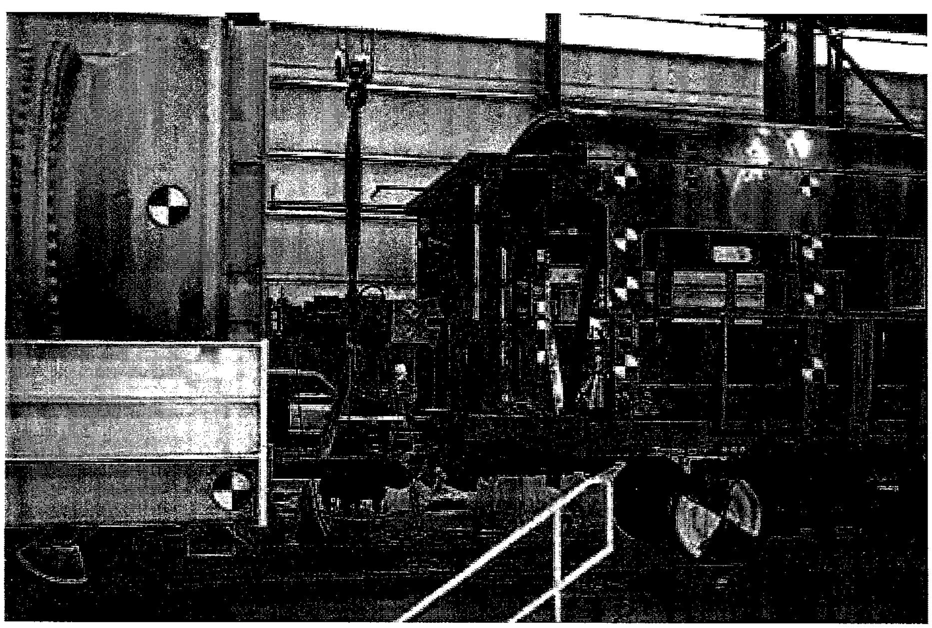

Figure 15. Test Setup for Collision Post Test, Opposite View

4.2 Collision Post Test

As load was applied, the collision post went through a process of yielding, with a series of fracture failures at component joints. As stated in subsection 3.5, video cameras were focused on the collision post to document the deformation taking place as the load was applied and was time dated to correlate with data collection. Camera videos are on the CD, along with a series of still photos taken to document each of the two tests. The following series of figures show the type of deformation encountered and the location of the fracture failures that occurred. Figure 16 shows the location of the collision post after approximately 10 inches of displacement at the load point. The first series of fracture failures took place at the interior side of the collision post and at reinforcing gussets inside the post adjacent to the bulkhead shelf channel. Fracture failures in this area started at around 2 inches of displacement for the post shape and 4 inches of displacement for internal gussets. The outside edge of the impactor shape also made contact with the bulkhead shelf causing the shelf to bend and placing stress on the bulkhead plate where it is welded to the collision post.

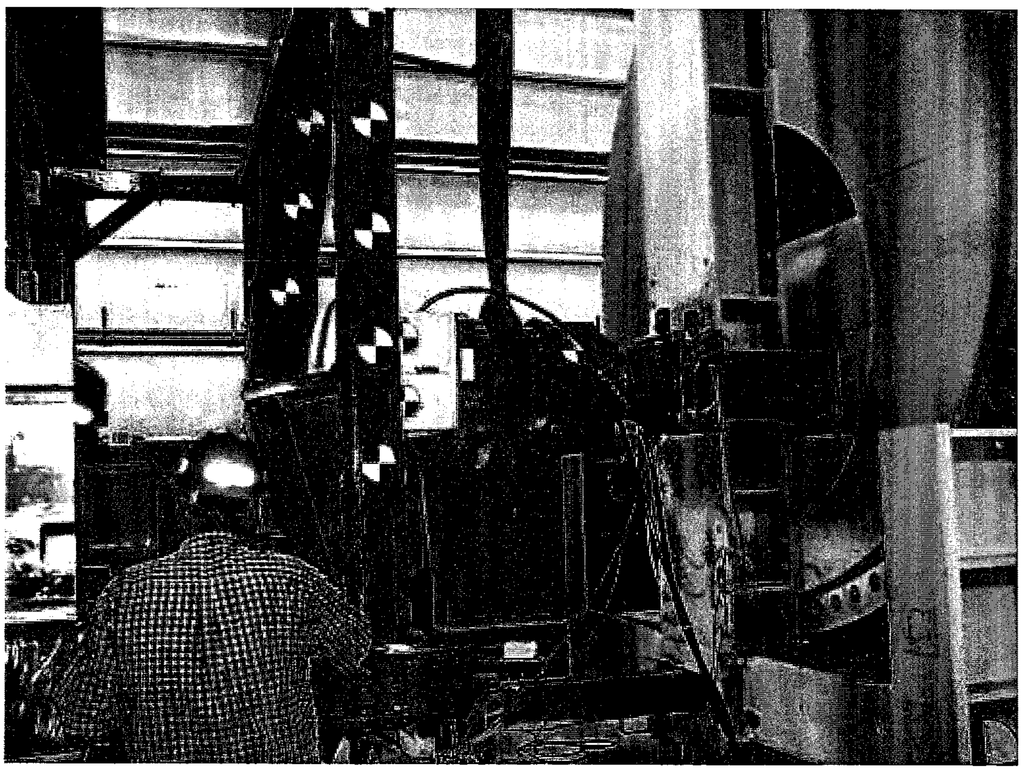

Figure 16. Collision Post Displacement

Figure 17 shows the collision post on the opposite side of the bulkhead at the load point. The tube shape of the post would continue to open along the fracture line as the post continued to deform. The exterior face of the post was in tension and remained in place through the test.

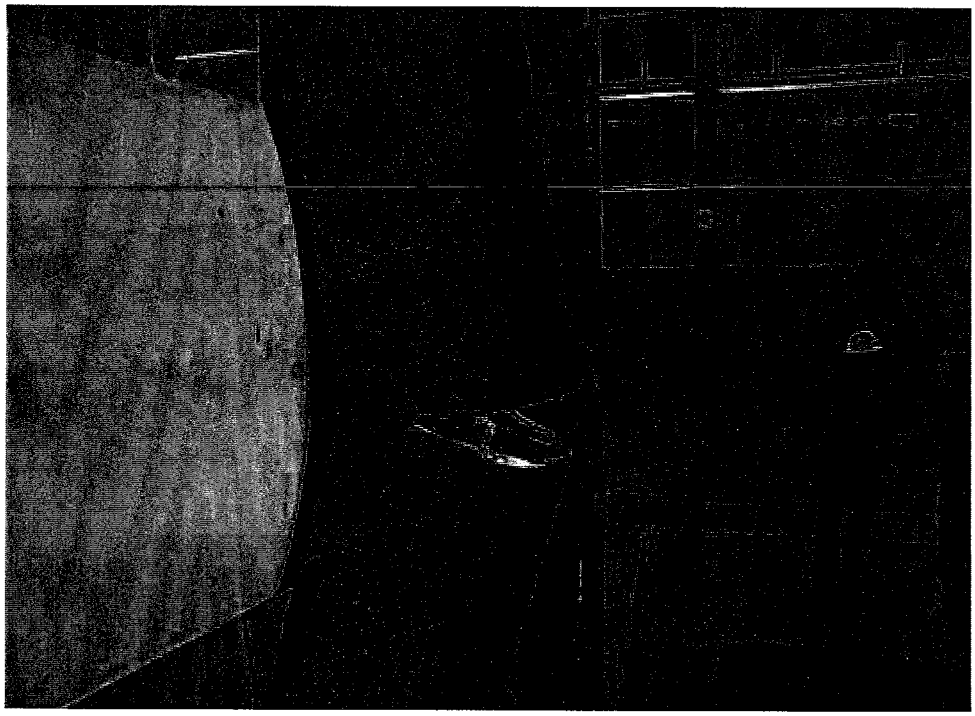

Figure 17. Failure at the Point of Force Application

Figure 18 shows the failure mode for the collision post at the buffer beam connection. The collision post extends through the buffer beam, along with the reinforcing lugs on two sides of the post. Fracture cracks initiated at around 3 inches of displacement at the load point. The inward face of the tube was in tension at this point and ended the test when separation occurred along the top of the fillet weld at the base of the collision post, with approximately 18 inches of displacement at the point of load.

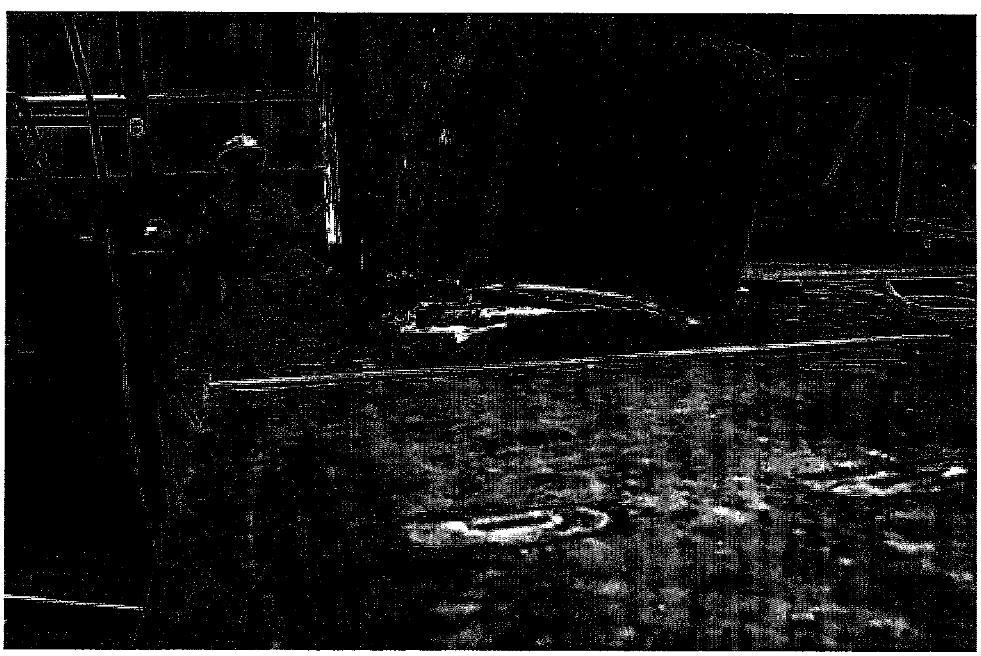

Figure 18. Failure of Collision Post at Buffer Beam

Figures 19 and 20 show the deformation that occurred at the top of the collision post where it attached to the AT beam. As with the buffer beam, the collision post was extended through the AT beam as part of the design. The AT beam shape yielded during the test instead of the collision post at this connection. No fracture failures occurred at this connection.

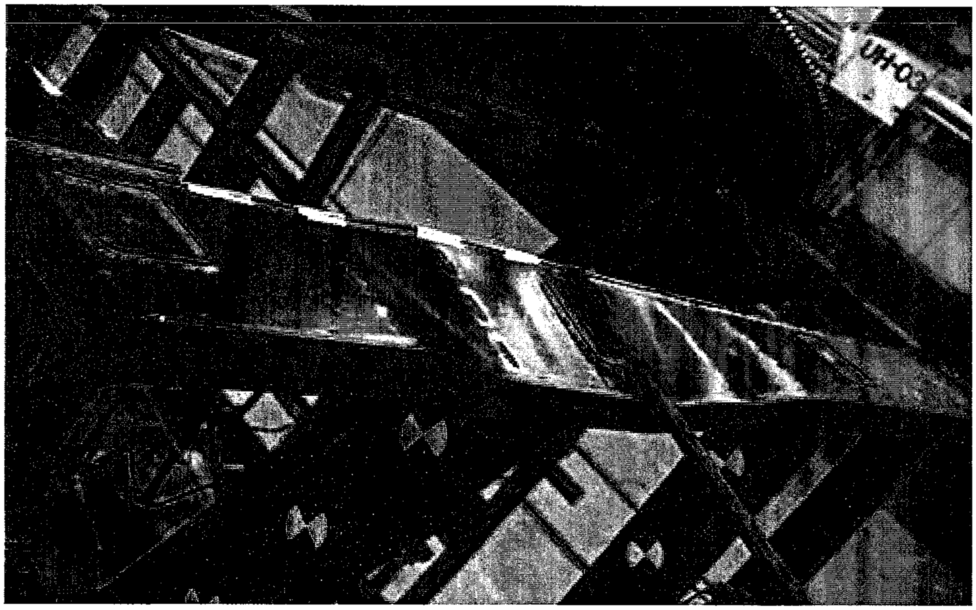

Figure 19. Top View, Failure of Collision Post at the AT Beam

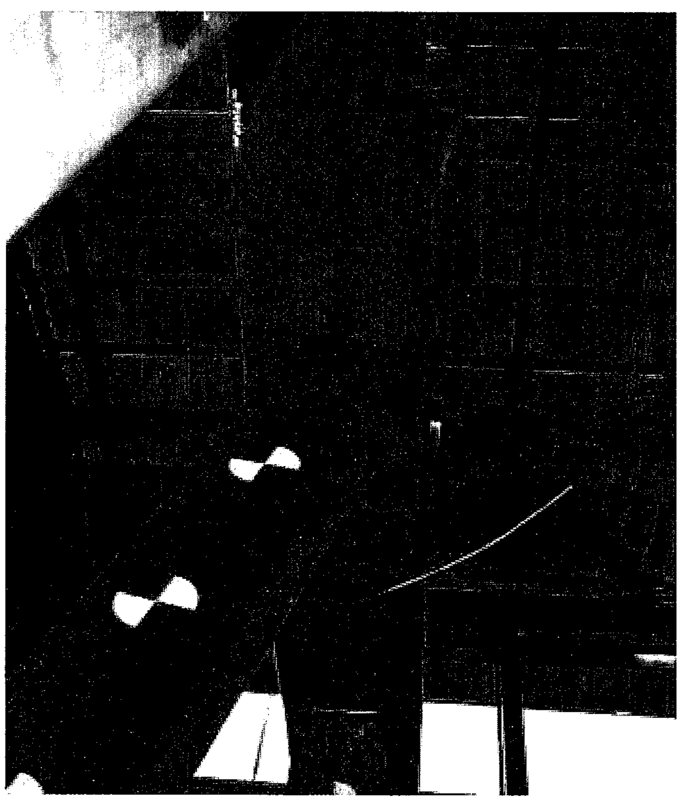

Figure 20. Bottom View, Failure of Collision Post at the AT Beam

4.3 End Post Test

Minor modifications were made to the design of the end frame assembly as a result of the test on the collision post. The modifications were in the area of the bulkhead plate and shelf, where they attach to the collision and end posts. Changes reduced some of the high stress areas noticed during the collision post test. Test setup for the end post test was similar to the collision post test, as Figure 21 shows.

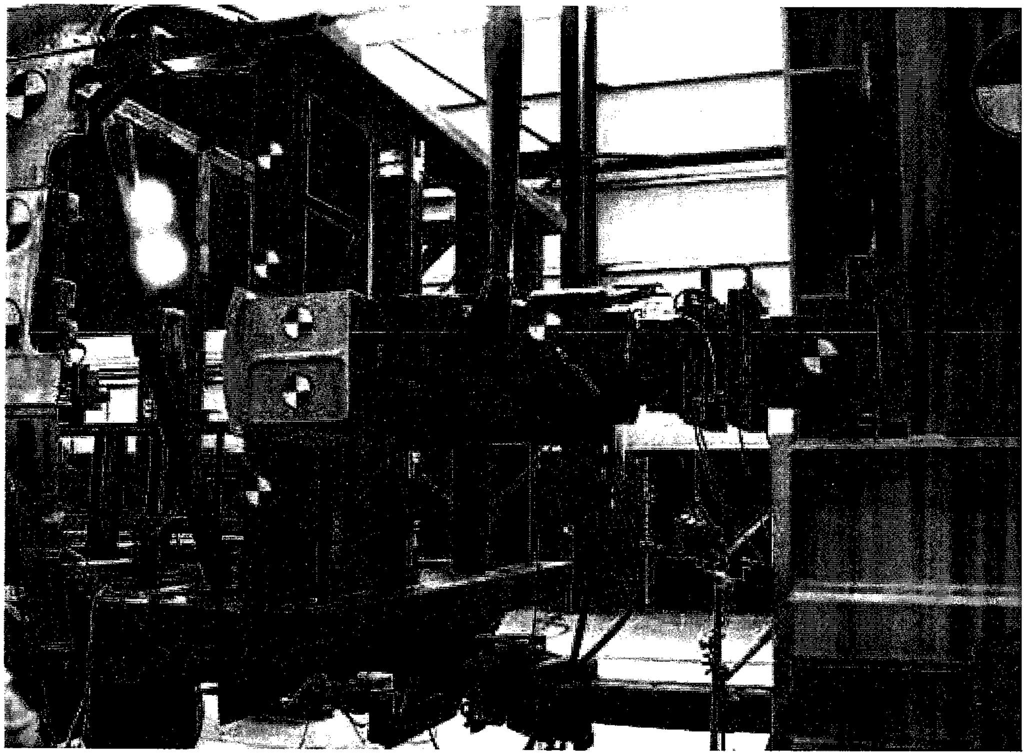

Figure 21. End Post Test Setup

The end post showed more elastic behavior than the collision post during displacement with the load. Figure 22 shows the end frame assembly at around 6 inches of displacement. Torsional loads at the AT beam on the top and the buffer beam at the bottom were starting to buckle the attachment sections at the roof line and side sill, respectively. The end of the AT beam is yielding just past the collision post. The base of the end post is ready to crack at the outside face.

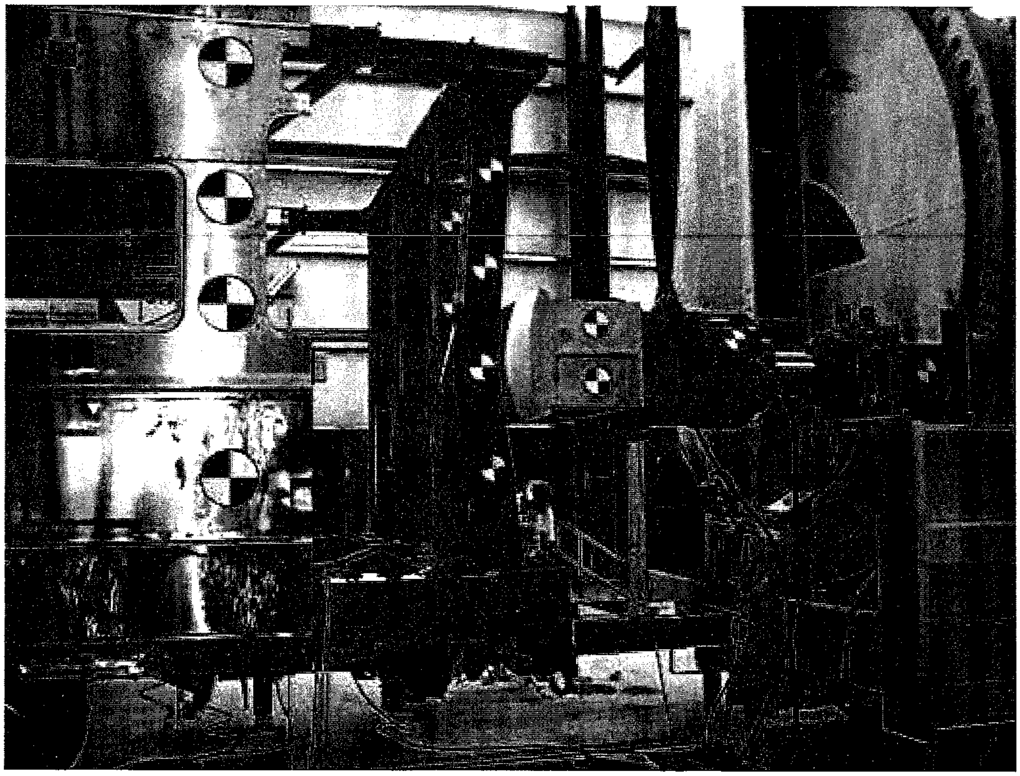

Figure 22. End Post Test During Initial Displacement

Figures 23 and 24 show the deformation taking place at the load application. The shelf/bulkhead plate is being buckled inward as a result of contact with the outside edged of the impactor shape. Figure 25 shows that the inward side of the shelf eventually fails by initiating a tear along the outside flange from the applied load and extends through the web of the C-channel shape. The bulkhead plate remains in place along the weld to the end post weld. Figure 24 shows a change in crossectional area as a result of high stresses on the web sides of the tube construction. The end post continues to yield with deformation without cracking in the load application area. The center position transducer attached to the front face of the impactor and tied back to the inside of the car is a change from the collision post test where this transducer was tied across the hydraulic ram to measure change in displacement. The string from the transducer, along with the 4-inch target, shows that the top portion of the end post is being displaced downward with the horizontal load application.

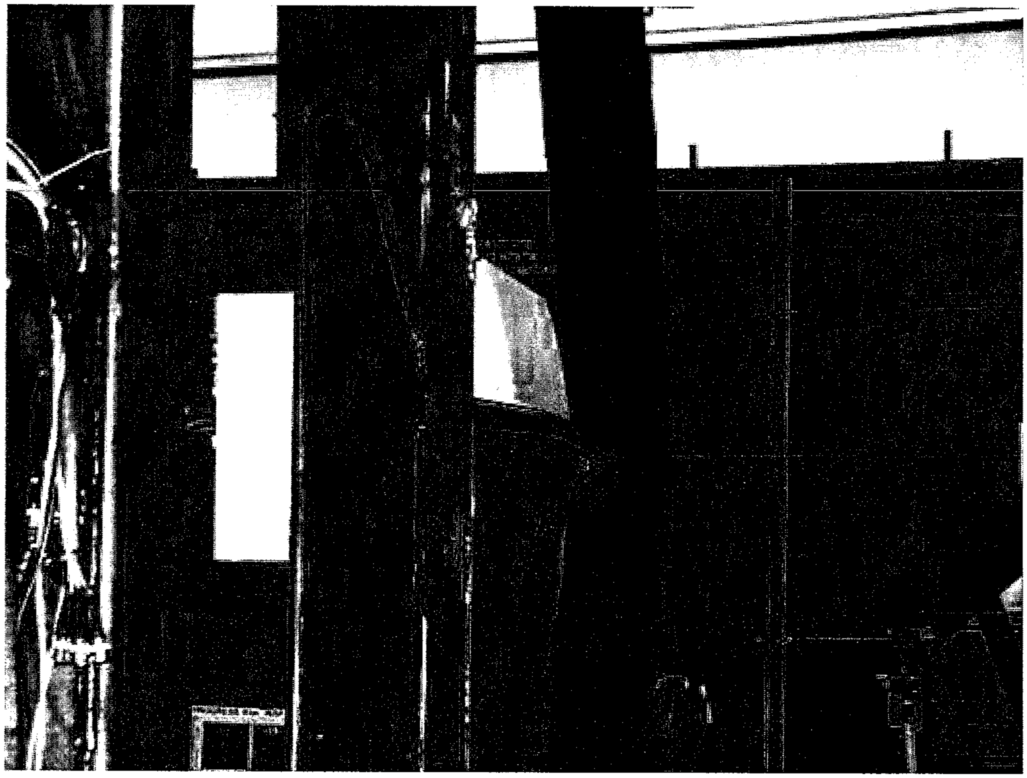

Figure 23. End Post Test Showing Deformation of Bulkhead Plate and Shelf

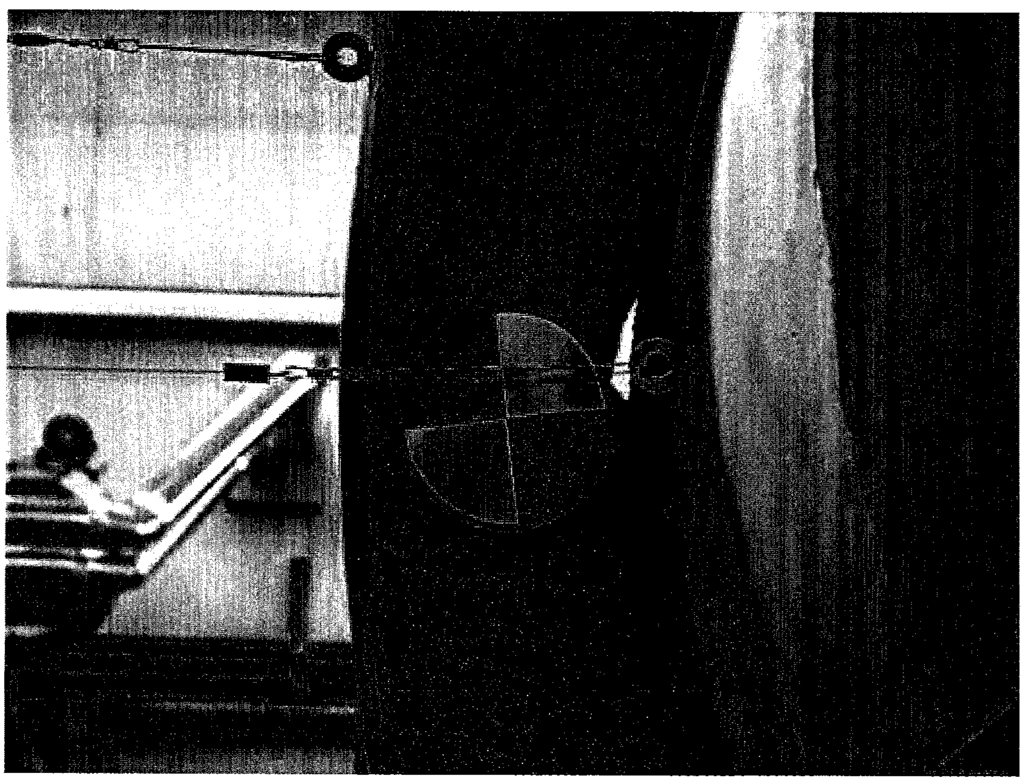

Figure 24. End Post Displacement at Load

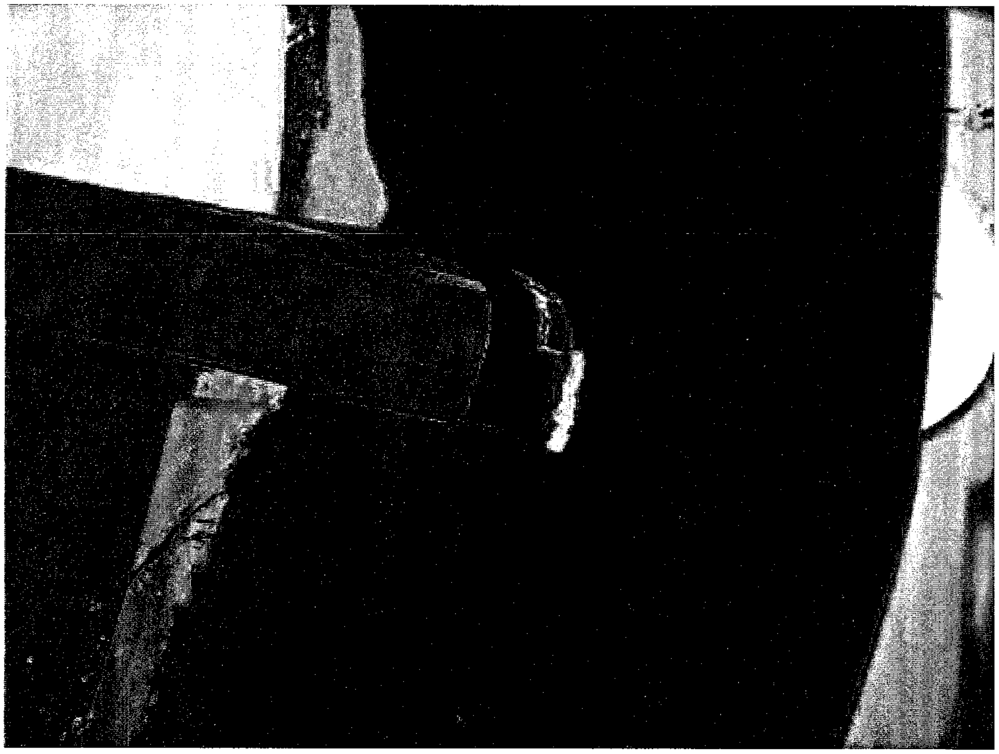

Figure 25. Tear at Shelf Attachment to End Post

Figure 26 shows the failure mode for the end post at the buffer beam connection. As previously stated, the end post extends through the buffer beam, along with the reinforcing lugs on each side of the post. The inward face of the tube was in tension at this point and remained in place when the test was discontinued after two sets of displacements with the loading fixture.

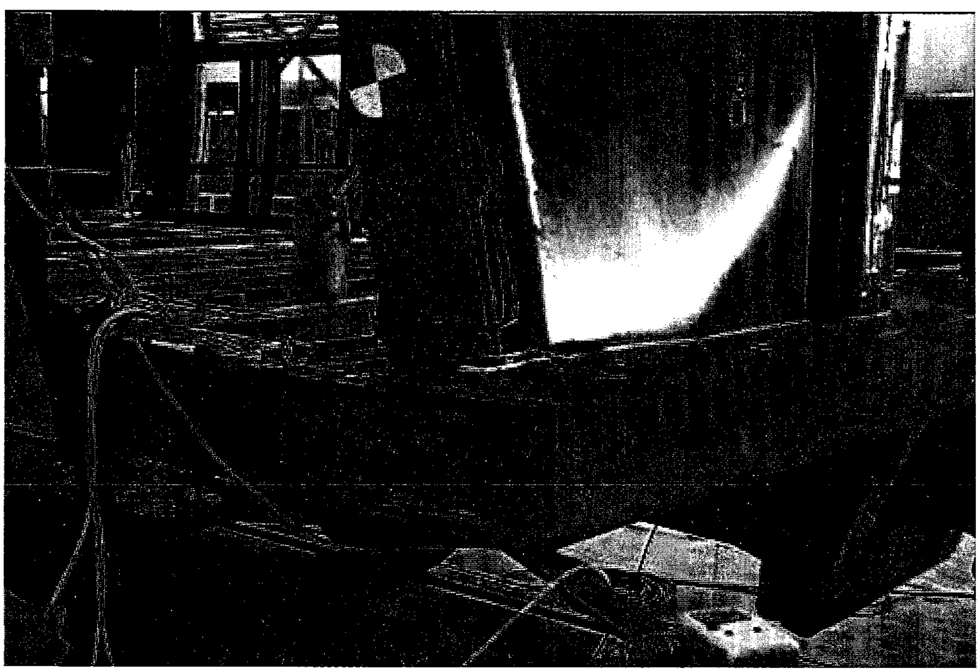

Figure 26. Failure of End Post at Buffer Beam

Figures 27 and 28 show the deformation that occurred at the top of the end post where attached to the AT beam. As with the buffer beam, the end post was extended through the AT beam as part of the design. The AT beam shape yielded during the test instead of the end post at this connection. The adapter shape used to tie to the roof line support also yielded, along with some minor damage to the roof line structure itself. No fracture failures occurred at this connection, although some rivets did shear in the roof line structure.

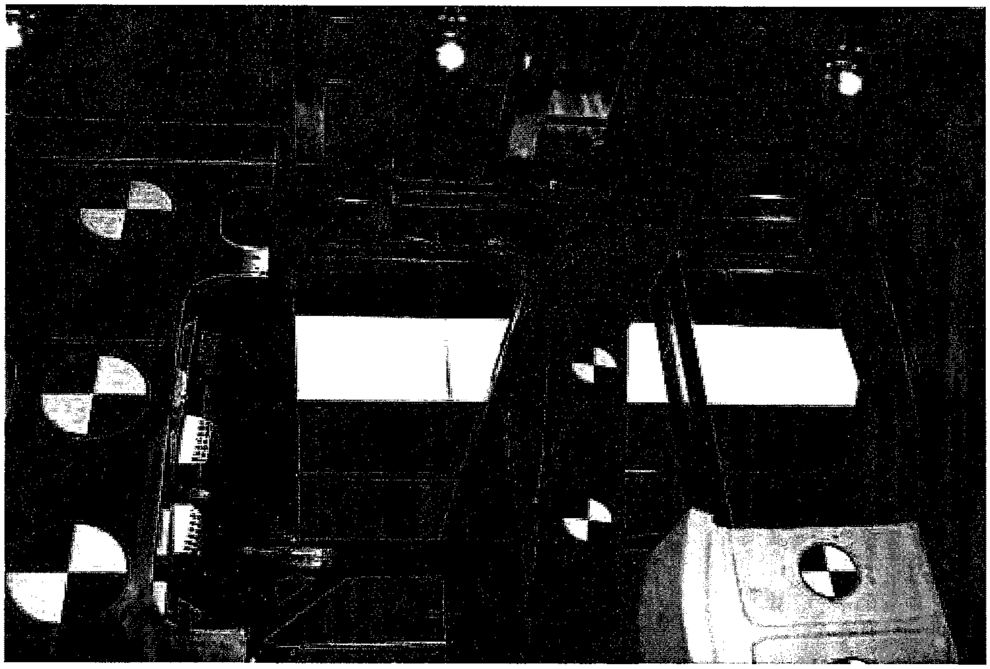

Figure 27. Failure of End Post at the AT Beam, Bottom View

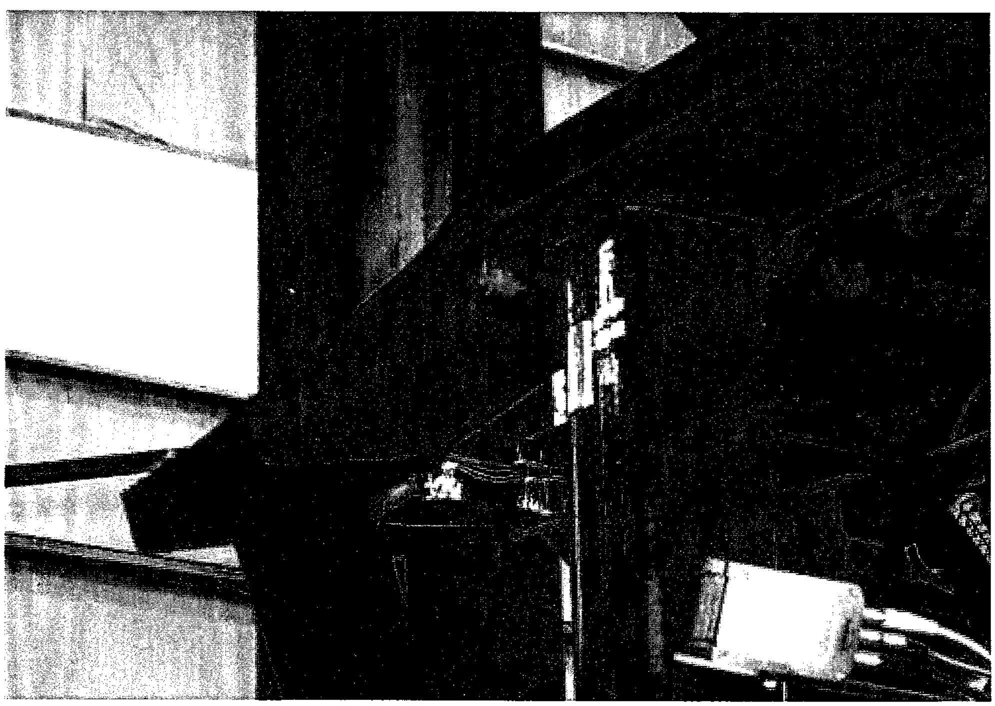

Figure 28. Failure of End Post at the AT Beam, Side View

Figures 29 and 30 show the end post test at the maximum displacement placed on the end frame. Although the attachment of the end post at the buffer beam did not fail completely, the load frame support at the roof line was failing. A slight torsional twist was present on the end of the buffer beam, along with signs of buckling at the side sill adapter section. Maximum displacement was around 23 inches.

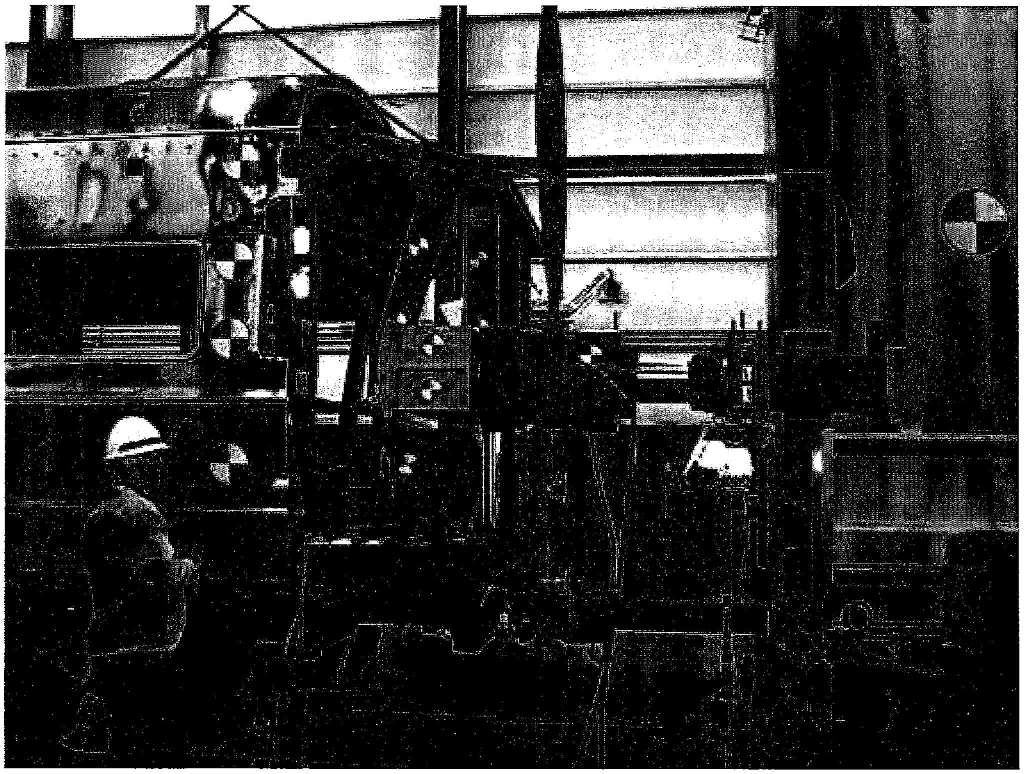

Figure 29. Final Position of End Post Test Setup

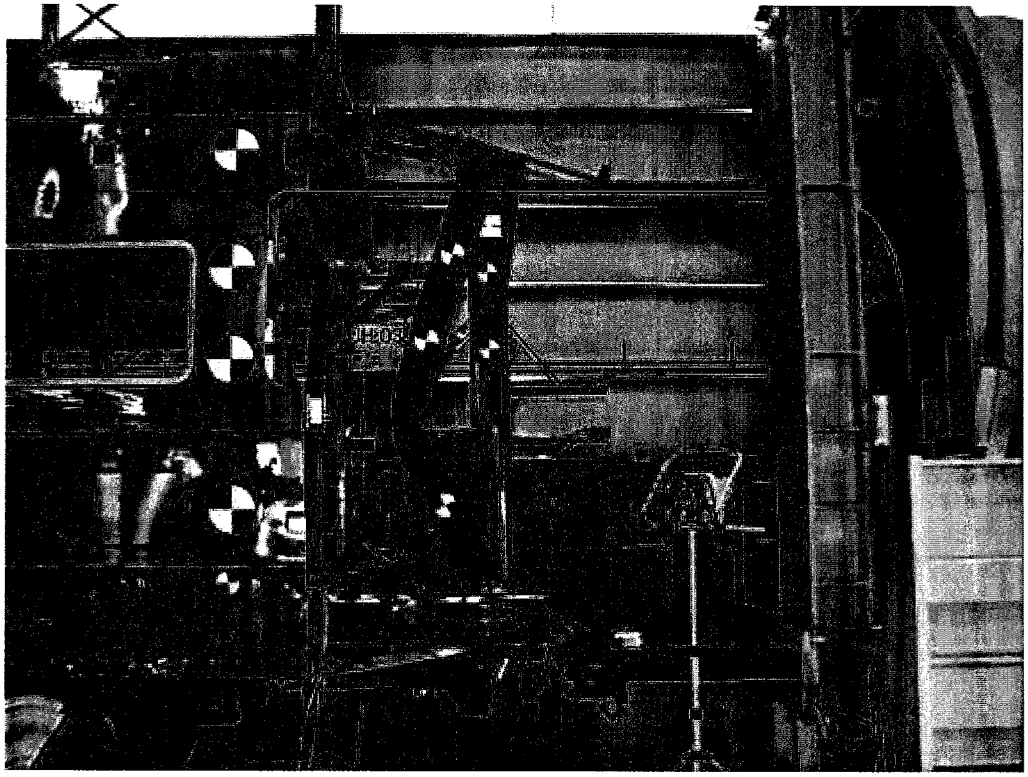

Figure 30. Final Position of End Frame Assembly with Loading Fixture Removed

4.4 Post Test Results

The tests were conducted as planned. The loading fixture was stable and capable of providing sufficient force to crush the end frame assembly safely, with additional capacity for higher loadings. The 12-inch stroke on the hydraulic cylinder is sufficient to reach the 10-inch deflection required to demonstrate the capability of meeting the standard for energy adsorption, but requires additional setup to extend the deflection to 16 inches as originally proposed in the TIP or to failure as requested during the test. Using the TTC reaction car coupled to the test car was also very stable and performed without incident.

Testing during the end post test did show some instability to the roof line reinforcing and side sill reinforcing where attached to the end frame assembly. Some repairs will be required prior to performing additional testing of a similar nature. Design modifications may also be warranted to improve on performance in this area.

All data was collected as planned and was made available to the FRA immediately following the test. Computer disks and a portable hard drive accompany this report and contain the following data files:

> **CD Data Disk – Power Point Progress Reports Test Car Mods./End Frame Fabrication.** Contains a series of progress reports using MS Word, 2003, software to show work progress, document problems discovered during fabrication work, and sequence of assembly to fabricate the end frame assemblies.

CD Data Disk – Photos, Collision Post. Contains a series of still photos in jpg format taken of the test setup and during the test conduct.

CD Data Disk – Video 5 Cameras, Collision Post Test.

CD Data Disk – Photos, Corner Post. Contains a series of still photos in jpg format taken of the test setup and during the test conduct.

Portable Hard Drive – Contains documents developed by the Instrumentation Group, which are (1) still photos of the collision post test (quasi-static test No. 1) and the end post test (quasi static test No. 2). Photos document the instrumentation placement and setup, (2) videos from the five cameras used for the end post test, (3) data files for the instrumentation channels that data was collected with respect to time. In addition, hard drive resource files are listed on the hard drive directory for reference and to operate the drive.