Moving Barrier into Left Side of a Modified Hydrogen Fuel Cell Electric Vehicle

TRC Inc. Test Number: 120414

Prepared by:
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Final Report
April May 2012

Prepared for:
Battelle
505 King Avenue
Columbus, Ohio 43201

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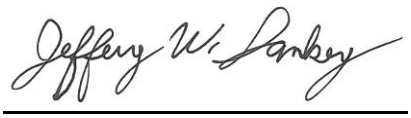
Test Performed By: John Shultz, Test Supervisor

Report Approved May 7, 2012 by:



Jeffery W. Sankey,
Manager, Project Operations

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Section 1.0

Purpose and Test Procedure

Purpose

This 53.9 km/h (target speed) moving deformable barrier into left side impact test was conducted for Battelle by Transportation Research Center Inc. (TRC Inc). The purpose of this test was to research the crashworthiness of the subject vehicle, a modified hydrogen fuel cell electric vehicle, in the 53.9 km/h (target speed) FMVSS 214-like moving deformable barrier into left side impact mode.. The vehicle was modified by Battelle to isolate the front fuel container and to provide redundant vent lines for releasing pressure after the test.

Test Procedure

This test was conducted per Battelle's instructions. The front fuel container was pressurized with helium and nitrogen to a nominal pressure of 5000 psi and maintained at pressure for one hour prior to impact.

The test vehicle was instrumented with fourteen (14) accelerometers to measure longitudinal axis accelerations; eleven (11) accelerometers to measure lateral axis accelerations; eleven (11) accelerometers to measure vertical axis accelerations; and five (5) displacement data channels.

The moving deformable barrier's specified impact velocity range was 53.1 to 54.7 km/h. The moving deformable barrier was not instrumented. The moving barrier impacted the left side of the vehicle. The moving barrier's intended impact point was 940 mm forward of the wheelbase midpoint.

The test vehicle contained two (2) Part 572B anthropomorphic test devices (dummies). The dummies were positioned in the driver (Pos. #1) and left rear (Pos. #4) designated seating. The dummies were not instrumented.

The forty-one (41) data channels were digitally sampled and recorded at 10,000 samples per second and processed per SAE J211 Mar95.

The crash event was recorded by six (6) high-speed motion picture cameras operating at 1000 frames per second and one (1) real time motion picture camera.

Following the impact, additional helium sensor data was acquired by the National Renewable Energy Laboratory and electrical isolation measurements were acquired by Battelle.

The vehicle data are summarized in Section 2.0. The camera measurements are presented in Section 3.0. Appendix A contains the still photographic prints. Appendix B contains the vehicle data plots. Appendix C contains barrier certification information. Appendix D contains the FARO measurement Data.

Section 2.0

Moving Barrier into Left Side Impact Test Summary

Test Results Summary

This 53.9 km/h (target speed) moving deformable barrier into left side test was conducted by TRC Inc. on April 14, 2012.

The test vehicle was a modified Hydrogen Fuel Cell Electric vehicle. The vehicle's test weight was 2053.8 kg. The actual impact point was 2 mm right of the intended impact point.

The moving deformable barrier's test weight was 1362.0 kg. The moving barrier's impact velocity was 53.1 km/h.

There was no evidence of gas escaping from the pressurized fuel system during the impact or during the one-hour period following the impact. Following the one-hour hold period, the pressure was released from the fuel system by using a remote-controlled robot to cut a lower-pressure nitrogen line, causing a pilot-operated valve to open a vent line to the high-pressure in the modified fuel system.

Data Acquisition Explanations

The Battery Passenger X-axis acceleration data channel lost data between approximately 90 and 120 milliseconds.

Table 1 Crash Test Summary

Test type:	Left Side Impact	
Test date:	04/14/12	
Test time:	13:46	
Ambient temperature:	13° C	
Vehicle:	Modified Hydrogen Fuel Cell Electric Vehicle	
Vehicle test weight:	2053.8 kg	
Moving barrier test weight:	1362.0 kg	
Impact angle:[1]	270°	
Impact velocity:[2]	Primary = 53.1 km/h Secondary = 53.2 km/h	
Impact point accuracy:	Primary = 10 mm up and 2 mm right of impact point Secondary = 11 mm up and 3 mm right of impact point	
Dummies:	Driver	Rear Passenger
Type:	Ballast	Ballast
Location:	Driver	Left rear
Restraint:	Seat belt	Seat belt
Number of data channels:	0	0
Number of cameras:		
High-speed:	6	

[1] With respect to tow track centerline.
[2] Speed trap measurement (± .08 km/h accuracy)

Table 2 Test Vehicle Information

Vehicle/body style:	Modified Hydrogen Fuel Cell Electric Vehicle
Color:	Blue
Engine data:	
Transmission data:	_3_ Speed, __ Manual, _X_ Automatic __ FWD, _X_ RWD, __ 4WD
Date vehicle received:	4/4/12
Odometer reading:	Unknown
Dealer's name and address:	Not applicable

Accessories:

Power steering	Yes	Automatic transmission	Yes
Power brakes	Yes	Automatic speed control	Yes
Power seats	No	Tilting steering wheel	Yes
Power windows	Yes	Telescoping steering wheel	No
Tinted glass	Yes	Air conditioning	Yes
Radio	Yes	Anti-skid brake	Yes
Clock	Yes	Rear window defroster	Yes
Other	None		

Certification data from vehicle's label:[1]

Vehicle manufactured by:		
Date of manufacture:		
VIN:		
GVWR:		kg
GAWR:	Front:	kg
	Rear:	kg
Tires on vehicle (mfr., line, size):		Kumho, ECSTA, P235/60R16
Tire pressure with maximum capacity vehicle load:	Front:	300 kPa
	Rear:	300 kPa
Spare tire (mfr., line, size):		None
Type of seats:	Front:	Bucket
	Rear:	Split bench
Type of front seat backs:		Manual adjustable

[1] The vehicle did not contain a label stating certification data.

Table 2 Test Vehicle Information, Continued

Location of "Recommended Tire Pressure" label:[1]

Data from vehicle's "Recommended Tire Pressure" label:[1]

"As tested" tire pressure:

	LF	221 kPa;	RF	221 kPa;	LR	221 kPa;	RR	221 kPa

Test vehicle attitudes:

Delivered attitude:	LF	750 mm;	RF	740 mm;	LR	787 mm;	RR	790 mm
Pre-test attitude:	LF	721 mm;	RF	727 mm;	LR	768 mm;	RR	763 mm
Post-test attitude:	LF	657 mm;	RF	728 mm;	LR	716 mm;	RR	812 mm

Weight of test vehicle as received (with maximum fluids):

Right front	569.8 kg	Right rear	332.8 kg
Left front	574.2 kg	Left rear	340.6 kg
Total front weight	1144.0 kg	(62.9% of total vehicle weight)	
Total rear weight	673.4 kg	(37.1% of total vehicle weight)	
Total test weight	1817.4 kg		

Target test weight: [2]

Total test weight	2031.0 kg

Weight of test vehicle with required dummies and cargo weight:

Right front	633.4 kg	Right rear	365.4 kg
Left front	668.6 kg	Left rear	386.4 kg
Total front weight	1302.0 kg	(63.4% of total vehicle weight)	
Total rear weight	751.8 kg	(36.6% of total vehicle weight)	
Total test weight	2053.8 kg		

Weight of ballast secured in vehicle: None

Components removed to meet target test weight: Right rear head restraint, tailgate weather stripping, and dummies arms.

CG rearward of front wheel centerline: 963 mm

[1] The vehicle did not contain a label stating tire and capacity data.

[2] Provided by Battelle.

Table 3 Moving Barrier Data

MDB face manufacturer and serial number: Cellbond, 30034

Weight of moving barrier:

Right front	324.2 kg	Right rear	359.8 kg
Left front	449.0 kg	Left rear	229.0 kg
Total front weight	773.2 kg	(56.8 % of total vehicle weight)	
Total rear weight	588.8 kg	(43.2 % of total vehicle weight)	
Total test weight	1362.0 kg		

Table 4 Test Conditions

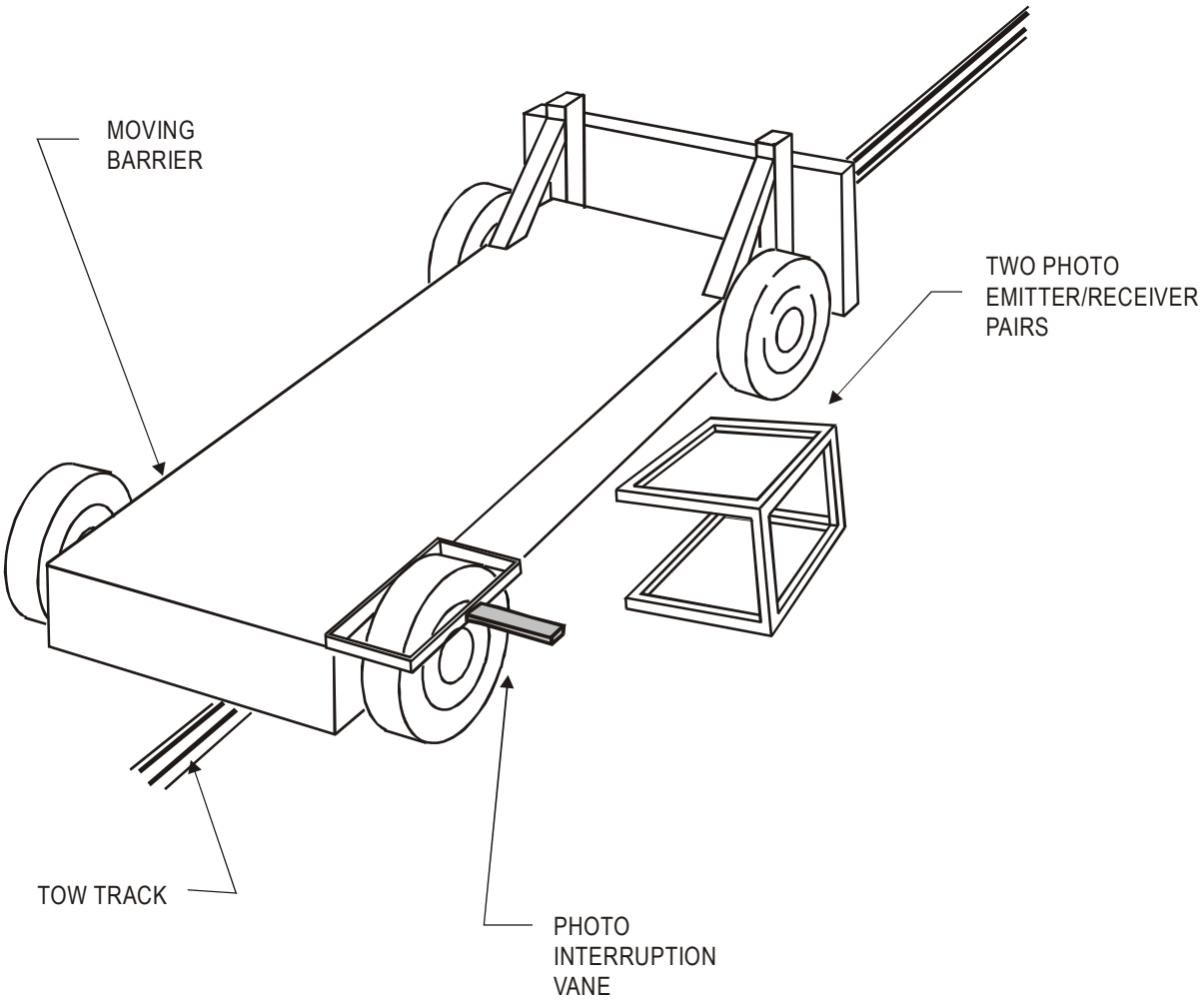
Test number:	120414
Date of test:	April 14, 2012
Time of test:	13:46
Ambient temperature at impact area:	13° C

Vehicle Data

	Actual	Intended
Subject vehicle test weight (kg):	2053.8	2031.0
Moving barrier test weight (kg):	1362.0	1365.3 – 1356.7
Moving barrier velocity (km/h)[1]:	53.1	53.1 - 54.7

[1] As measured over final 660 mm of travel.

Figure 1 Impact Velocity Measurement System



The vane clears the final emitter/receiver pair 50 millimeters before impact.

The emitter/receiver pairs have a spacing of 610-millimeters.

Table 5 Vehicle Accelerometer Locations and Data Summary

Accel. No.	Location		Positive Direction Max. (g)	Positive Direction Time (ms)	Negative Direction Max. (g)	Negative Direction Time (ms)
1	Vehicle CG	X	4.6	56.9	-6.2	21.0
		Y	15.3	9.1	-2.1	302.3
		Z	8.5	30.9	-8.6	25.7
		R	15.6	9.3		
2	Vehicle Body	X	5.3	11.8	-5.7	80.3
		Y	15.4	39.9	-2.4	111.9
		Z	3.6	54.0	-4.9	10.4
		R	15.9	39.5		
3	Front Container, Passenger	X	7.4	46.2	-6.6	7.1
		Y	22.0	41.9	-4.3	58.6
		Z	12.1	46.4	-18.1	58.7
		R	23.5	43.3		
4	Front Container, Driver	X	8.4	25.8	-8.8	50.6
		Y	21.8	41.8	-3.2	58.4
		Z	11.5	5.9	-16.8	14.5
		R	23.4	41.7		
5	Middle Container, Passenger	X	11.3	46.4	-9.9	7.7
		Y	25.7	43.0	-5.9	84.0
		Z	9.3	44.1	-11.0	56.5
		R	28.4	43.6		
6	Middle Container, Driver	X	8.9	24.8	-14.4	48.3
		Y	26.0	42.9	-5.6	84.6
		Z	11.3	7.0	-16.5	14.2
		R	28.1	14.4		
7	Rear Container, Passenger	X	9.9	53.5	-5.2	11.6
		Y	31.4	28.4	-7.9	95.3
		Z	12.9	98.6	-20.6	20.1
		R	31.4	28.4		
8	Rear Container, Driver	X	20.3	18.9	-20.2	11.7
		Y	32.0	28.6	-7.9	95.7
		Z	9.6	56.5	-13.0	18.7
		R	35.8	29.1		

Table 5 Vehicle Accelerometer Locations and Data Summary, Continued

Accel. No.	Location		Positive Direction Max. (g)	Positive Direction Time (ms)	Negative Direction Max. (g)	Negative Direction Time (ms)
9	Engine	X	4.5	11.6	-2.8	54.2
		Y	2.9	80.9	-8.0	53.4
		Z	4.7	69.1	-4.4	22.1
		R	9.0	20.9		
10	Battery, Driver	X	9.2	50.4	-17.0	56.4
		Y	26.3	35.8	-2.9	115.1
		Z	17.4	28.6	-20.5	48.7
		R	27.3	35.6		
11	Battery, Passenger[1]	X	12.1	17.5	---	---
		Y	2.9	114.9	-23.6	36.5
		Z	19.9	43.7	-9.2	54.2
		R	---	---		
12	Front Container, Pitch	X	8.5	53.0	-8.6	12.9
13	Middle Container, Pitch	X	8.3	59.8	-5.4	12.6
14	Rear Container, Pitch	X	6.6	13.9	-9.5	59.0

[1] See Data Acquisition Explanations

Section 3.0

Camera Measurements

Figure 2 Camera Locations

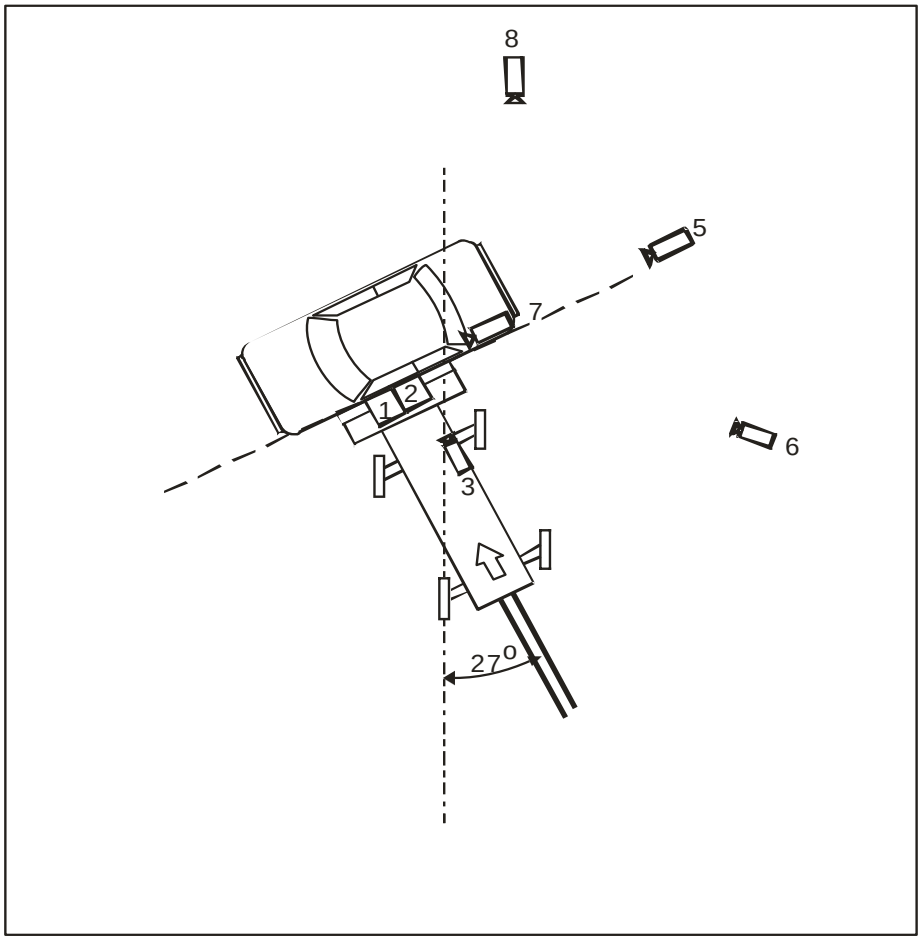


Table 6 Camera Information

Camera Number	Location	Type	Lens (mm)	Speed (fps)	Purpose of Camera Data
1	Overhead	Redlake-HGLE	8.5	1000	Vehicle dynamics
2	Overhead tight	Redlake-HGLE	25	1000	Vehicle dynamics
3	Onboard MDB – right	Redlake-HGLE	16	1000	Vehicle dynamics
4[1]	Onboard MDB – center	Redlake-HGLE	---	---	Vehicle dynamics
5	Rear	Redlake-HGLE	12.5	1000	Vehicle dynamics
6	Left oblique	Redlake-HGLE	16	1000	Vehicle dynamics
7	Onboard underbody	Redlake-HGLE	12.5	500	Vehicle dynamics
8[1]	Downstream real time	Cannon	Zoom	---	Vehicle dynamics

[1] Camera did not run.

Appendix A

Photographs

Figure A-1 Pre-Test Front View

Figure A-2 Post-Test Front View

Figure A-3 Pre-Test Left Front View

Figure A-4 Post-Test Left Front View

Figure A-5 Pre-Test Left Side View

Figure A-6 Post-Test Left Side View

Figure A-7 Pre-Test Left Rear View

Figure A-8 Post-Test Left Rear View

Figure A-9 Pre-Test Rear View

Figure A-10 Post-Test Rear View

Figure A-11 Pre-Test Right Rear View

Figure A-12 Post-Test Right Rear View

Figure A-13 Pre-Test Right Side View

Figure A-14 Post Test Right Side View

Figure A-15 Pre-Test Right Front View

Figure A-16 Post-Test Right Front View

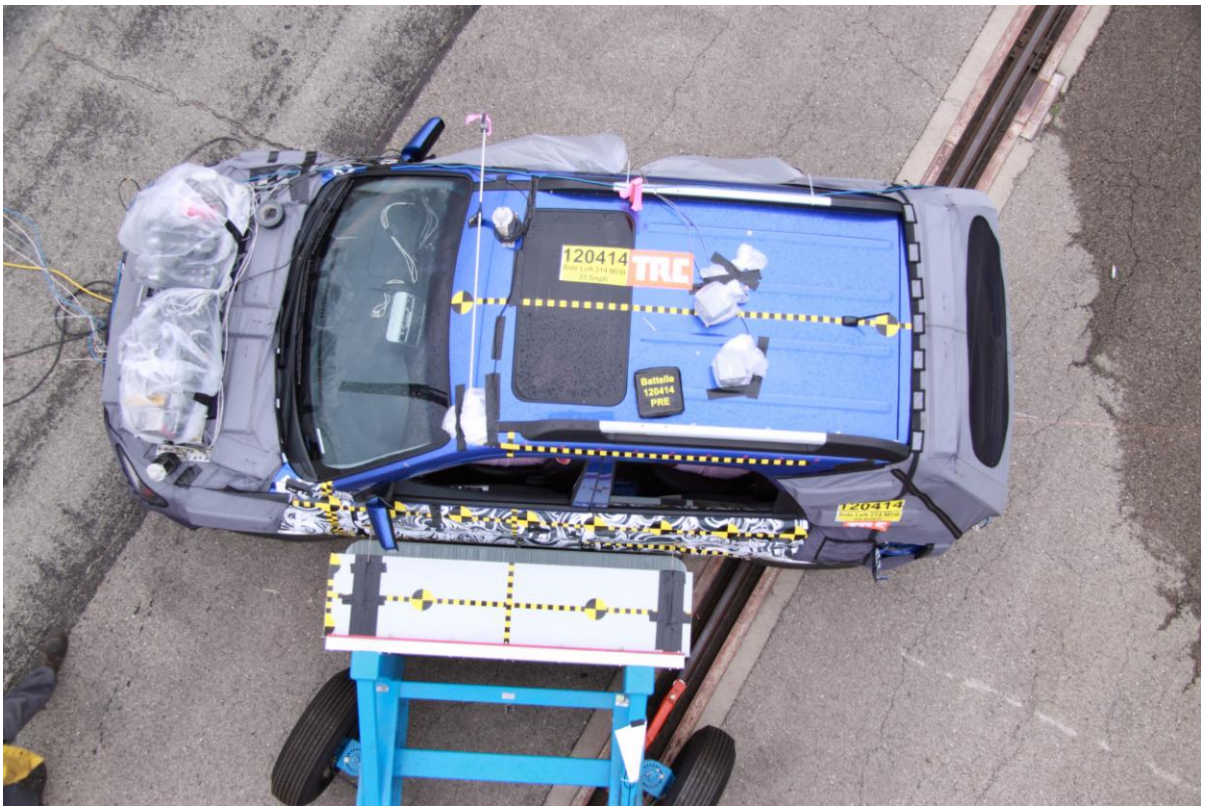


Figure A-17 Pre-Test Overhead View

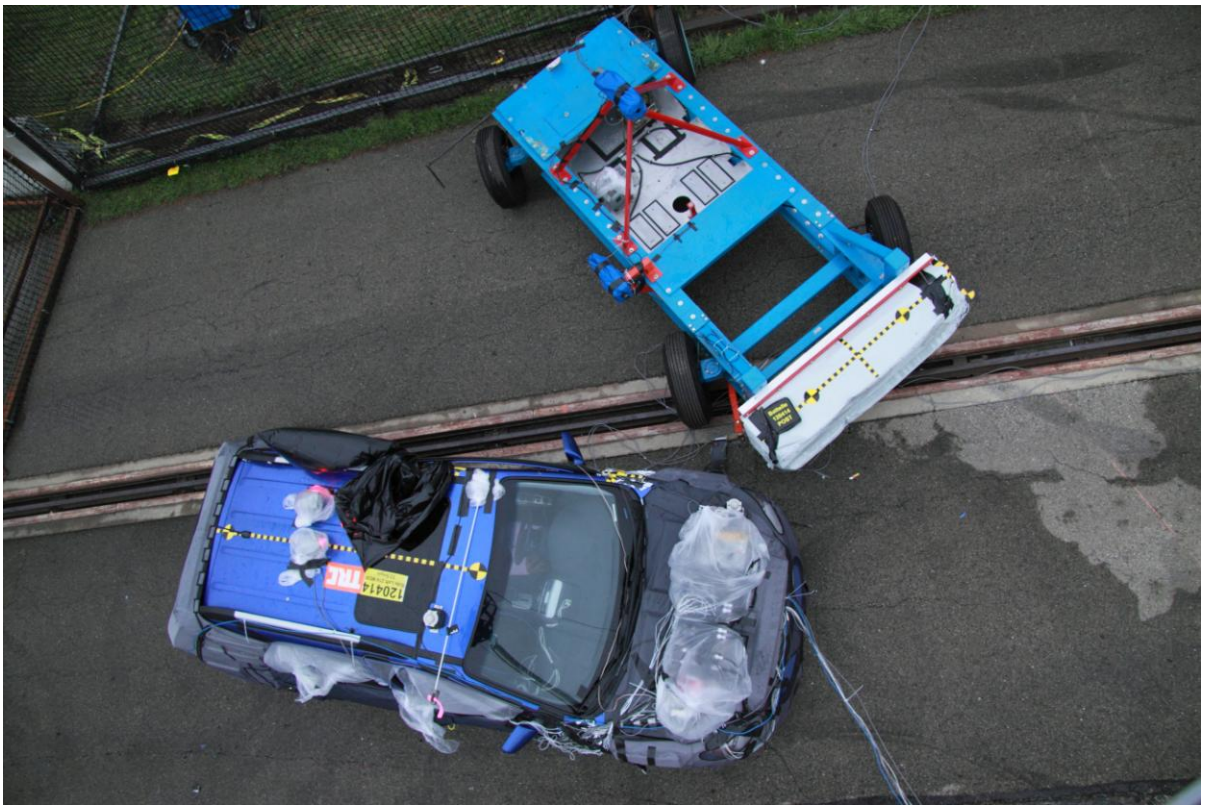


Figure A-18 Post-Test Overhead View

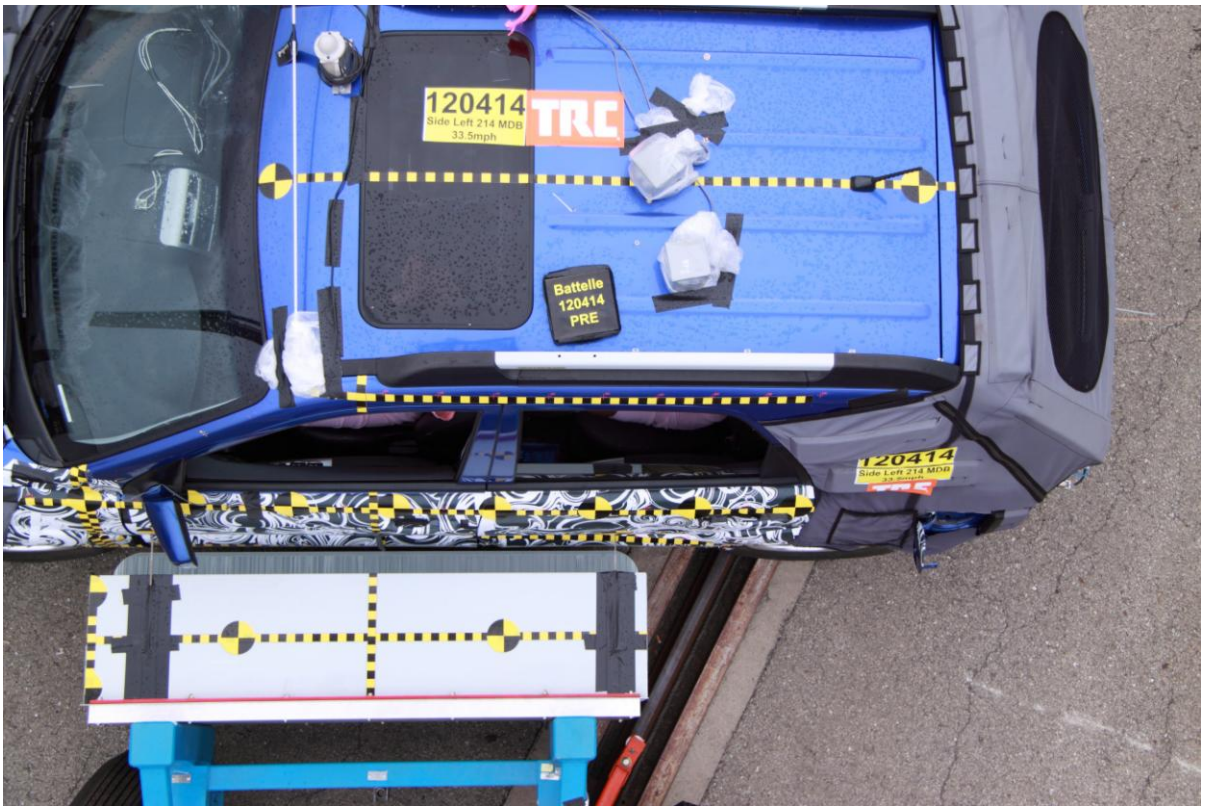


Figure A-19 Pre-Test Overhead Close Up View

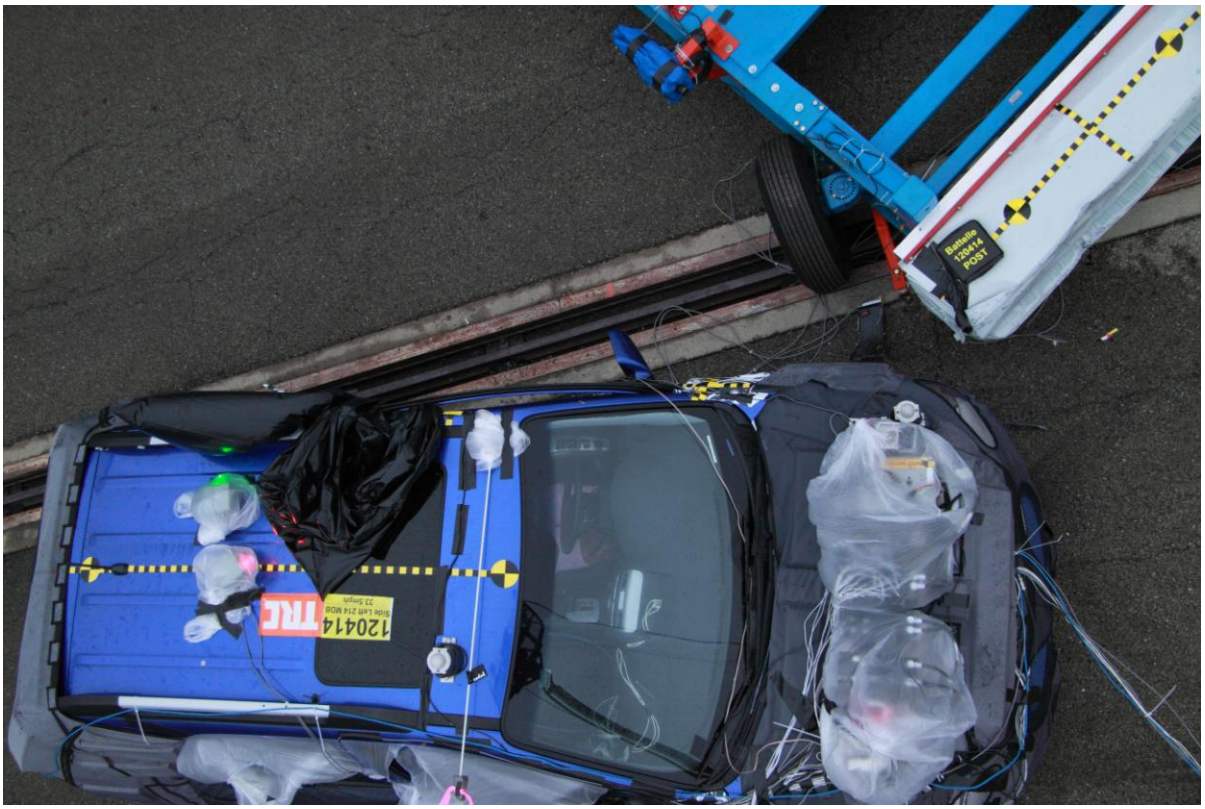


Figure A-20 Post-Test Overhead Close Up View

Figure A-21 Pre-Test Underbody - View 1

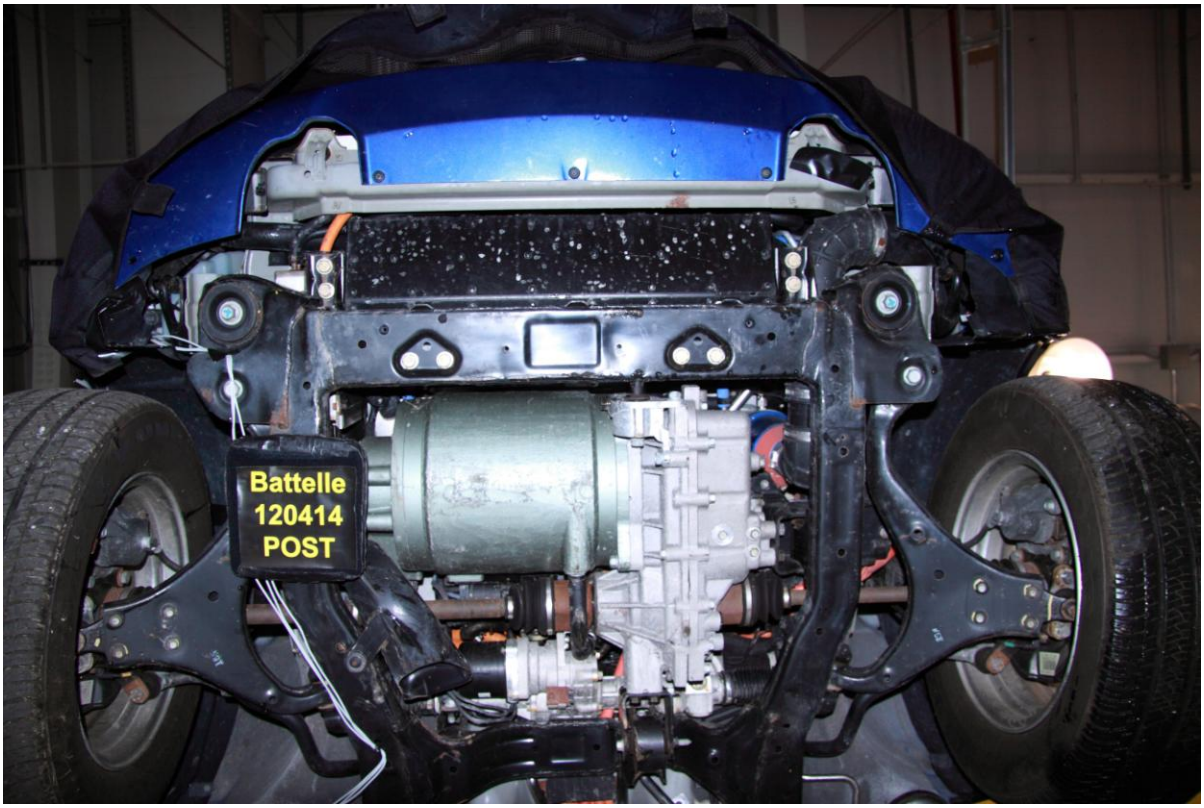


Figure A-22 Post-Test Underbody - View 1

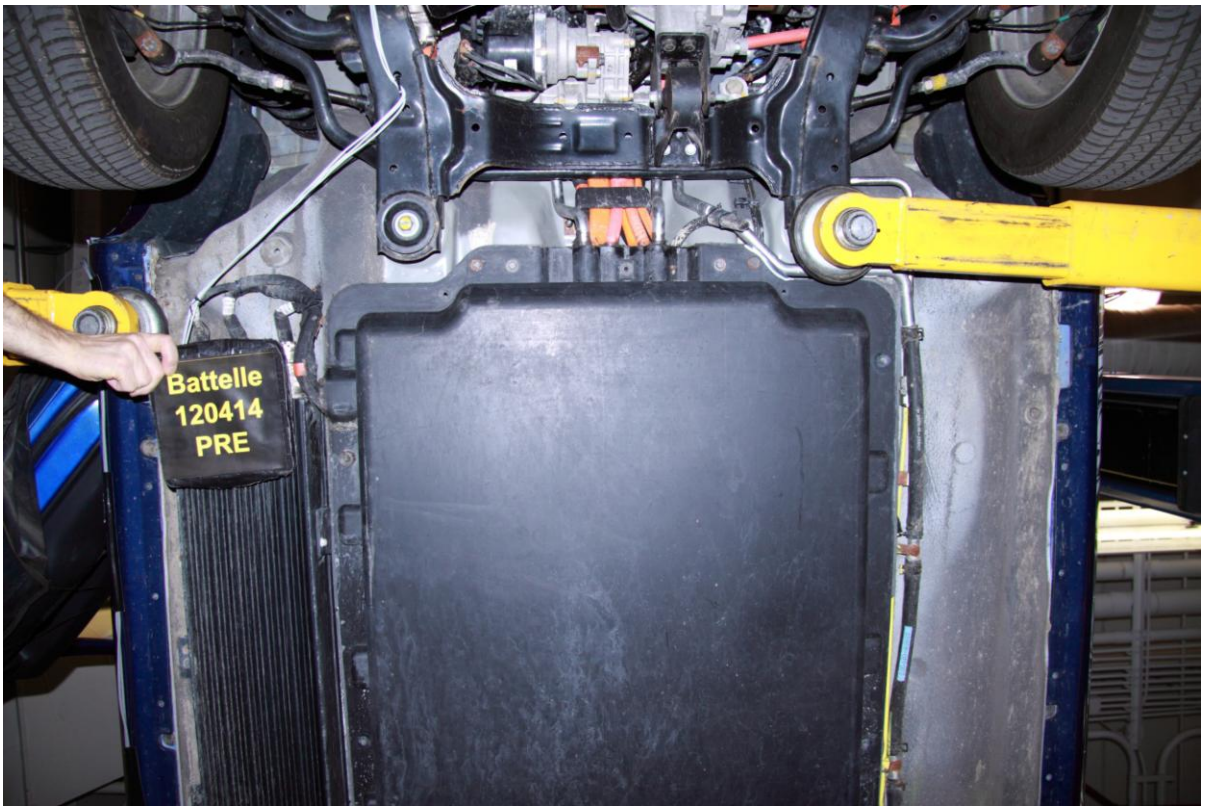


Figure A-23 Pre-Test Underbody - View 2

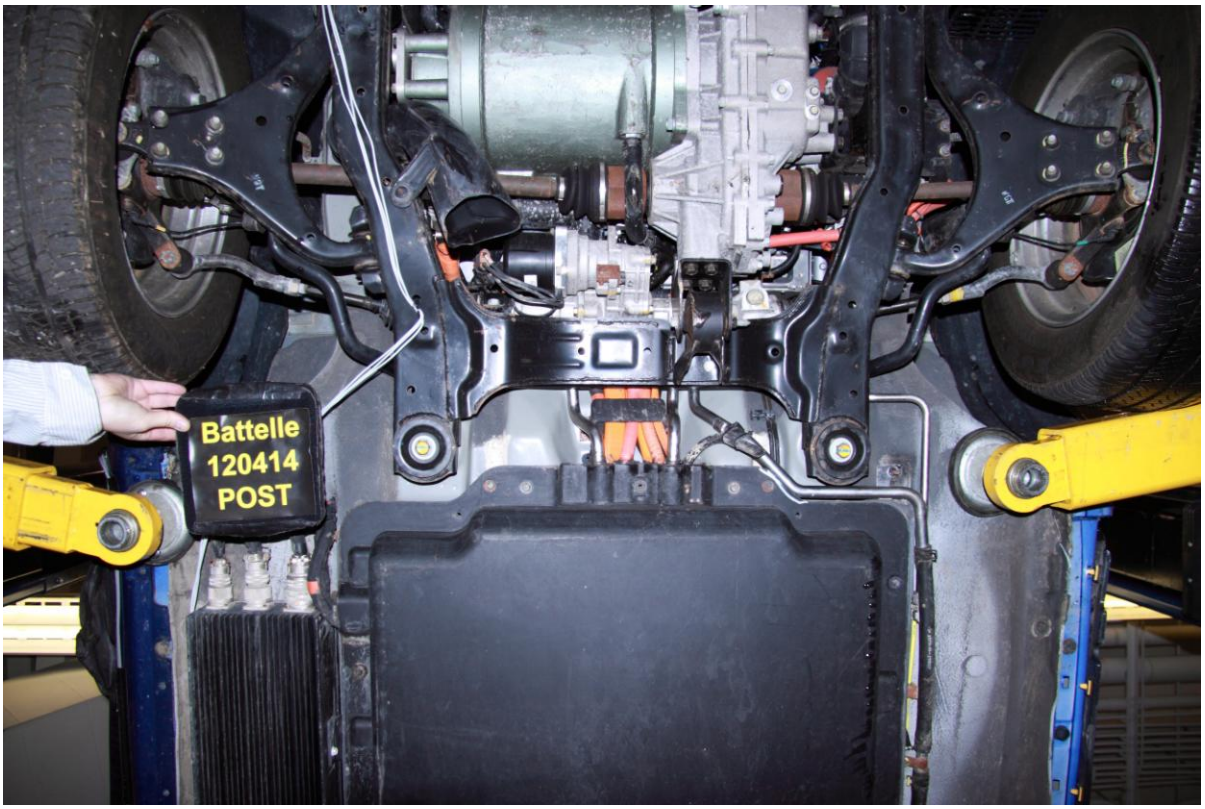


Figure A-24 Post-Test Underbody - View 2

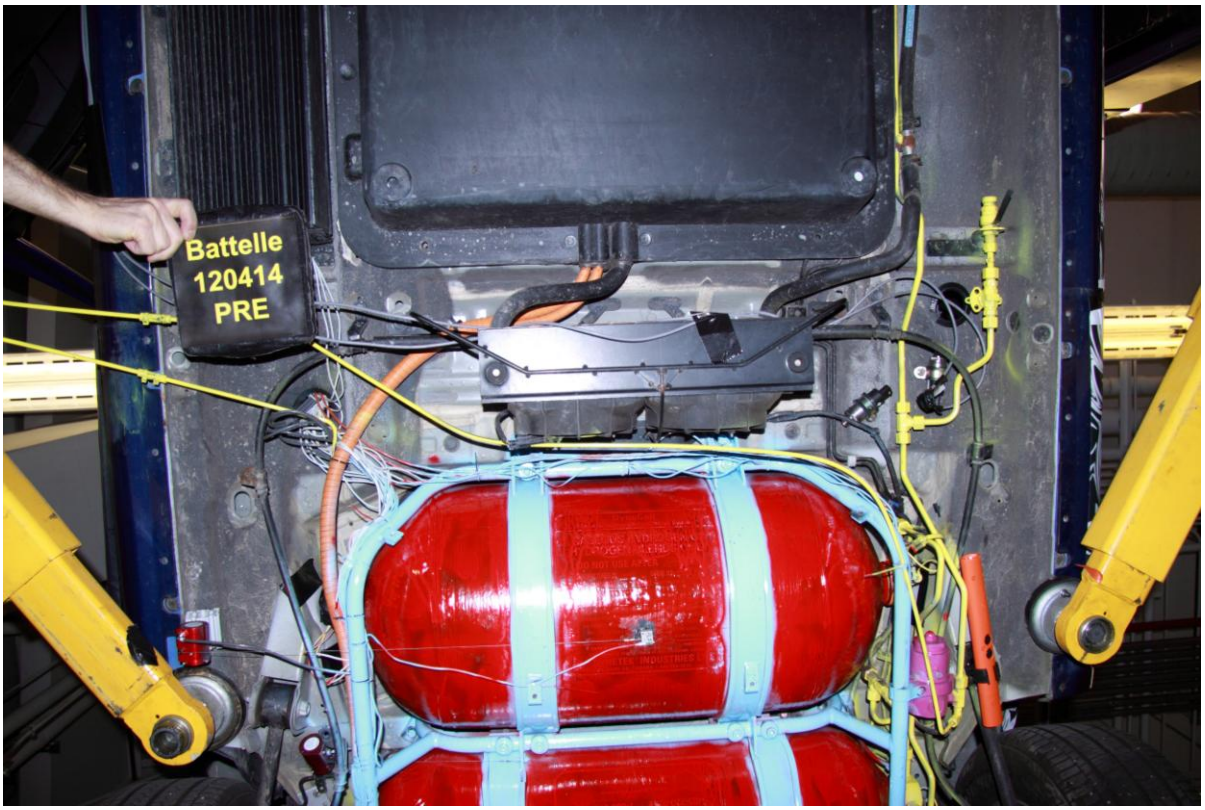


Figure A-25 Pre-Test Underbody - View 3

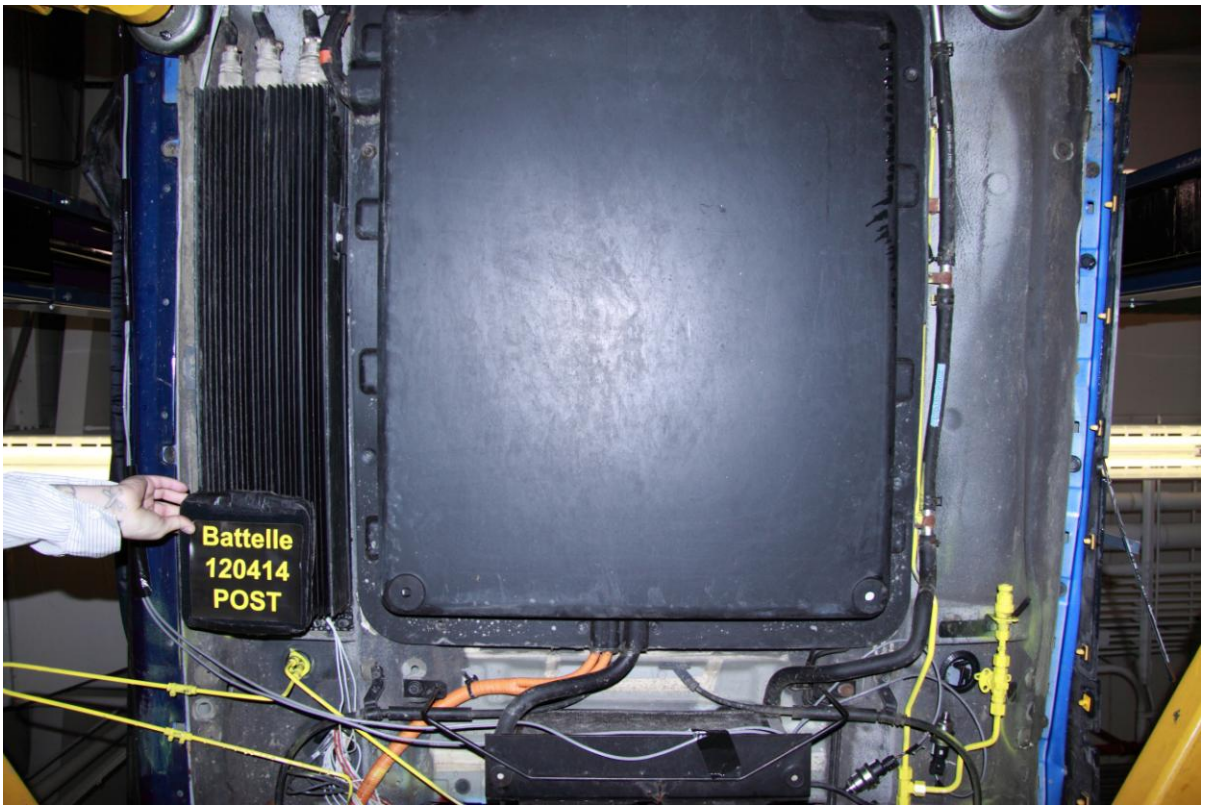


Figure A-26 Post-Test Underbody - View 3

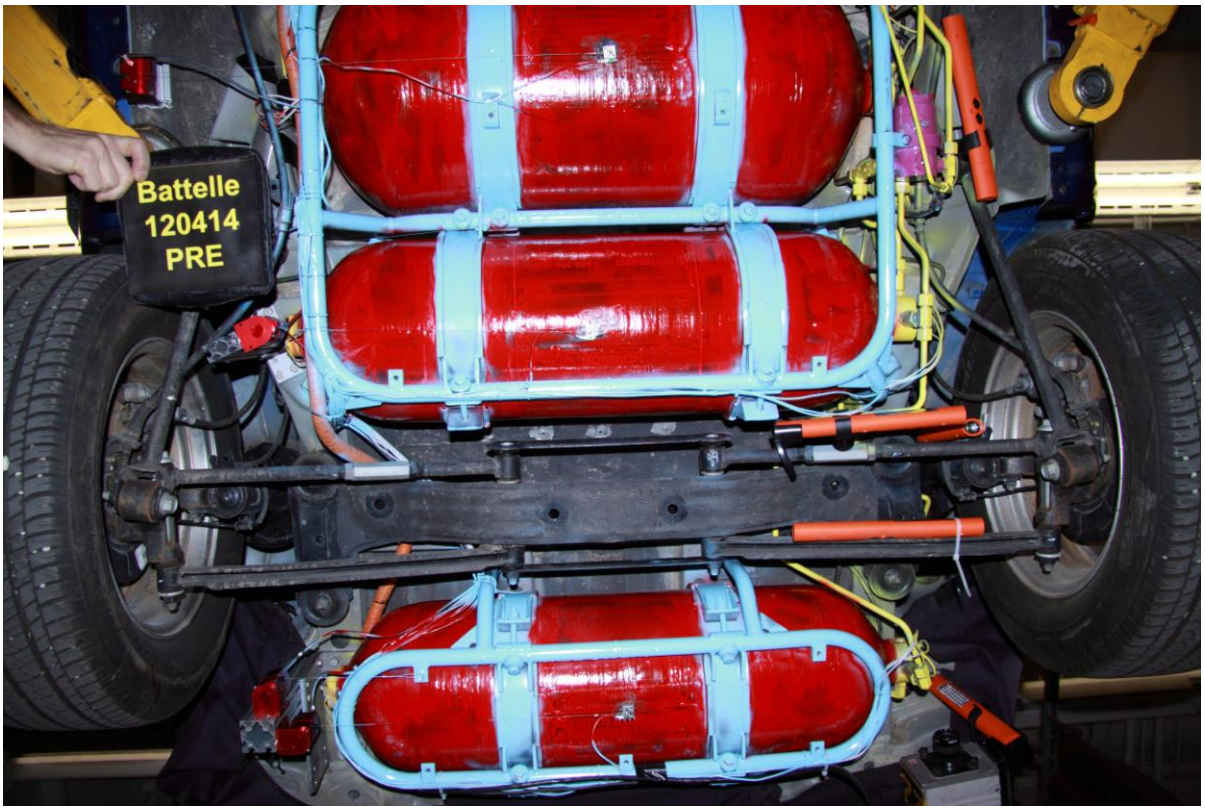


Figure A-27 Pre-Test Underbody - View 4

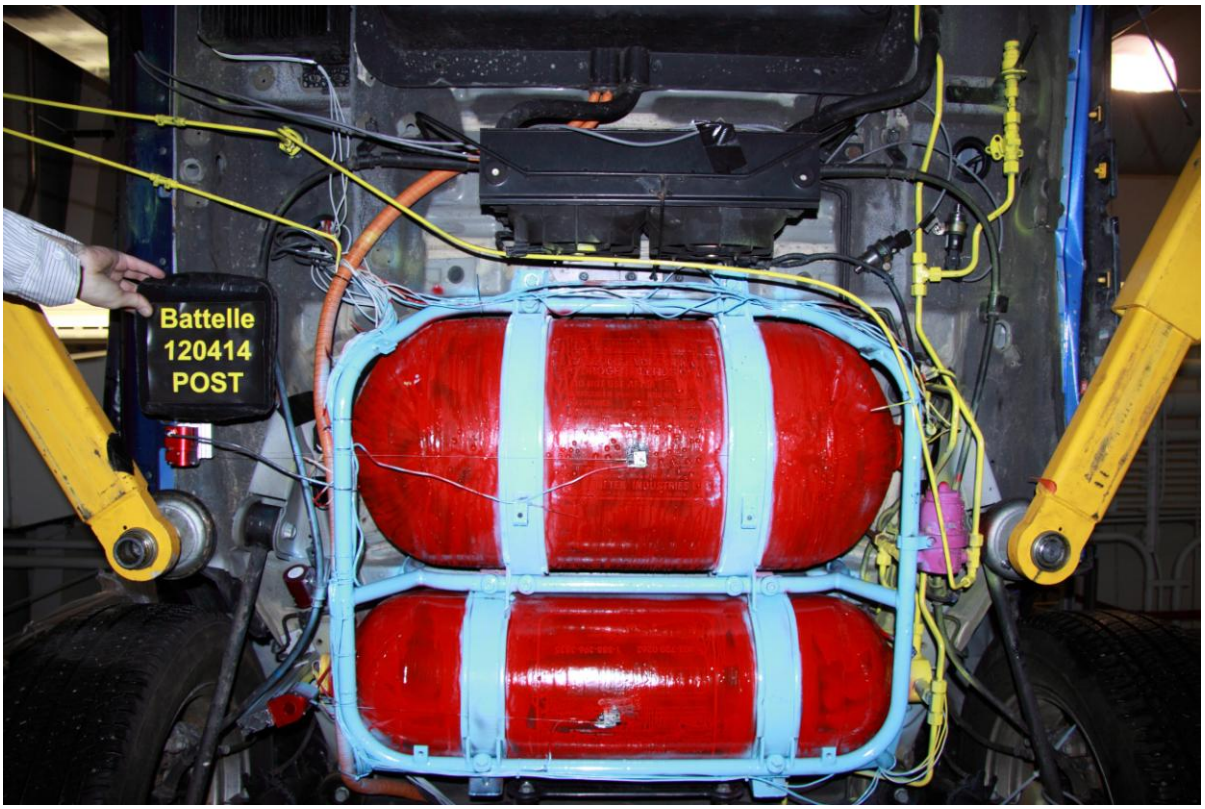


Figure A-28 Post-Test Underbody - View 4

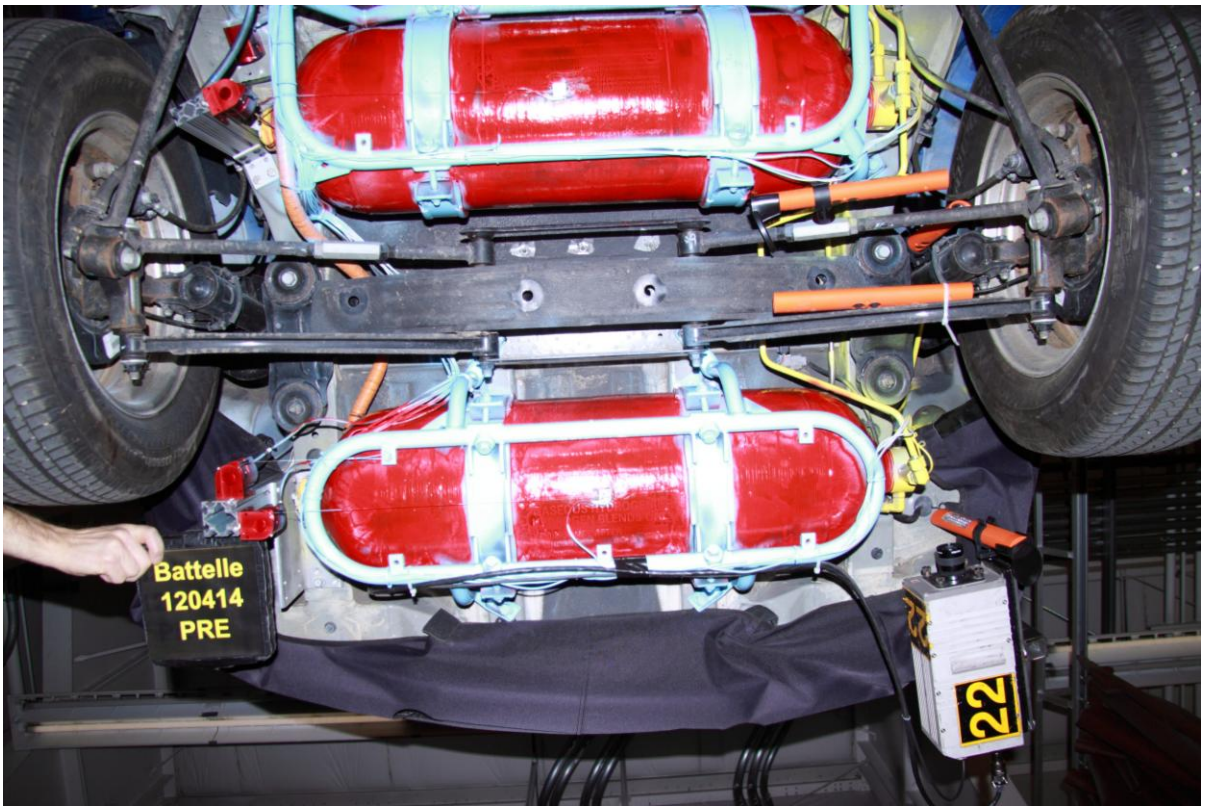


Figure A-29 Pre-Test Underbody - View 5

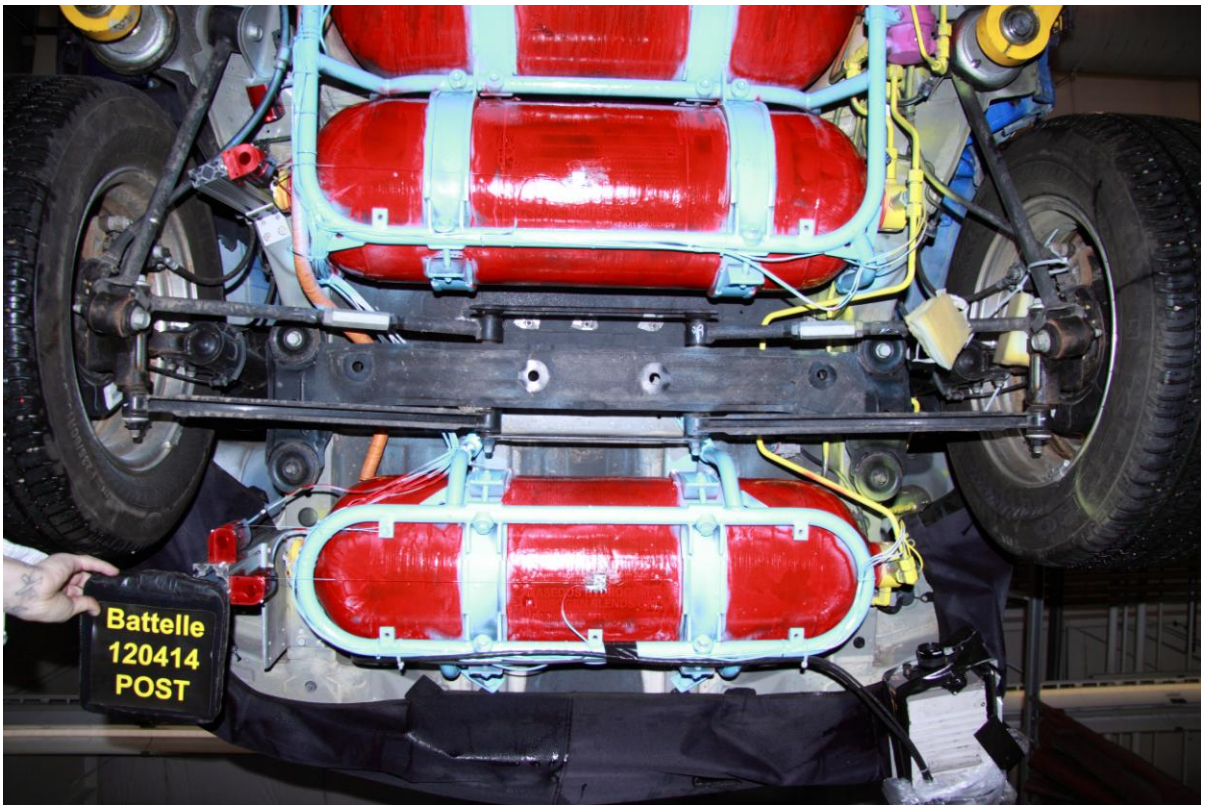


Figure A-30 Post-Test Underbody - View 5

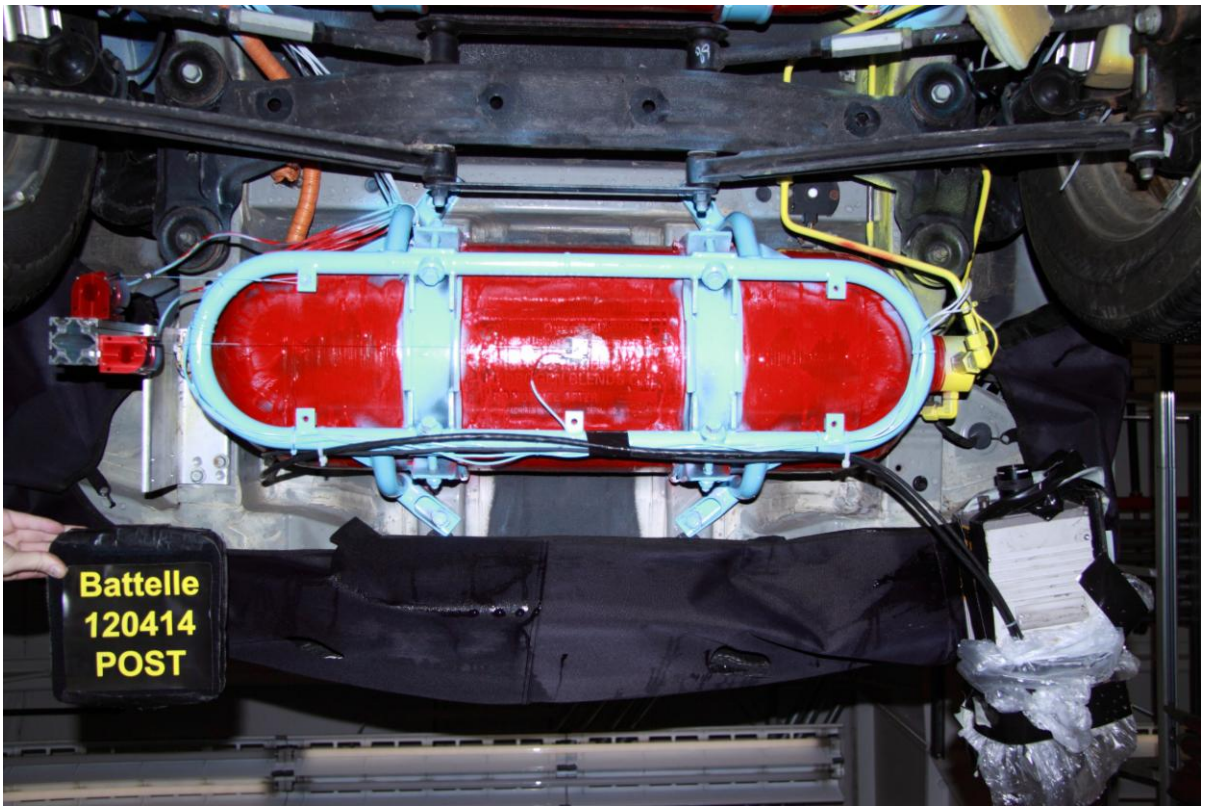


Figure A-31 Post-Test Fuel Containers - View 1

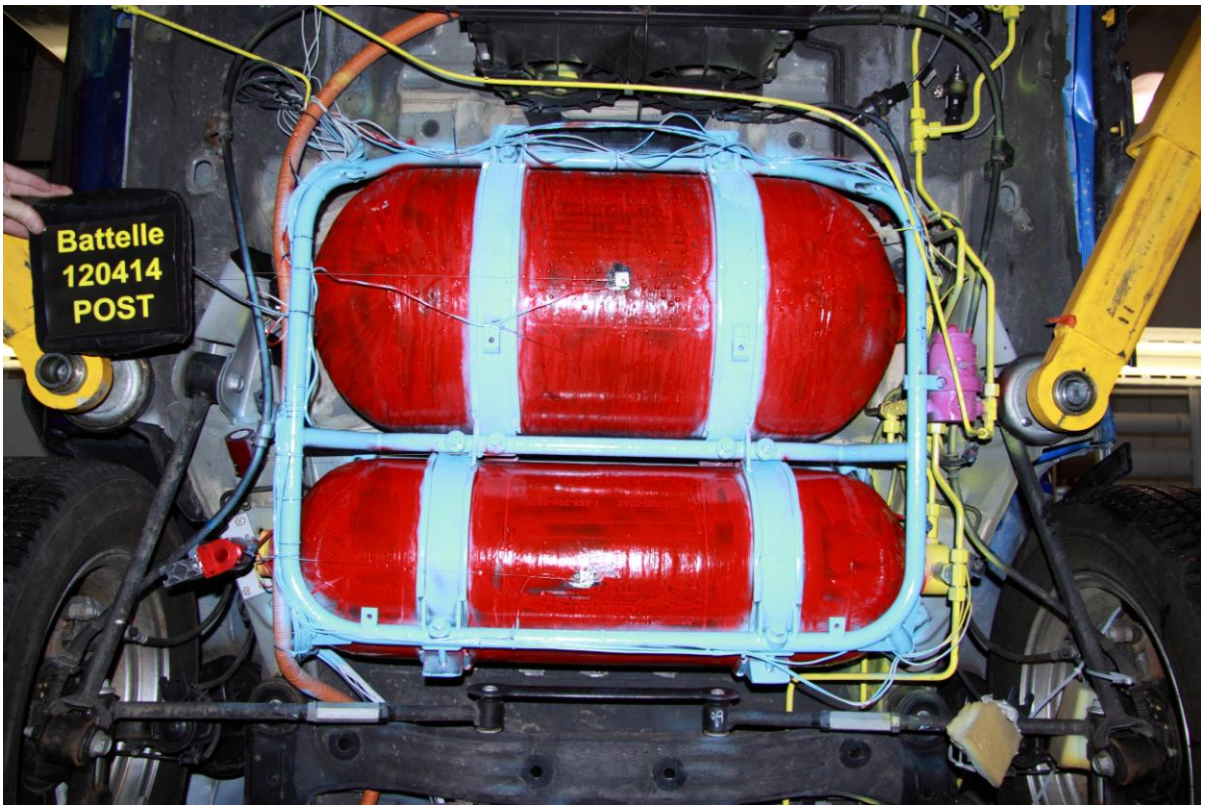


Figure A-32 Post-Test Fuel Containers - View 2

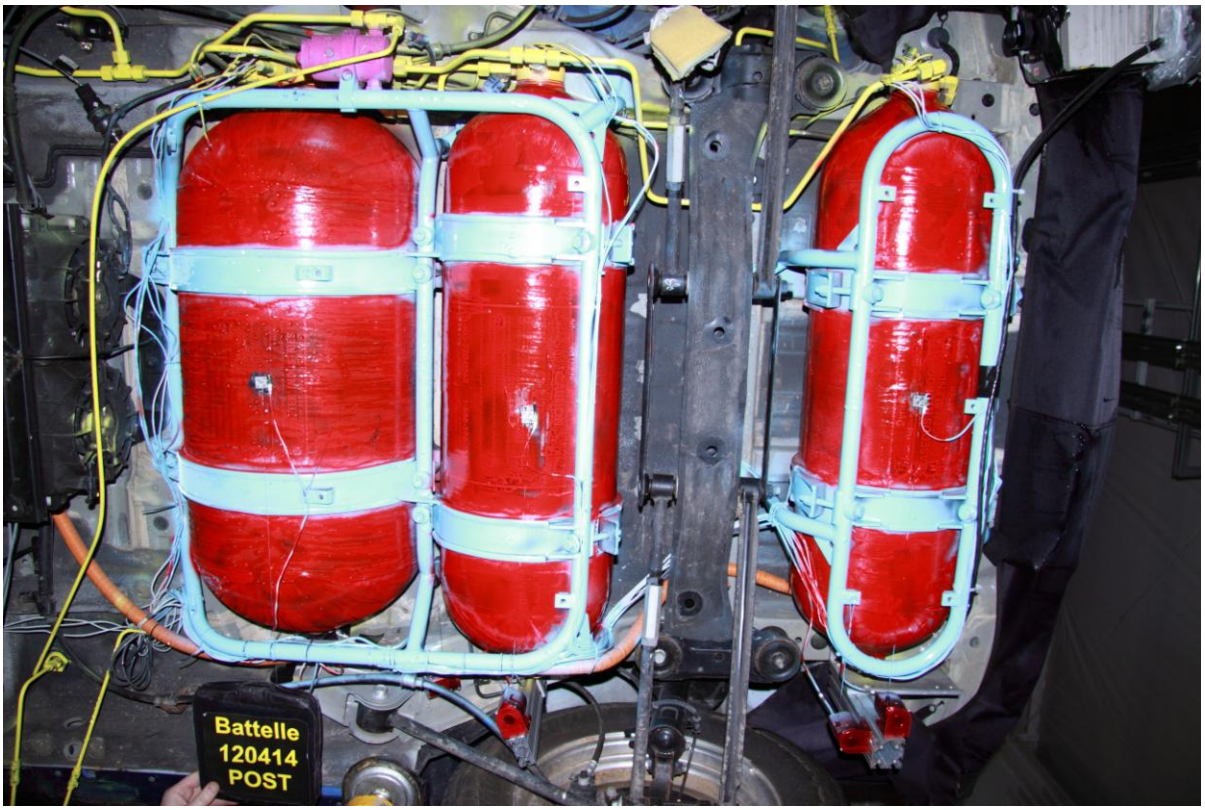


Figure A-33 Post-Test Fuel Containers - View 3

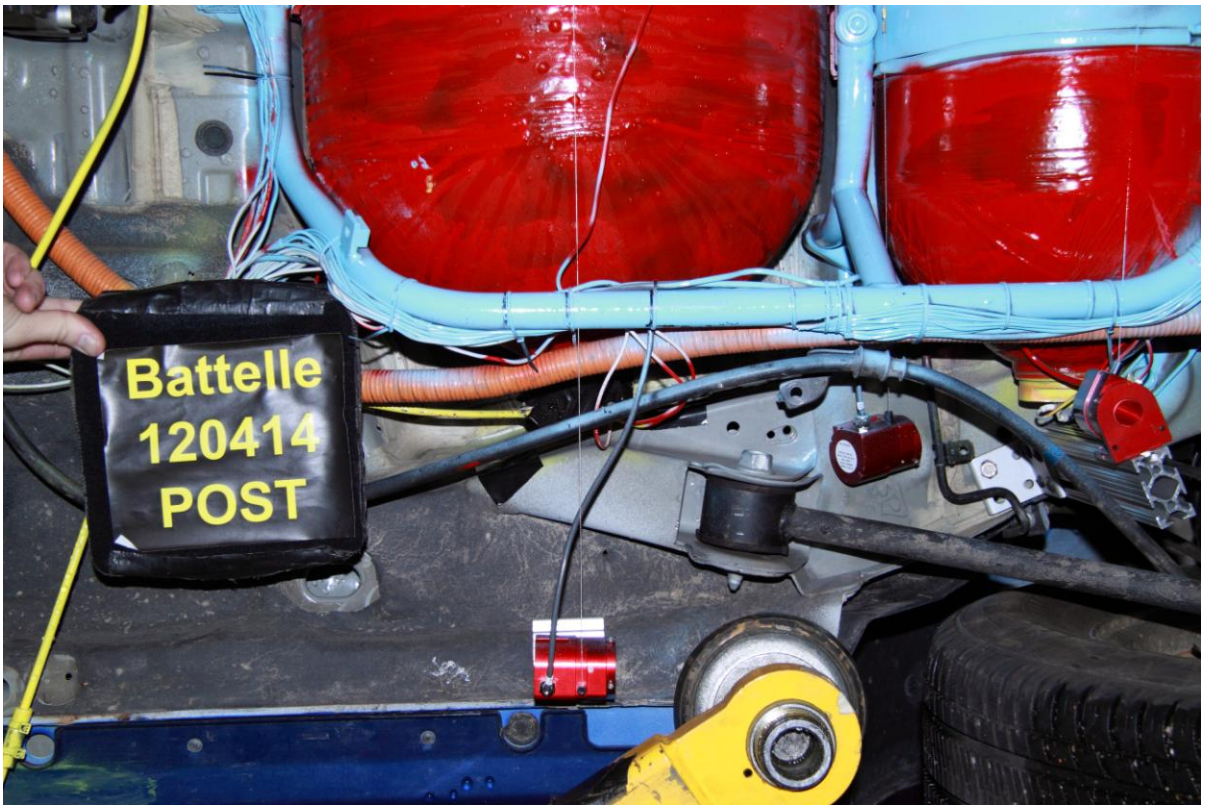


Figure A-34 Post-Test Fuel Lines - View 1

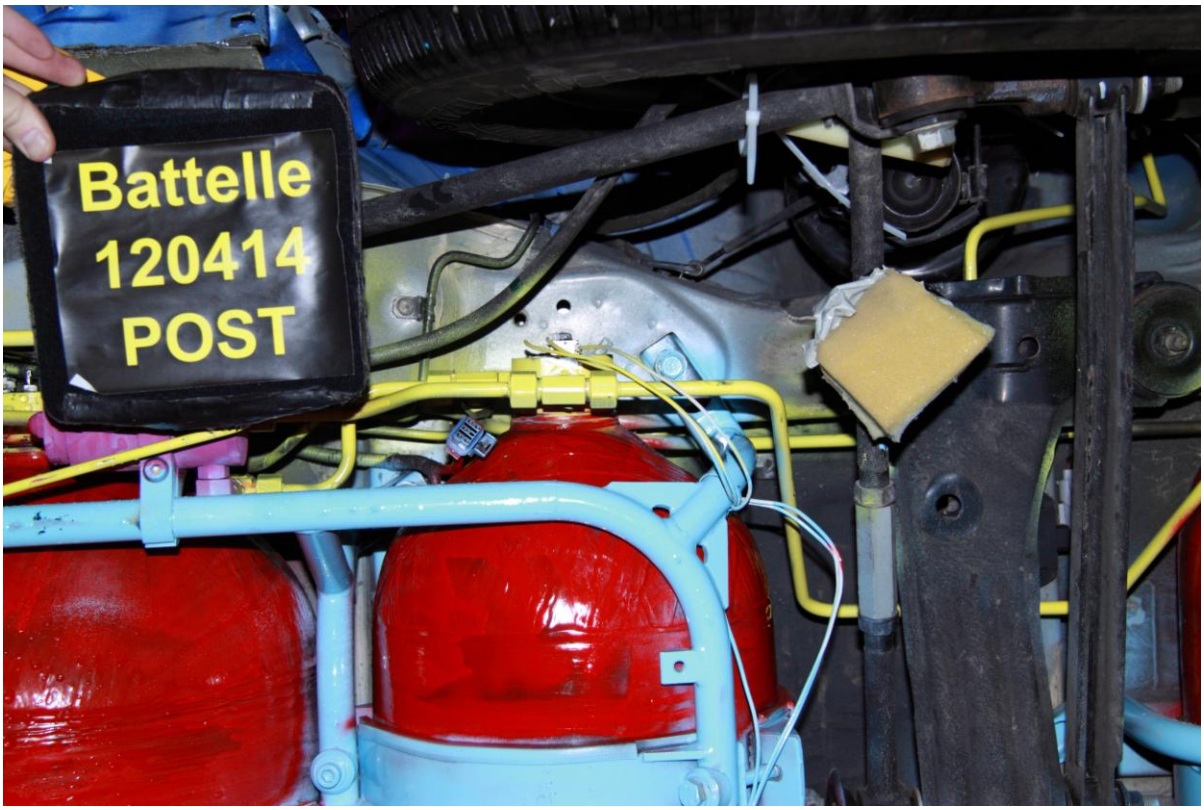


Figure A-35 Post-Test Fuel Lines - View 2

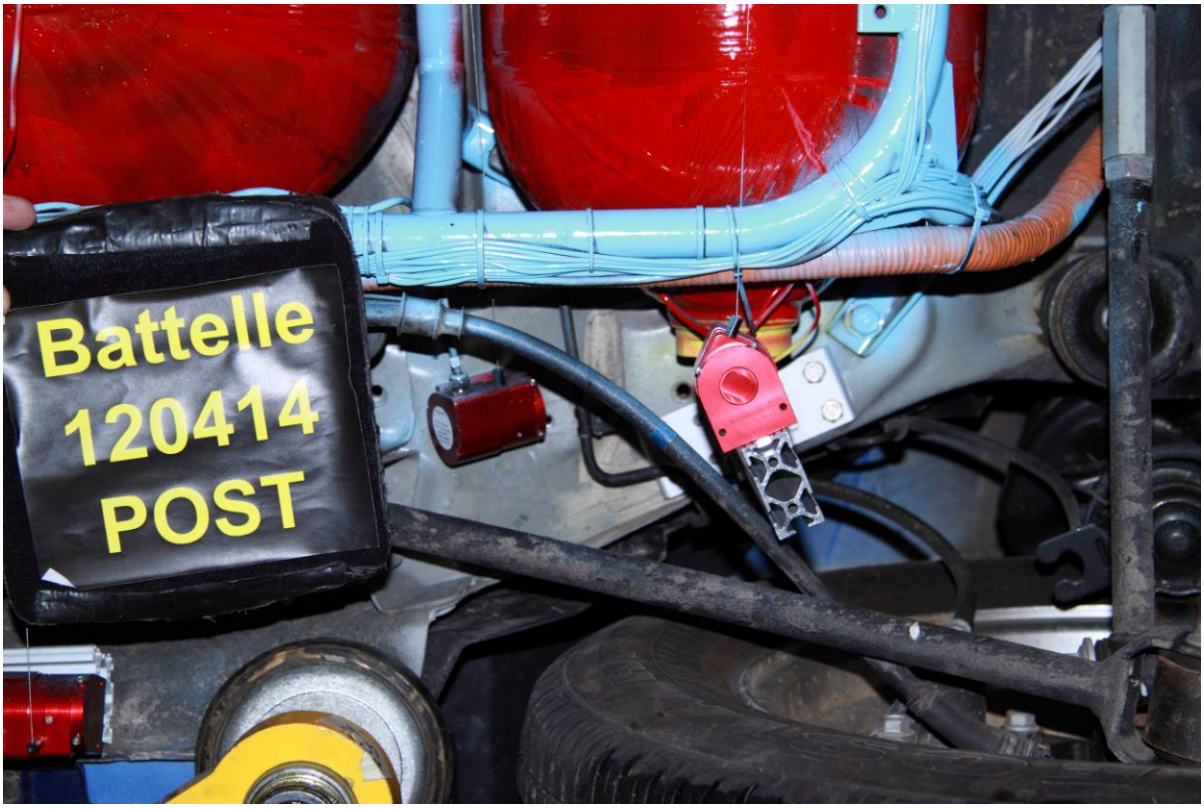


Figure A-36 Post-Test Fuel Lines - View 3

Figure A-37 Post-Test Fuel Lines - View 4

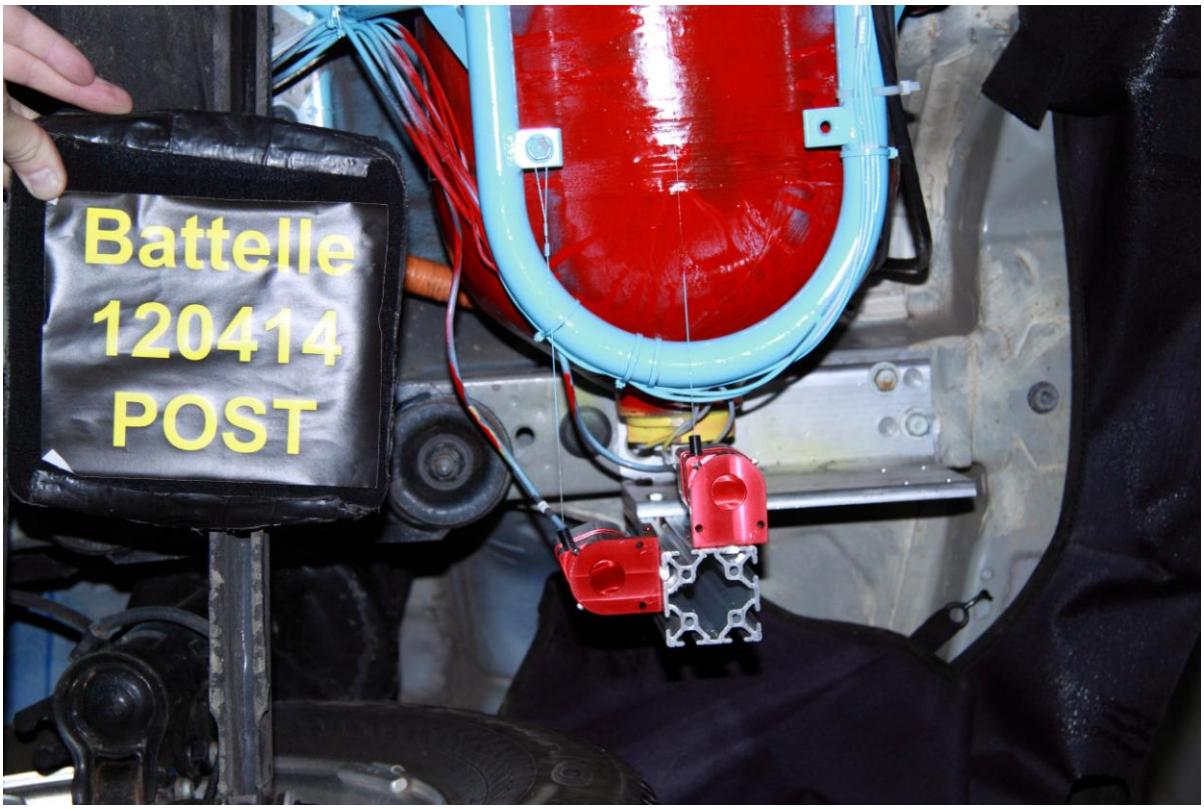


Figure A-38 Post-Test Fuel Lines - View 5

Figure A-39 Pre-Test Tank Overall View

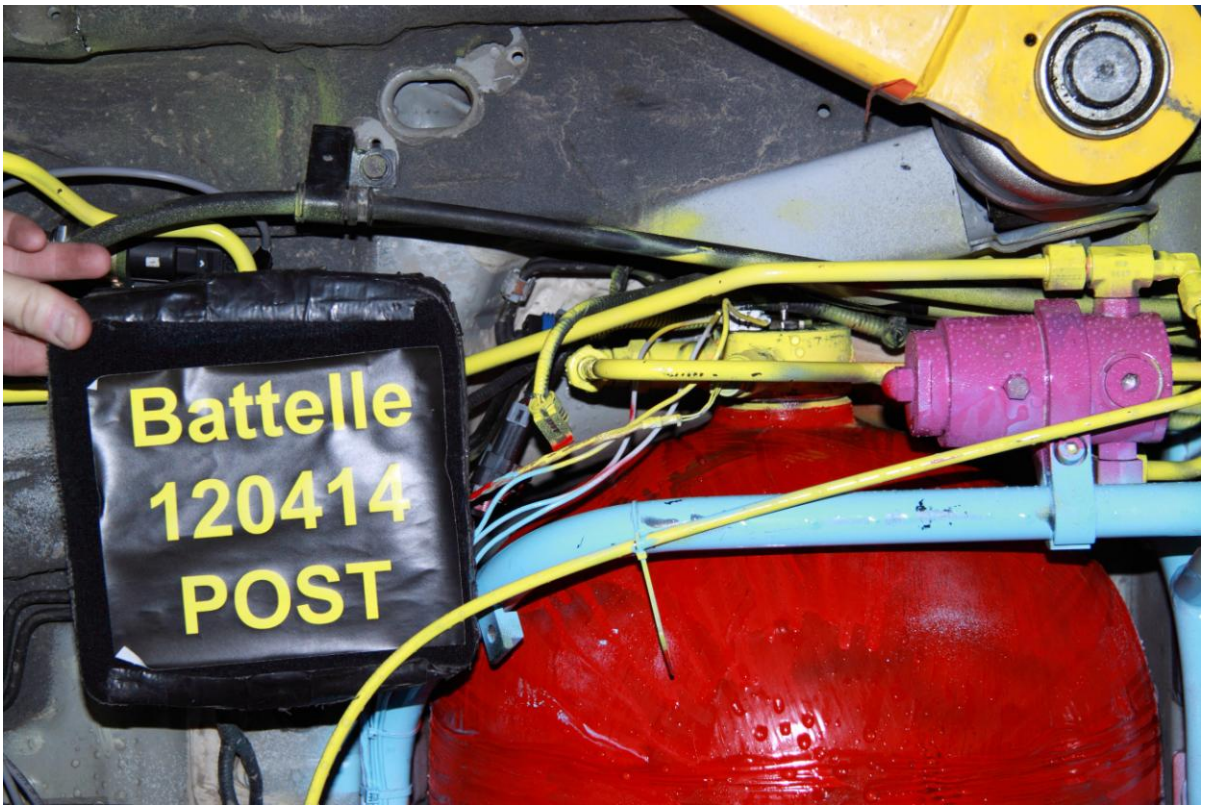


Figure A-40 Post Test Fuel Filler View

Figure A-41 Pre-Test Primary Impact Point View

Figure A-42 Post Test Primary Impact Point View

Figure A-43 Pre-Test Secondary Impact Point View

Figure A-44 Post-Test Secondary Impact Point View

Figure A-45 Pre-Test Driver and Passenger Dummy Side View

Figure A-46 Pre Test Moving Barrier with Vehicle Overall View

Figure A-47 Pre-Test Moving Barrier Right Side View

Figure A-48 Post-Test Moving Barrier Right Side View

Figure A-49 Pre-Test Moving Barrier Left Side View

Figure A-50 Post-Test Moving Barrier Left Side View

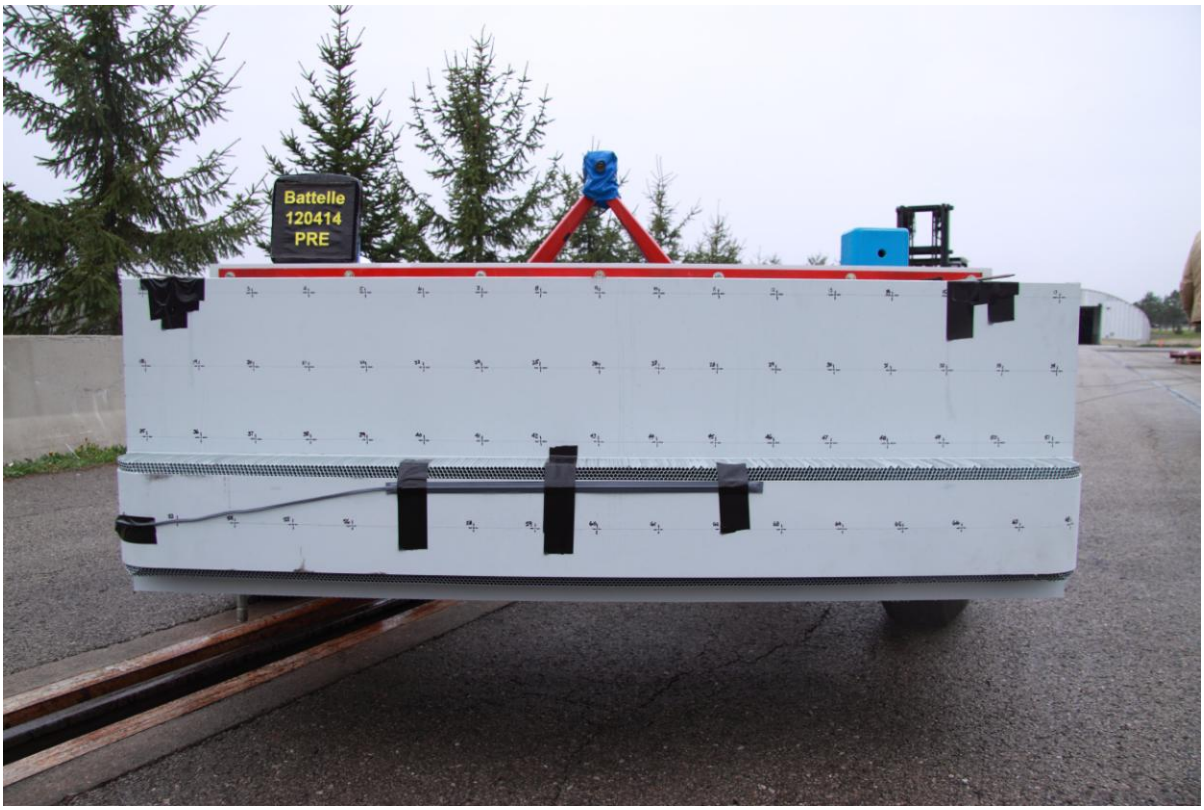


Figure A-51 Pre-Test Moving Barrier Front View

Figure A-52 Post-Test Moving Barrier Face

Appendix B

Data Plots

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

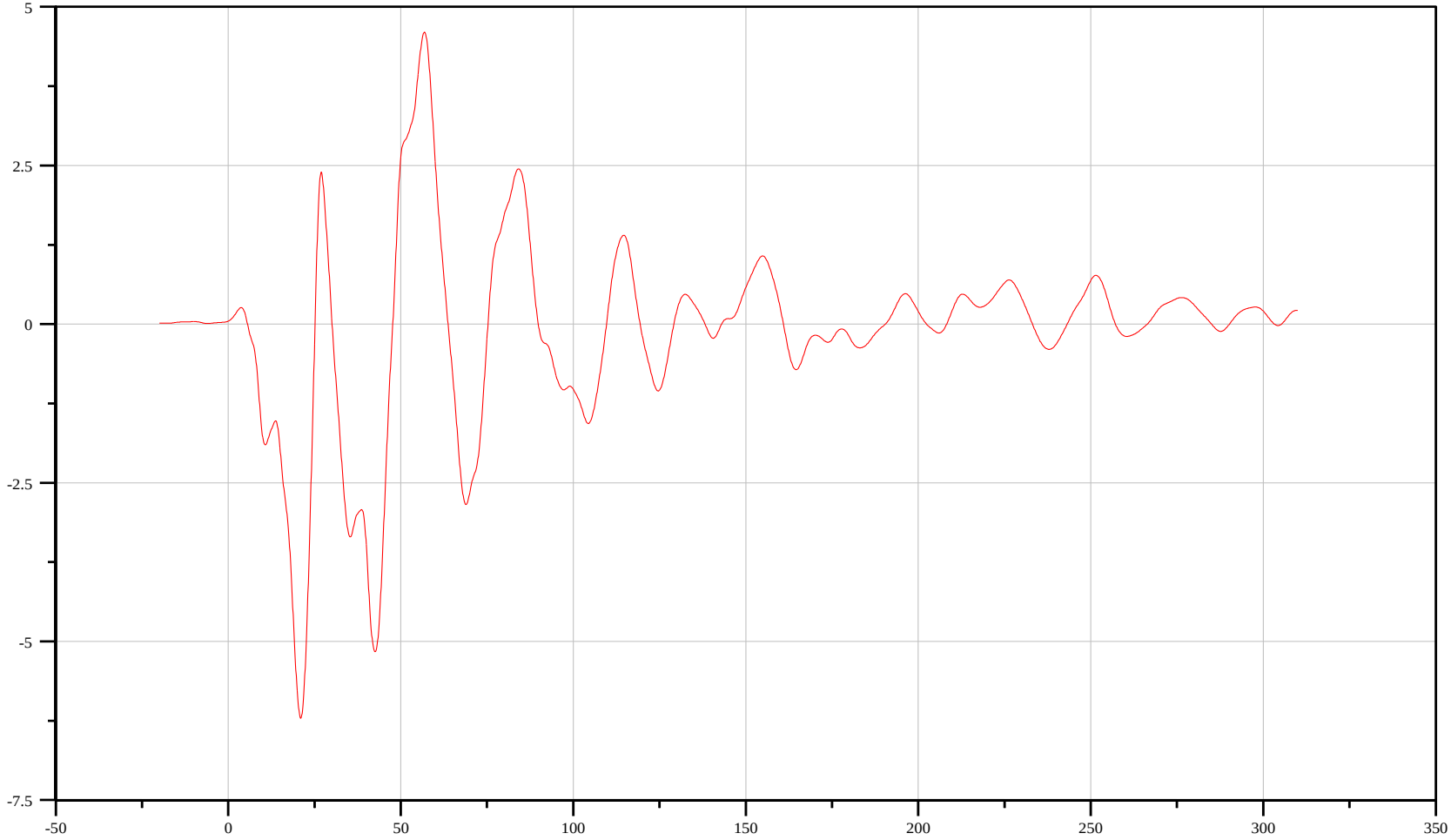
Vehicle CG X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10VEHCCG0000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-6.21 g at 21.00 ms

Max. Value
4.60 g at 56.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

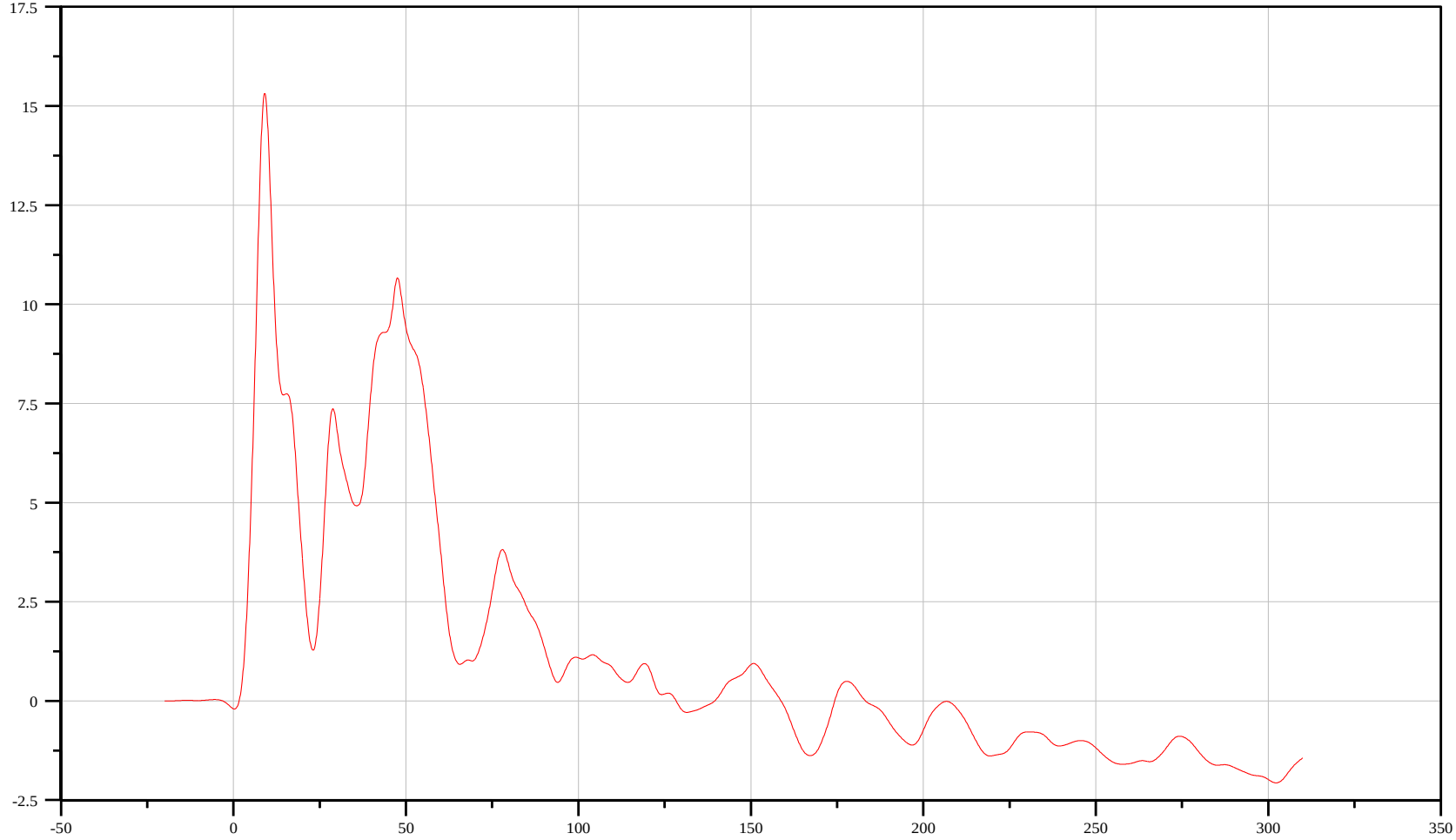
Vehicle CG Y-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10VEHCCG0000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-2.07 g at 302.30 ms

Max. Value
15.32 g at 9.10 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

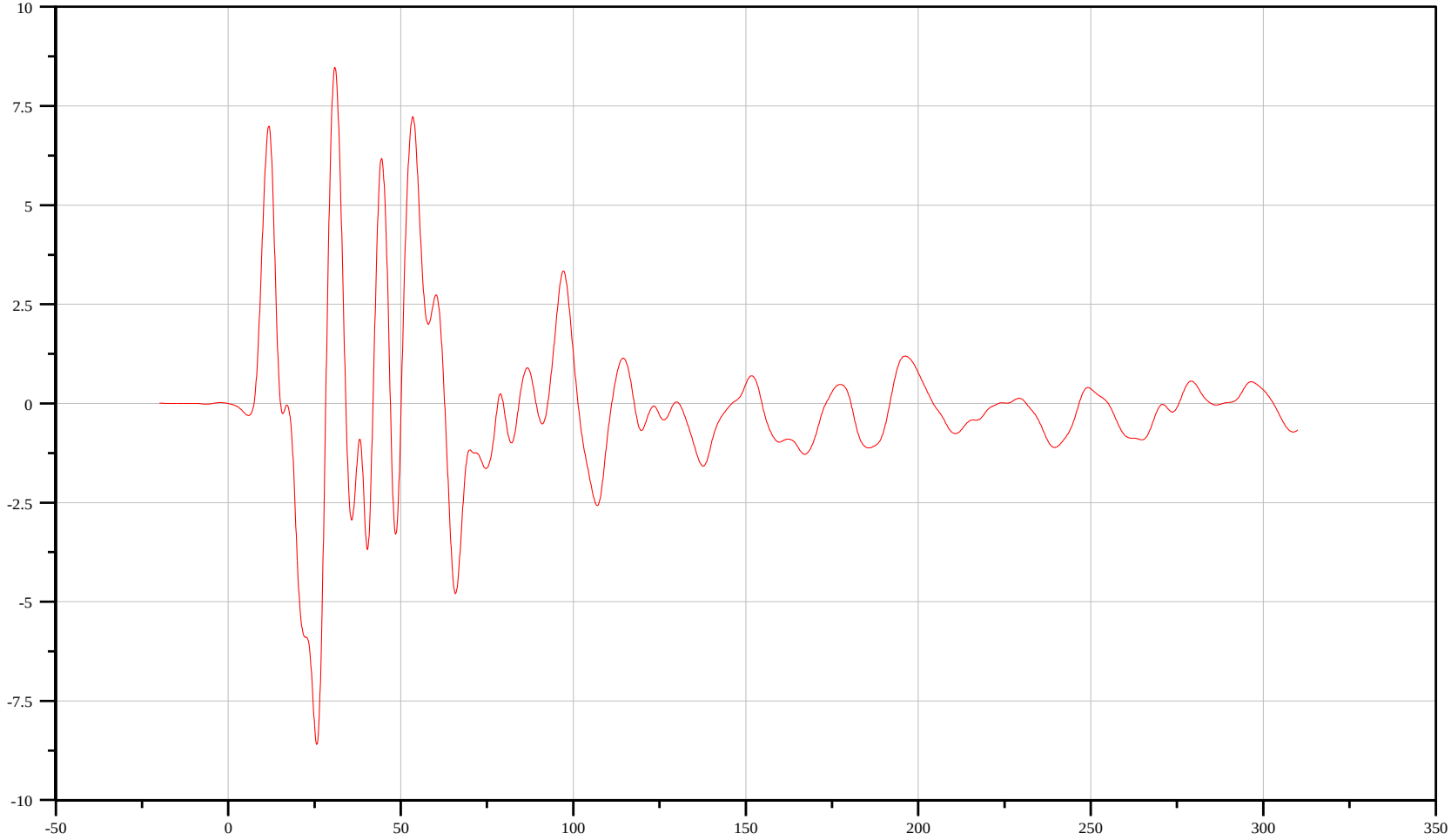
Vehicle CG Z-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10VEHCCG0000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-8.59 g at 25.70 ms

Max. Value
8.48 g at 30.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

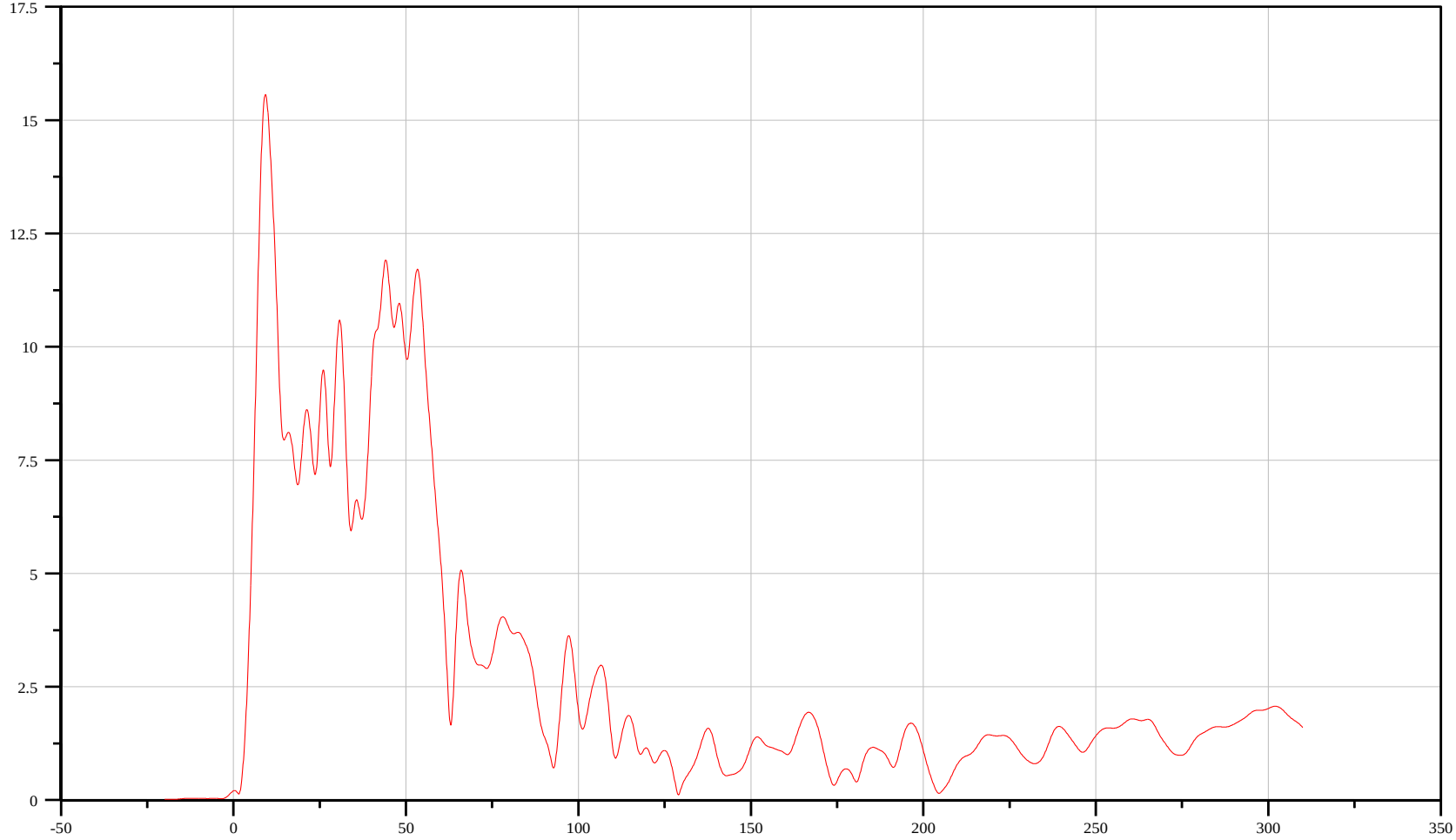
Vehicle CG Resultant Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10VEHCCG0000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.01 g at -17.50 ms

Max. Value
15.57 g at 9.30 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

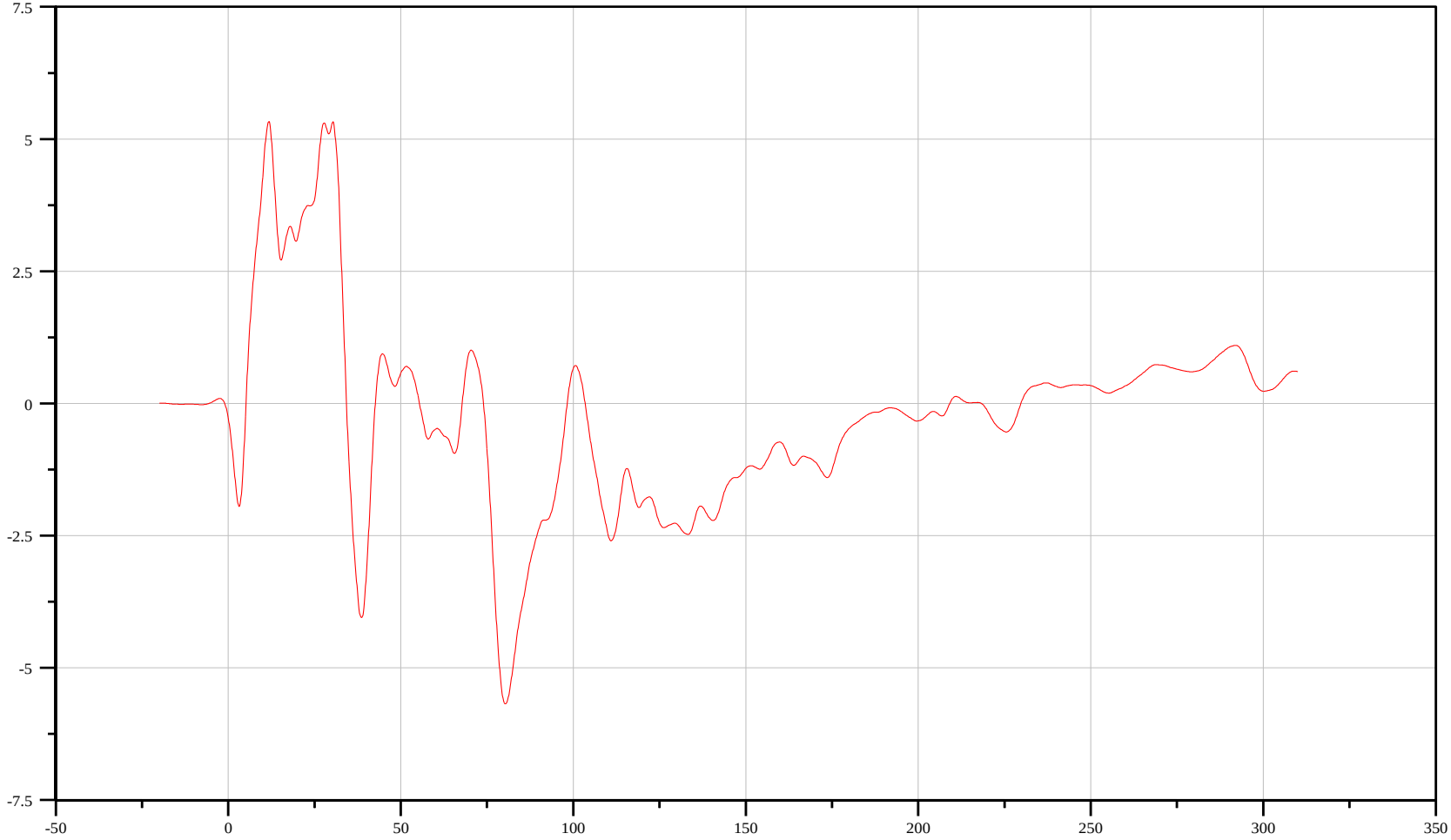
Vehicle Body X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10VEHC000000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-5.68 g at 80.30 ms

Max. Value
5.33 g at 11.80 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

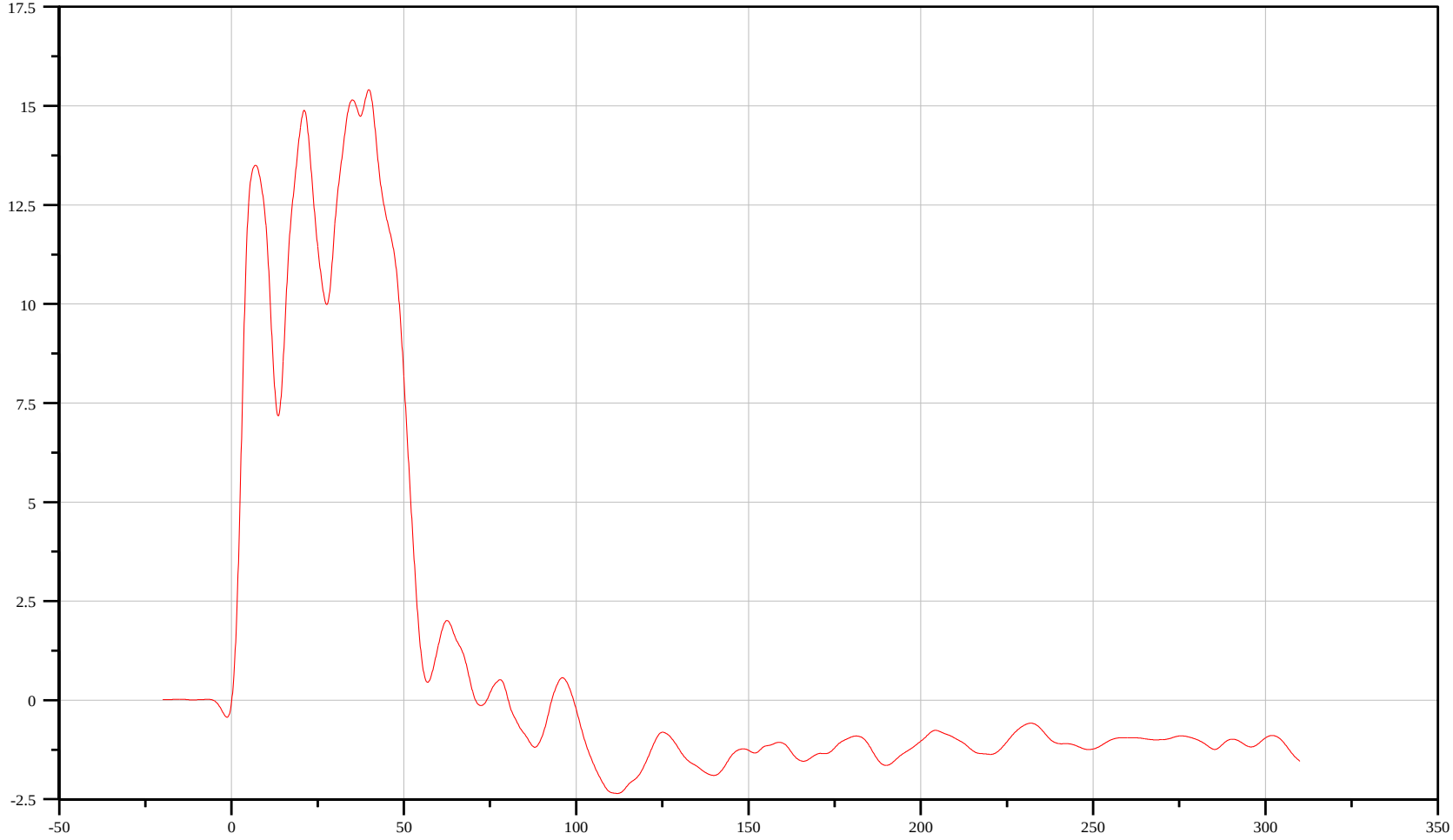
Vehicle Body Y-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10VEHC000000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-2.35 g at 111.90 ms

Max. Value
15.41 g at 39.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

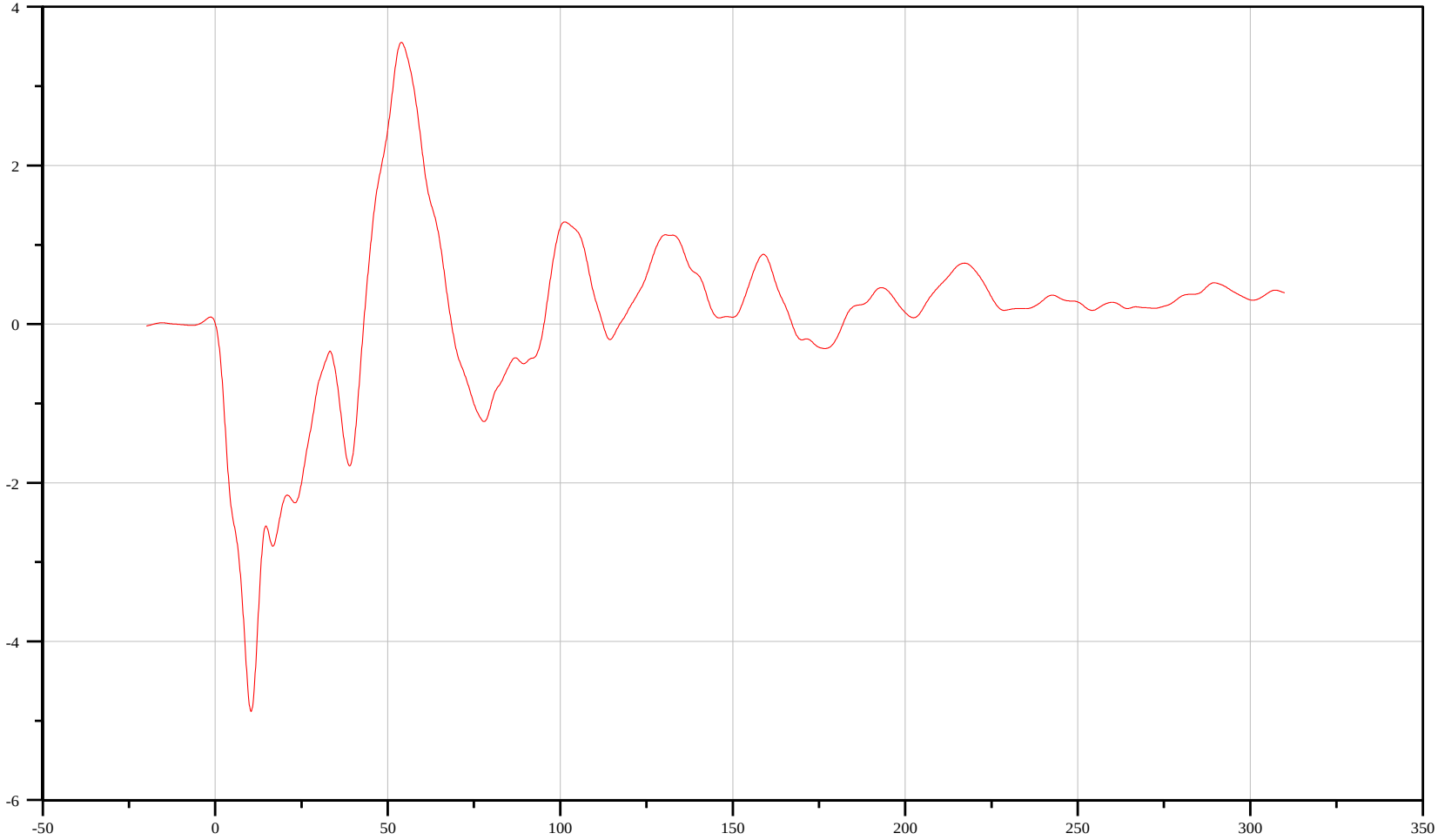
Vehicle Body Z-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10VEHC000000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-4.88 g at 10.40 ms

Max. Value
3.55 g at 54.00 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

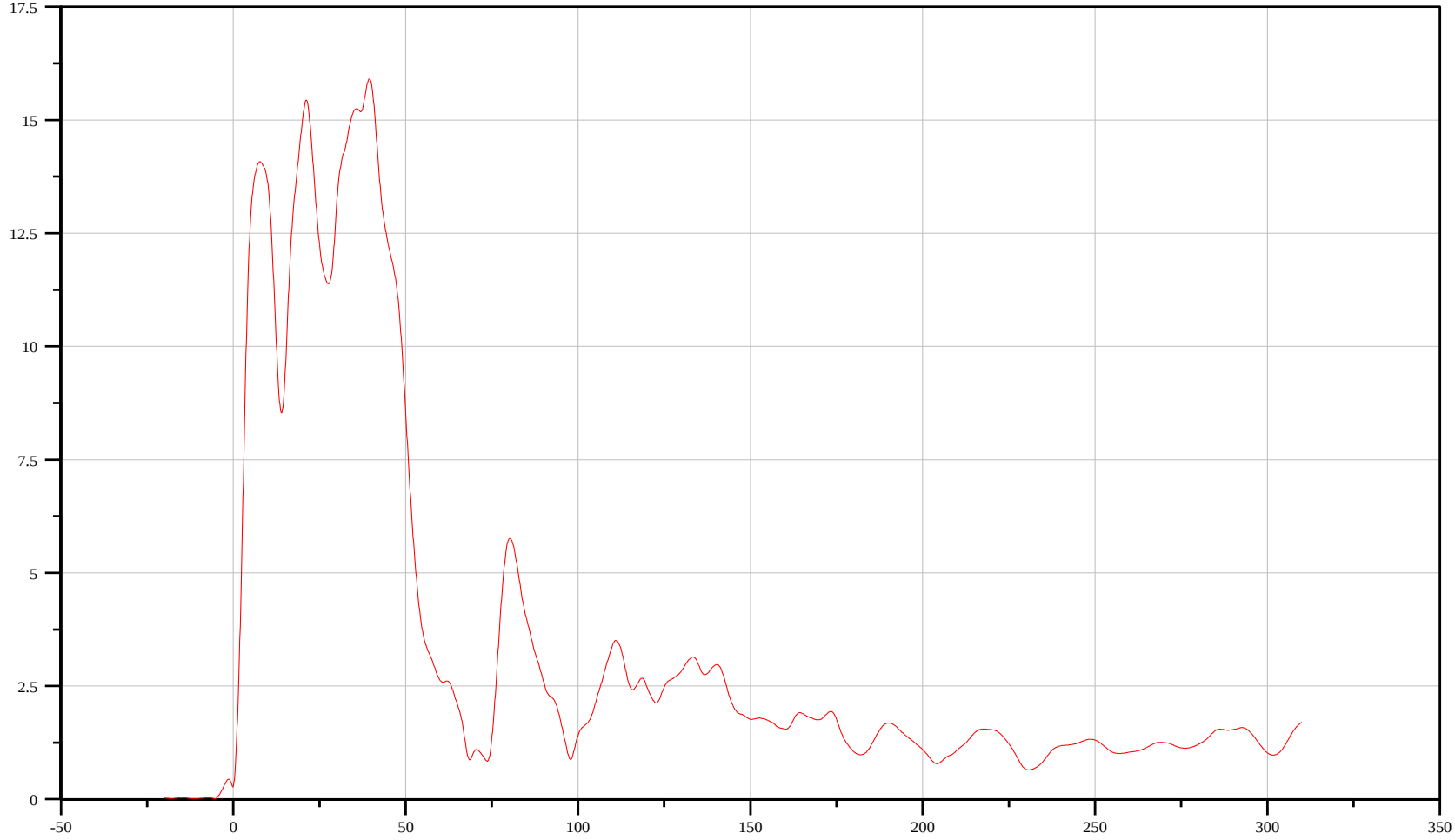
Date: 04/16/2012
Time: 08:34

Vehicle Body Resultant Acceleration

Customer: Battelle

10VEHC000000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.01 g at -5.40 ms

Max. Value
15.91 g at 39.50 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

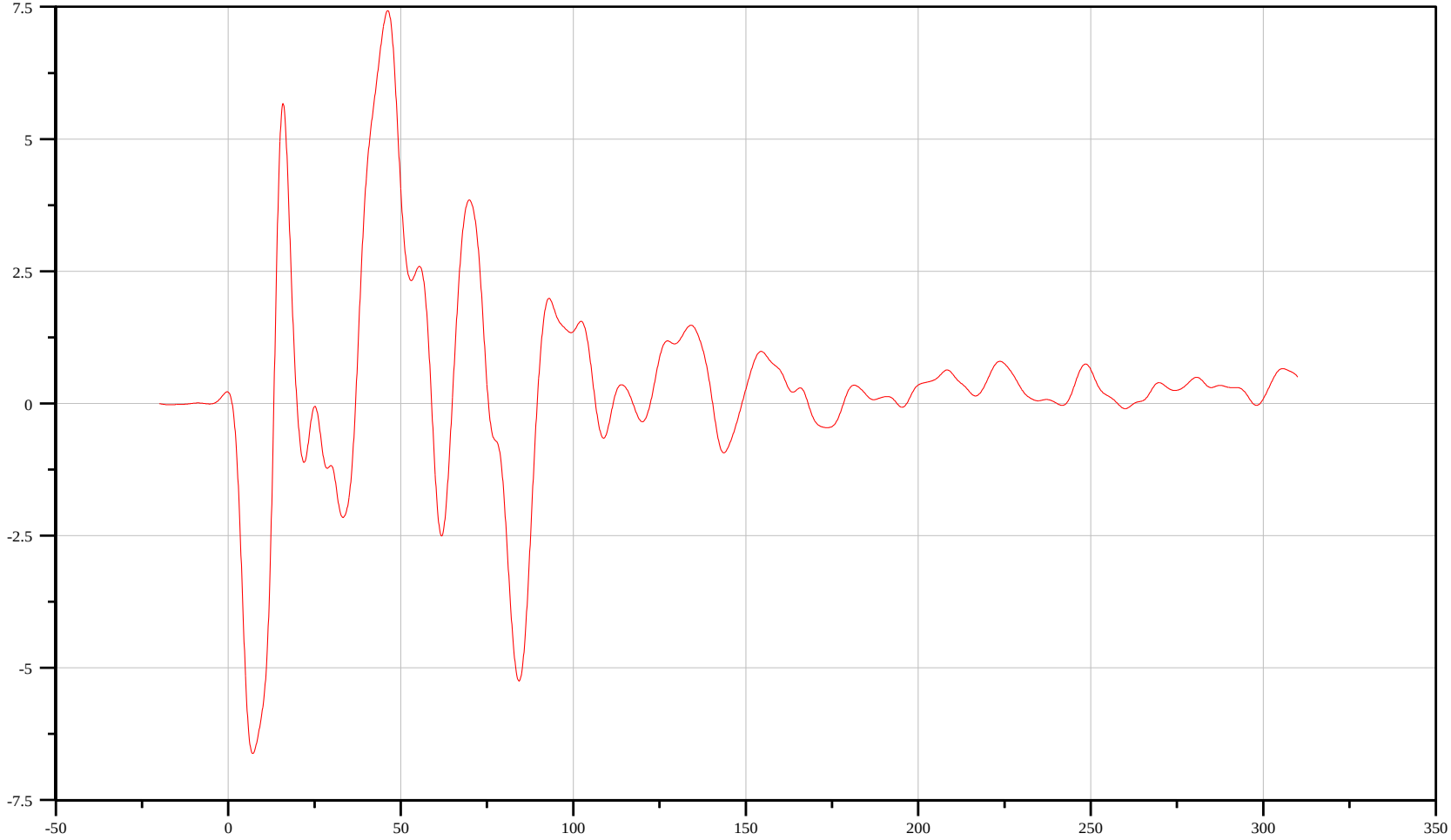
Front Container, Passenger X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTFR0000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

	Min. Value	Max. Value
	-6.62 g at 7.10 ms	7.43 g at 46.20 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

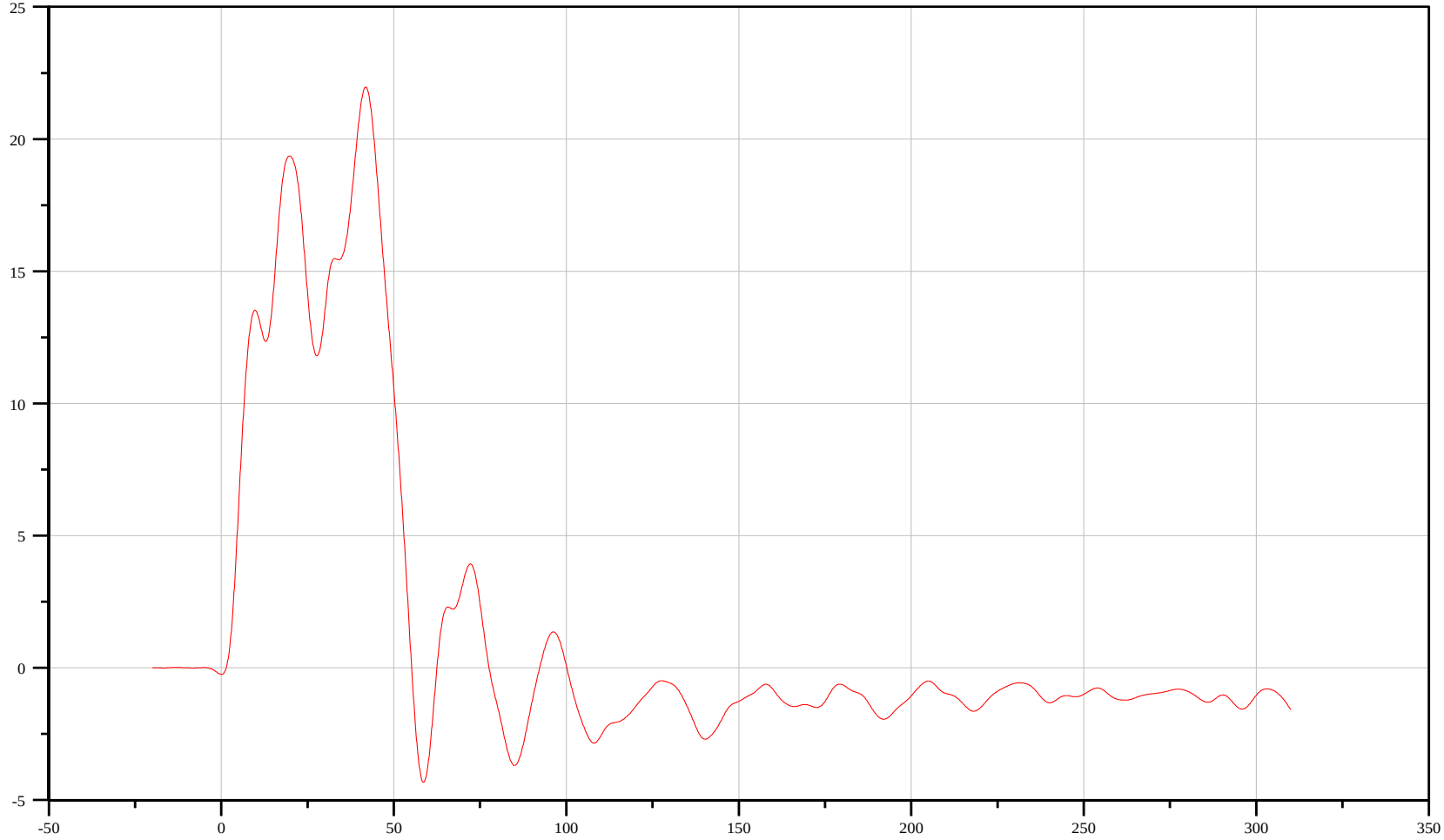
Front Container, Passenger Y-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTFR0000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-4.33 g at 58.60 ms

Max. Value
21.97 g at 41.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

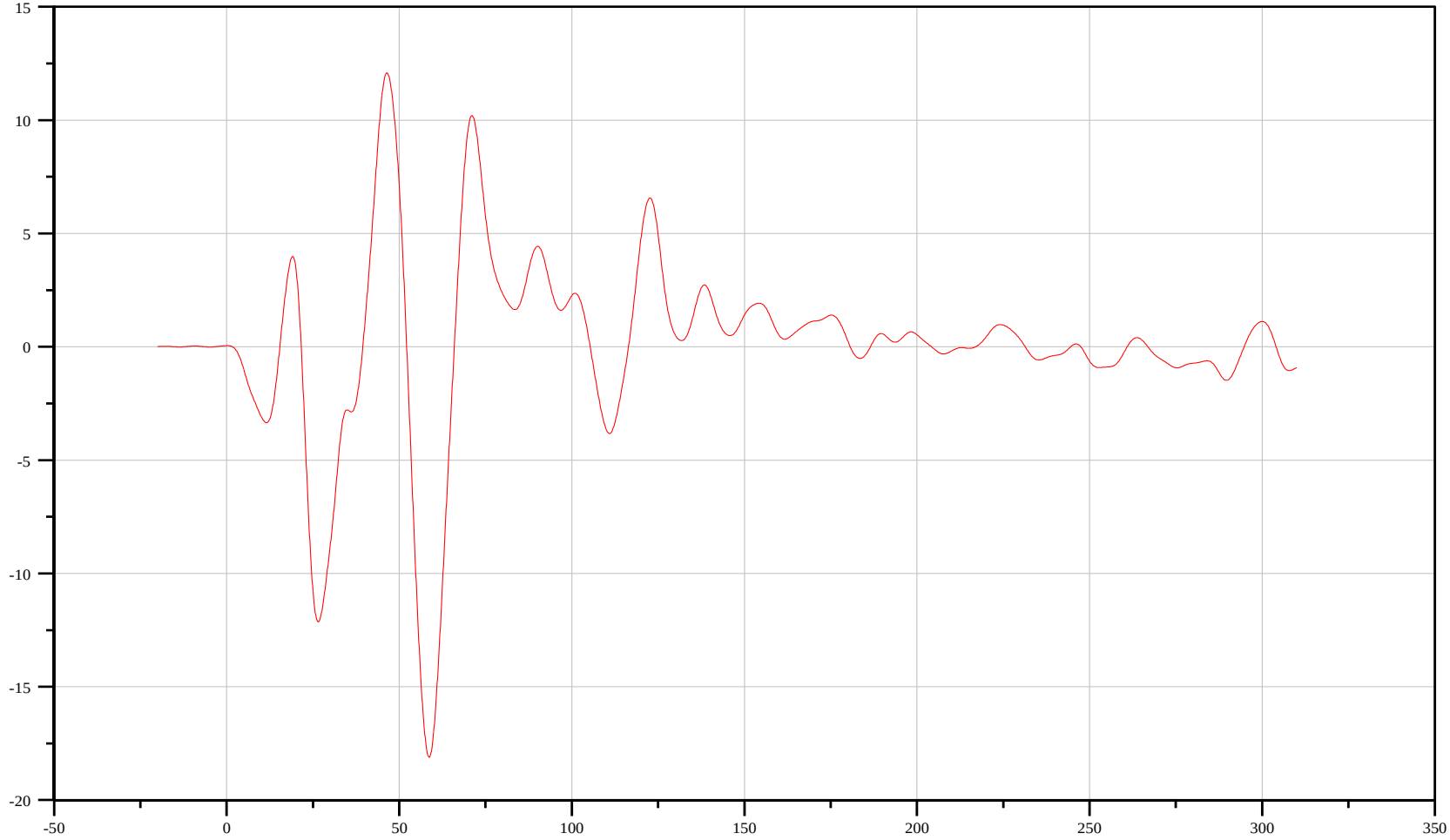
Front Container, Passenger Z-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTFR0000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

	Min. Value	Max. Value
	-18.11 g at 58.70 ms	12.09 g at 46.40 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

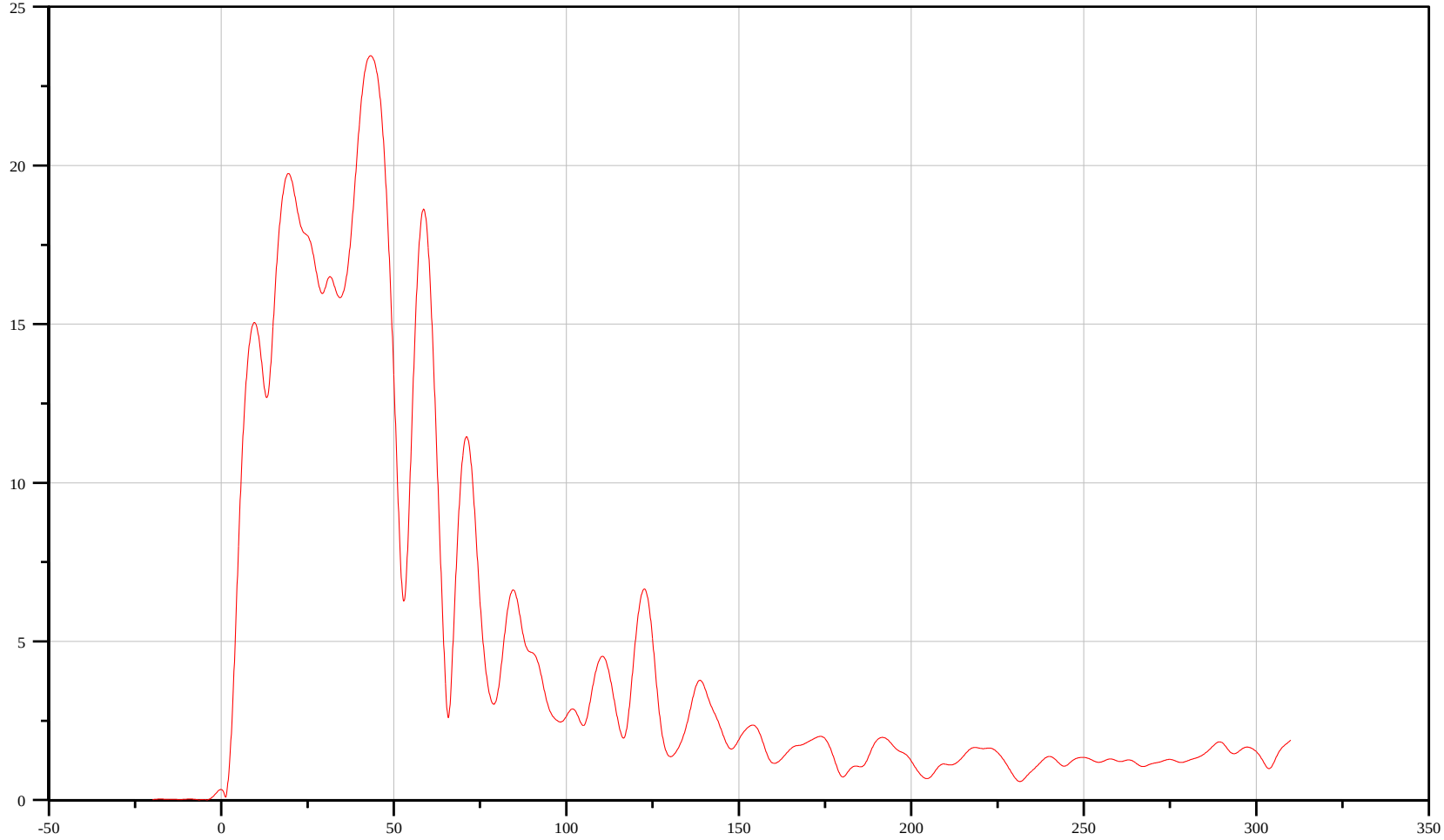
Front Container, Passenger Resultant Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTFR0000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.01 g at -4.10 ms

Max. Value
23.46 g at 43.30 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

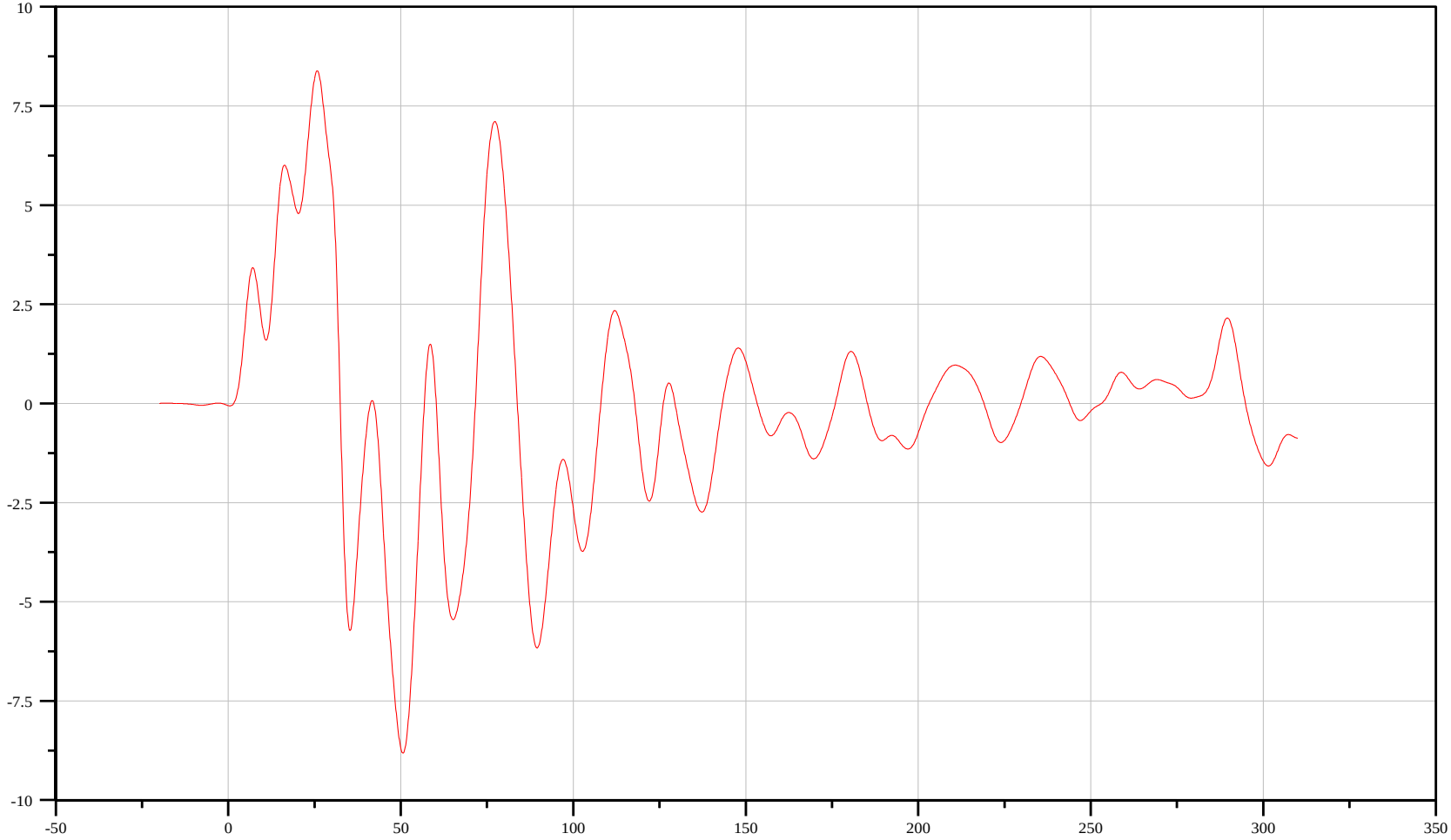
Front Container, Driver X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTFR0000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-8.82 g at 50.60 ms

Max. Value
8.39 g at 25.80 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

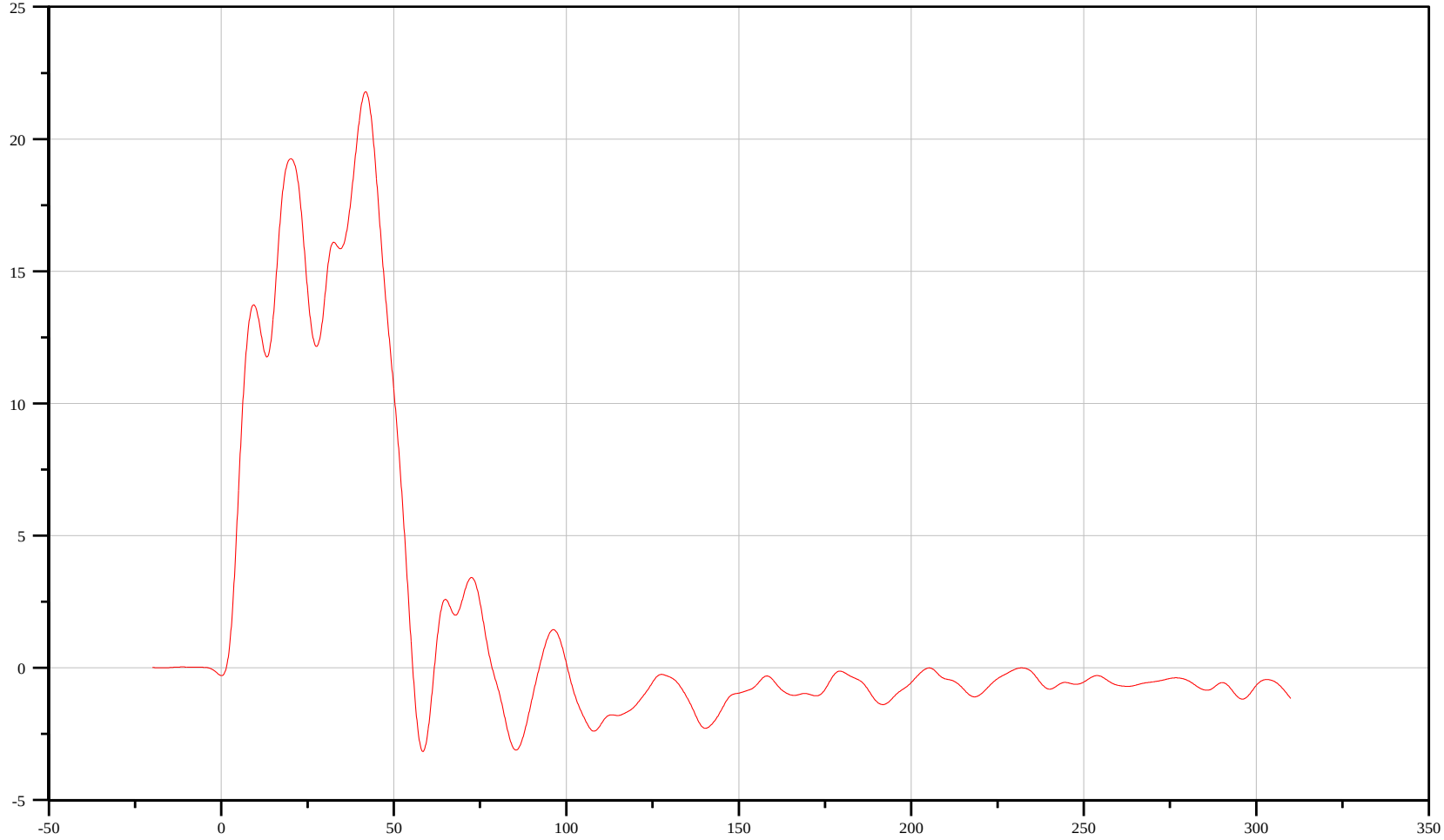
Front Container, Driver Y-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTFR0000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-3.16 g at 58.40 ms

Max. Value
21.79 g at 41.80 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

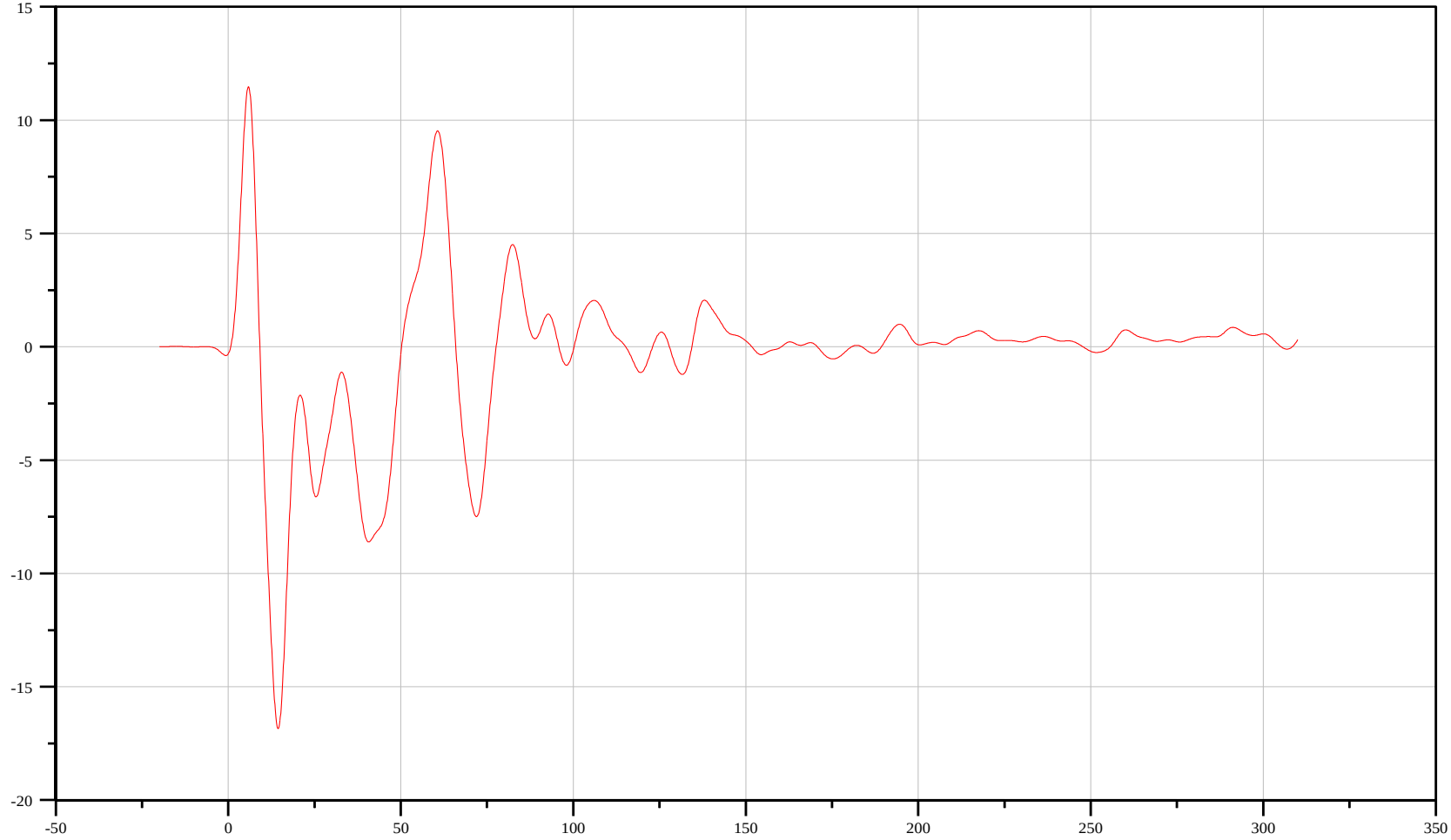
Front Container, Driver Z-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTFR0000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

	Min. Value	Max. Value
	-16.84 g at 14.50 ms	11.48 g at 5.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

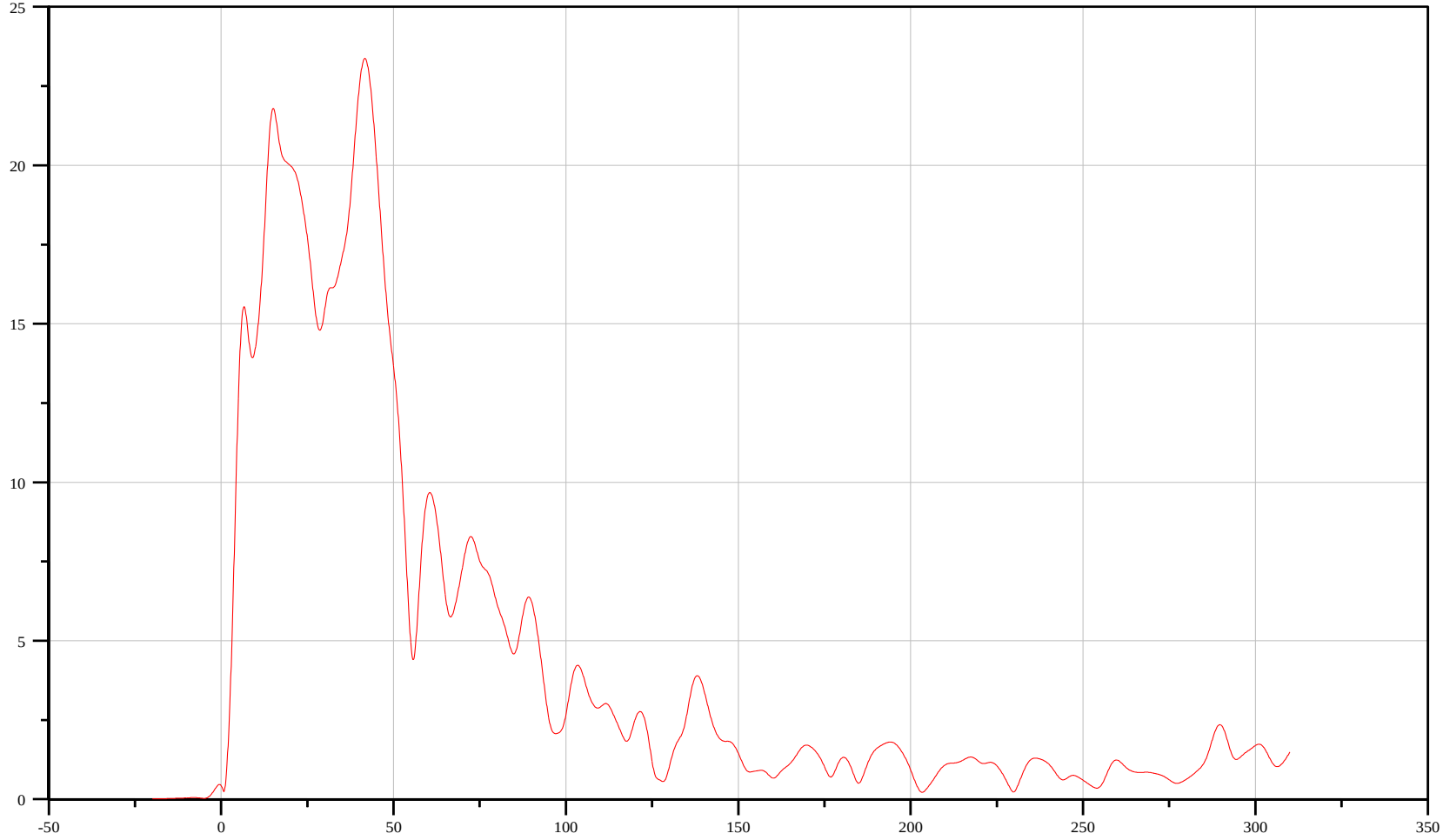
Front Container, Driver Resultant Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTFR0000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.01 g at -19.60 ms

Max. Value
23.37 g at 41.70 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

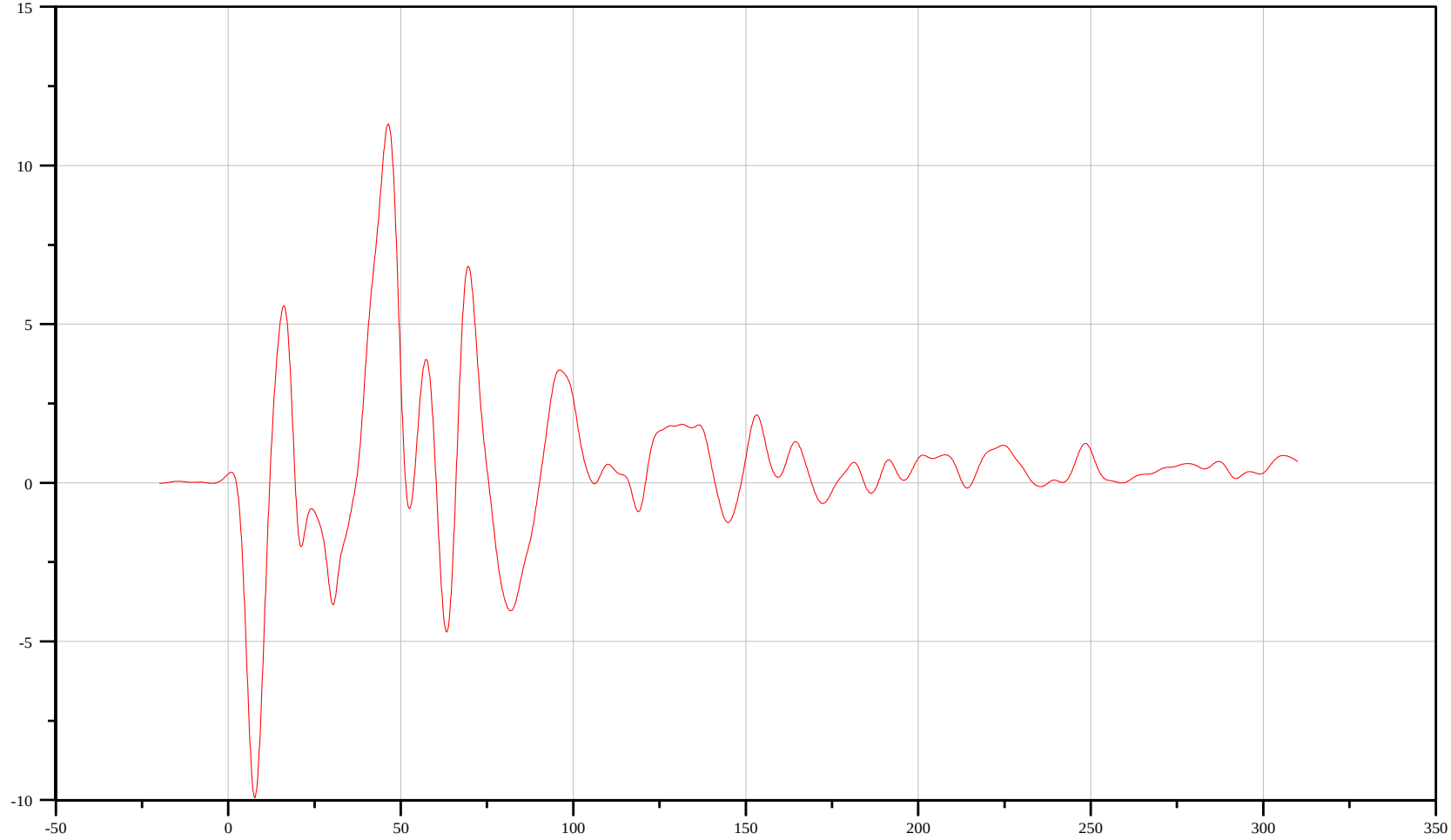
Middle Container, Passenger X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTMI0000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-9.92 g at 7.70 ms

Max. Value
11.31 g at 46.40 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

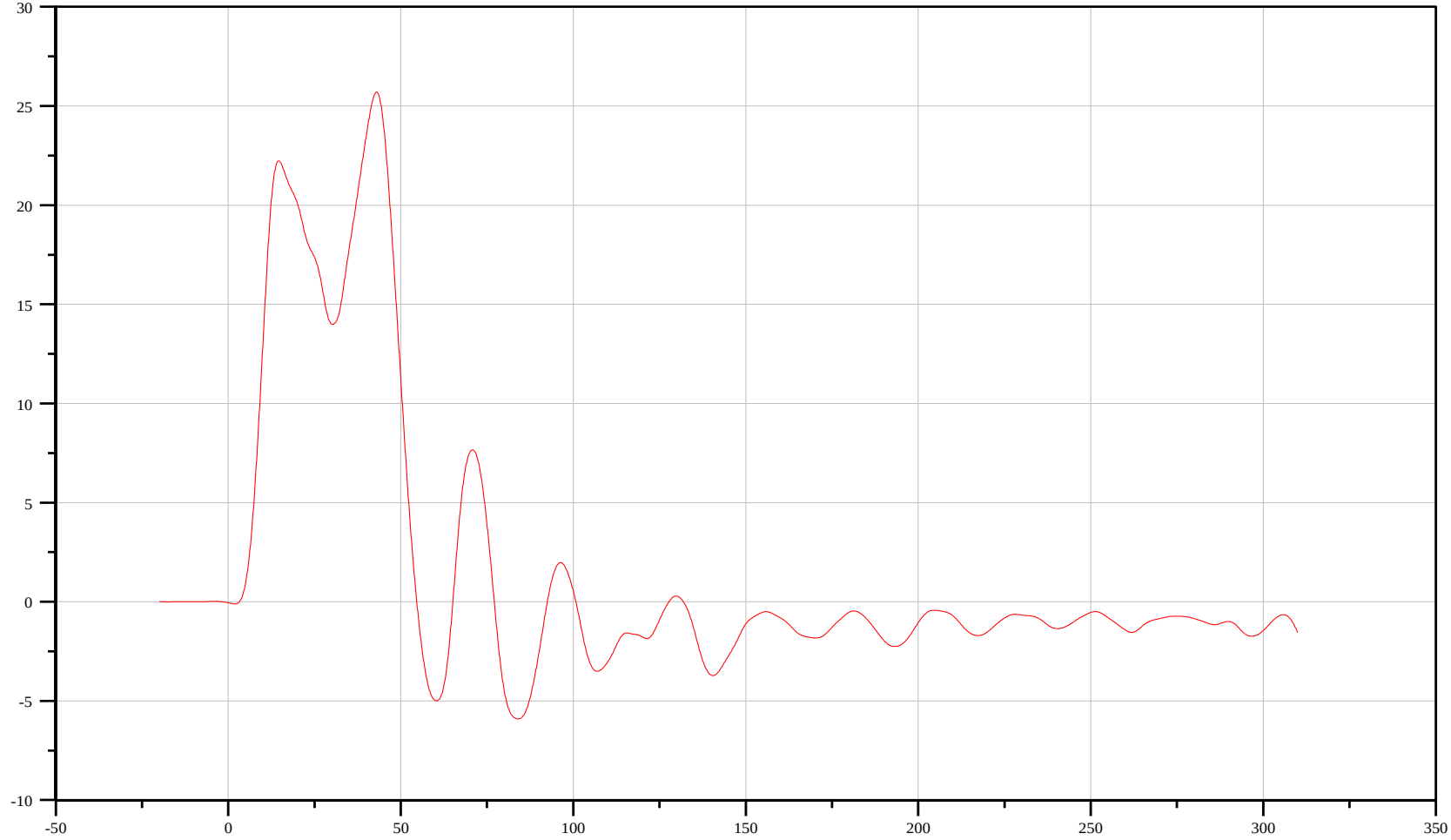
Middle Container, Passenger Y-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTMI0000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-5.91 g at 84.00 ms

Max. Value
25.70 g at 43.00 ms

Time [ms]

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

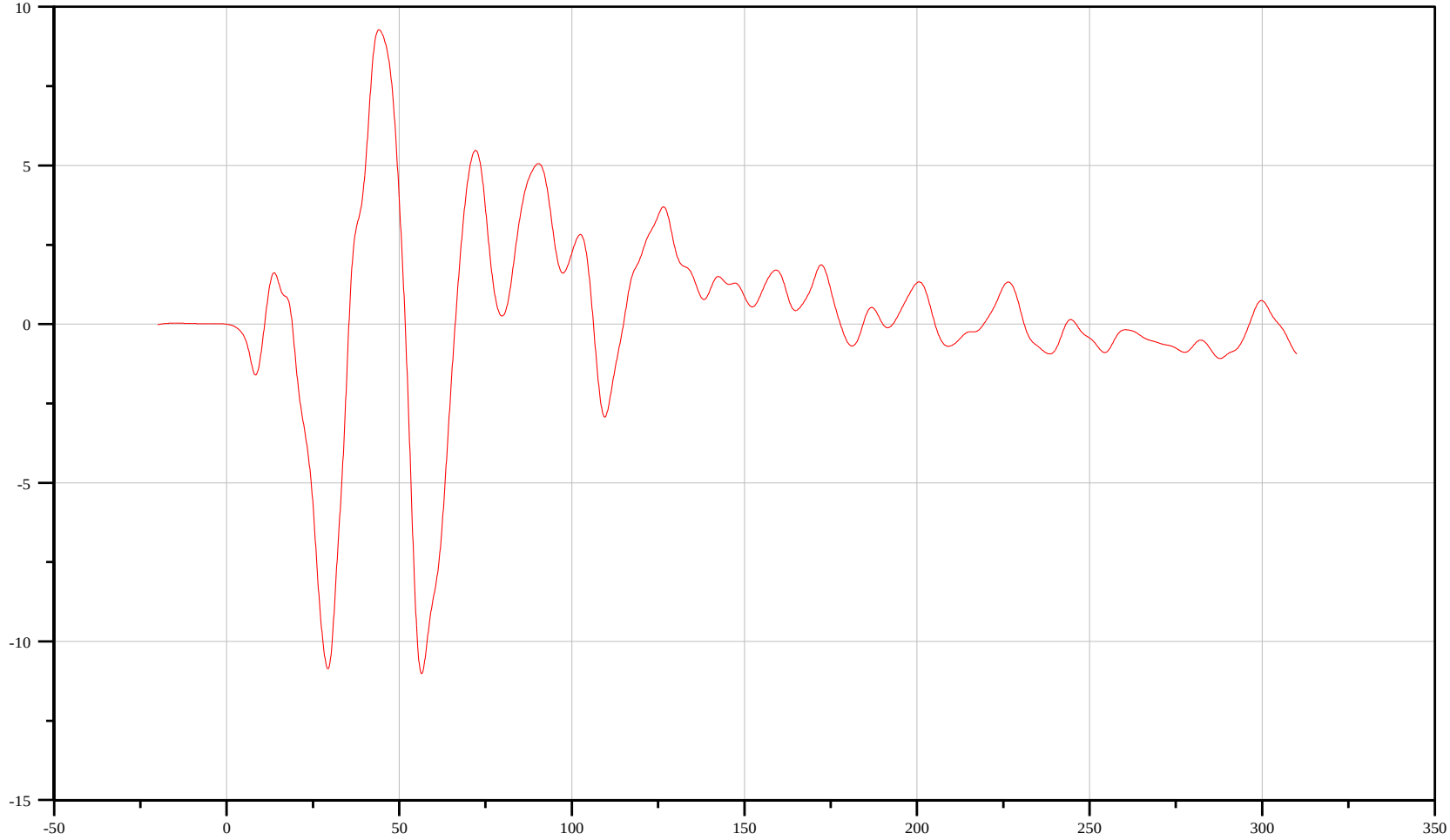
Middle Container, Passenger Z-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTMI0000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-11.01 g at 56.50 ms

Max. Value
9.28 g at 44.10 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

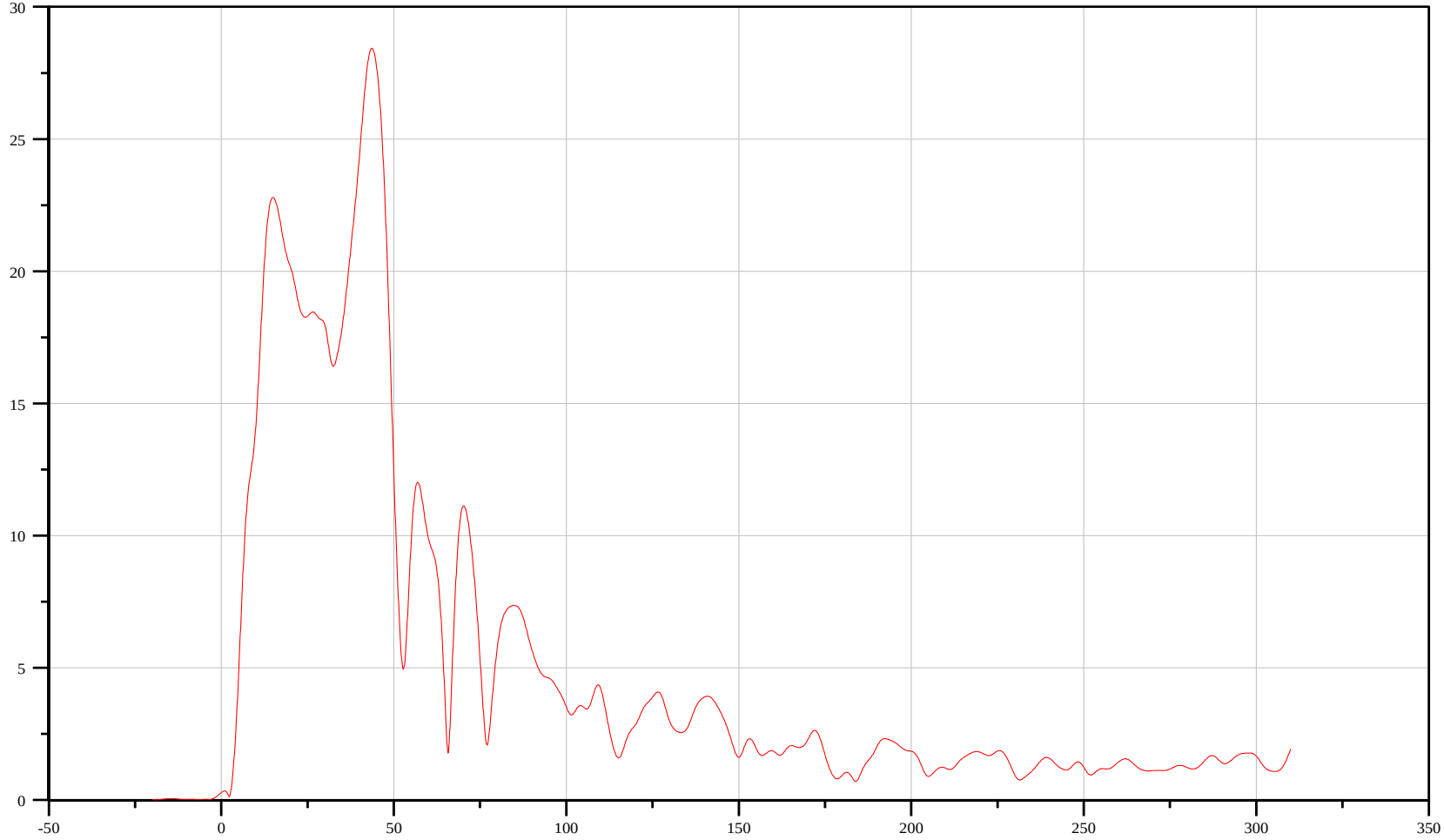
Middle Container, Passenger Resultant Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTMI0000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.01 g at -18.80 ms

Max. Value
28.44 g at 43.60 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

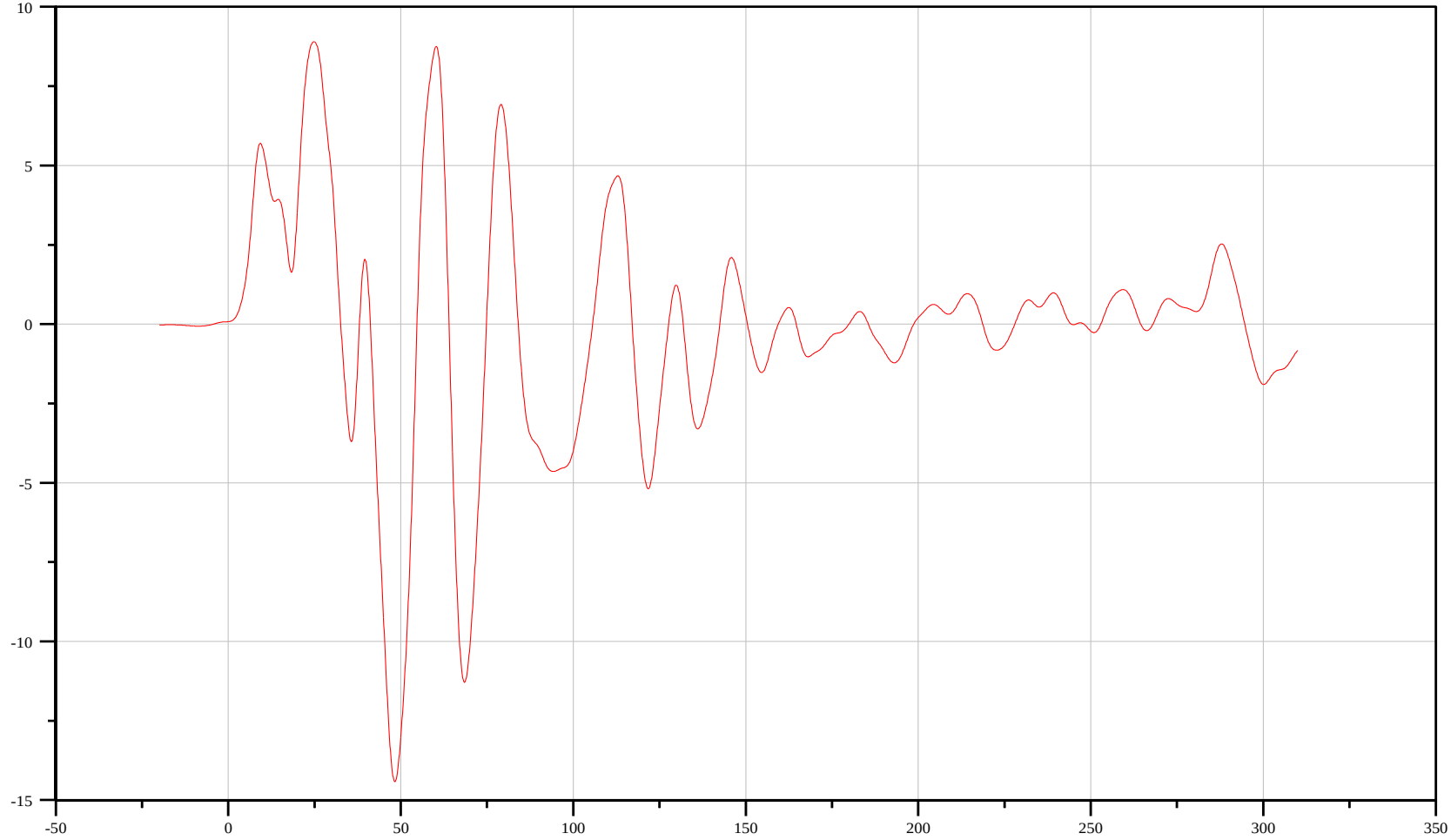
Middle Container, Driver X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTMI0000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-14.42 g at 48.30 ms

Max. Value
8.90 g at 24.80 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

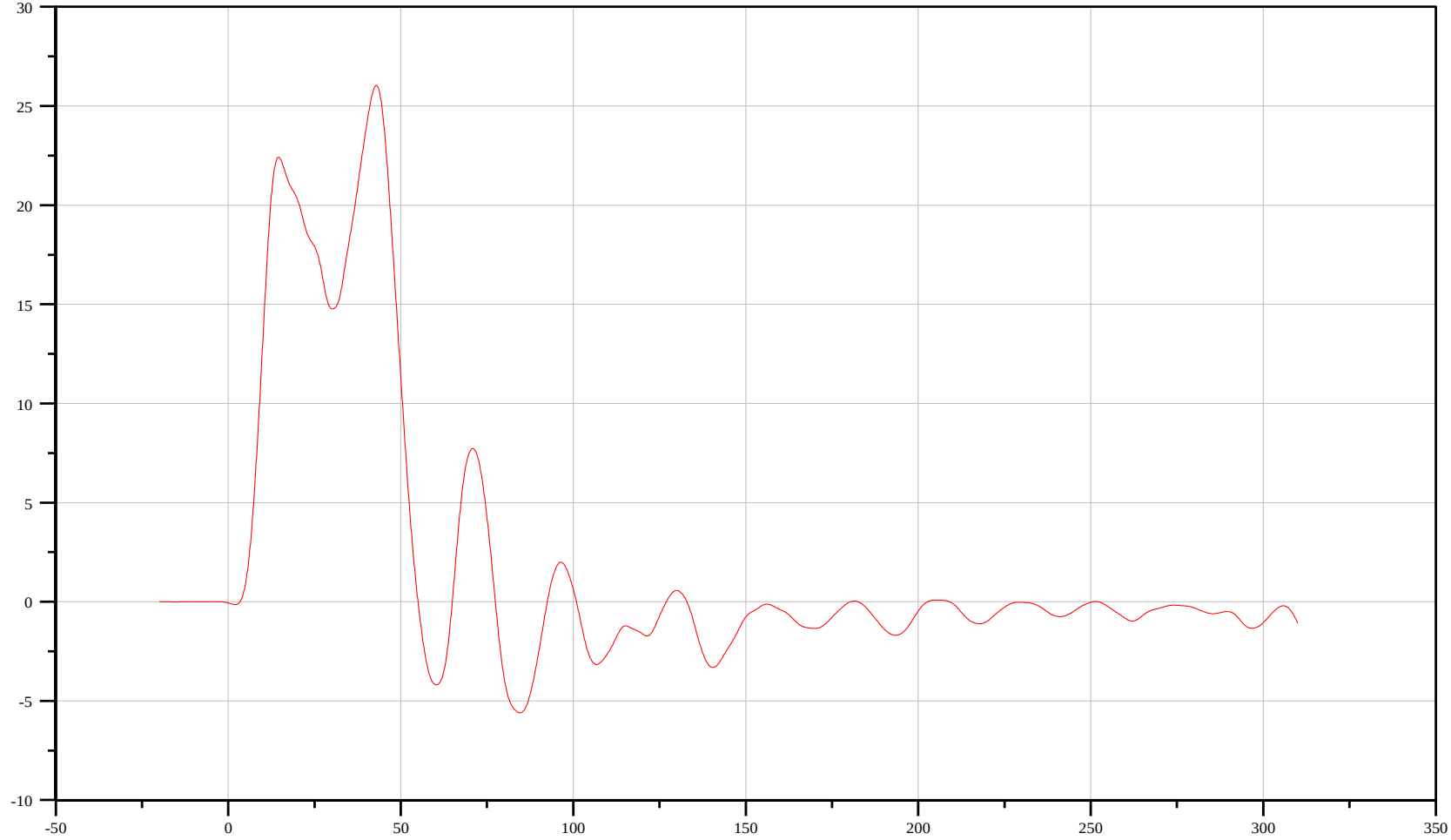
Middle Container, Driver Y-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTMI0000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-5.60 g at 84.60 ms

Max. Value
26.04 g at 42.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

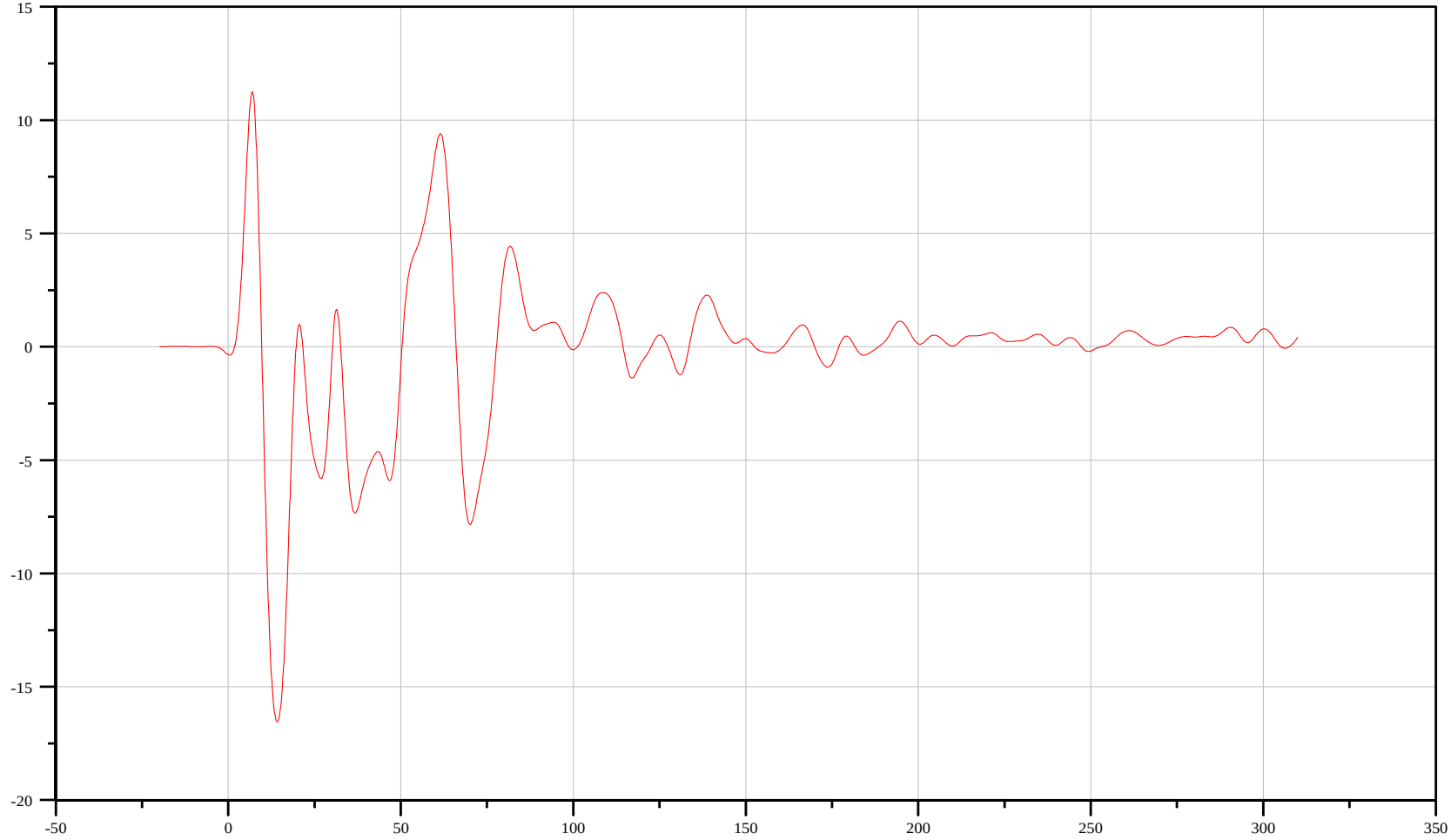
Middle Container, Driver Z-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTMI0000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-16.55 g at 14.20 ms

Max. Value
11.25 g at 7.00 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

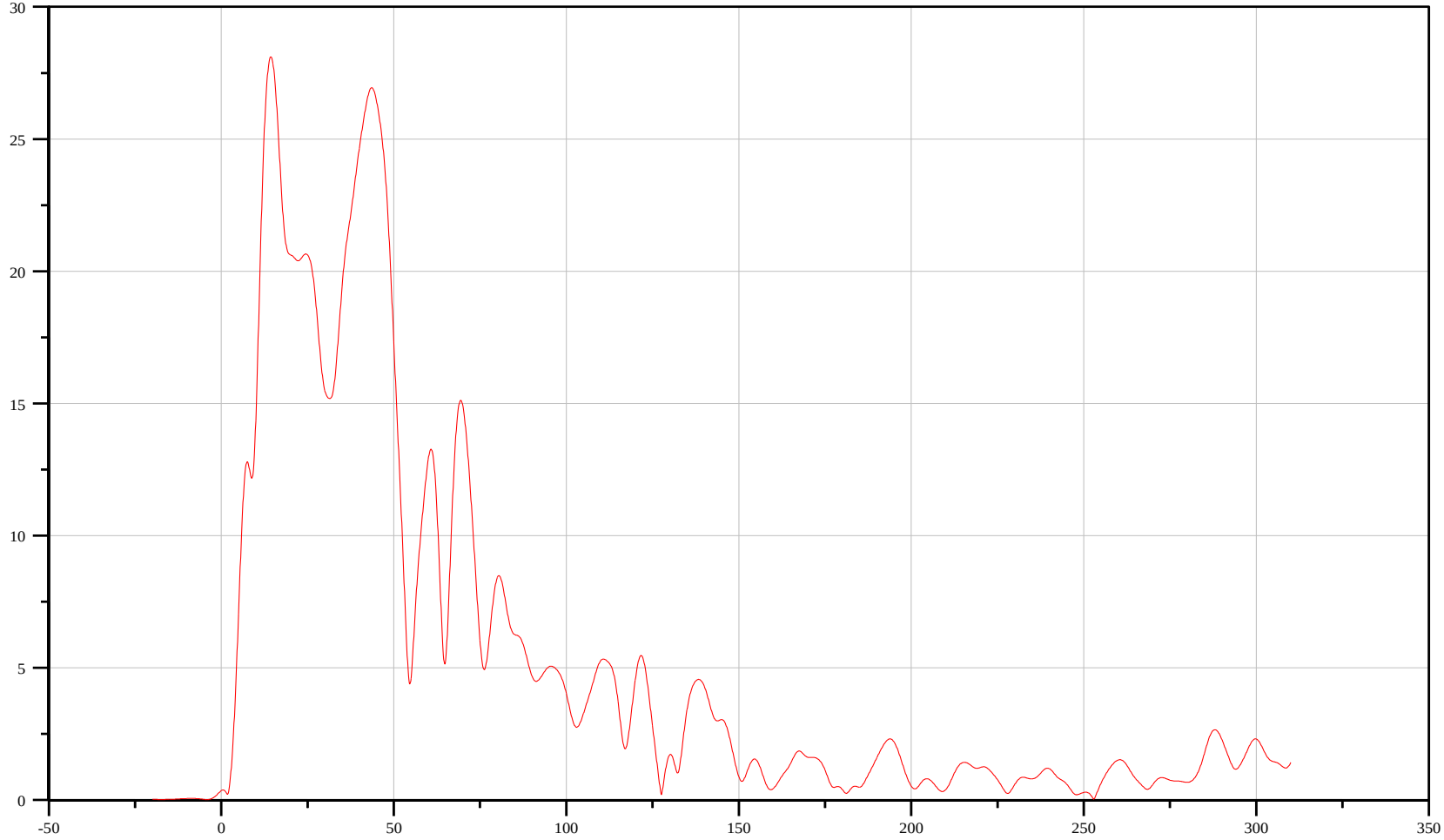
Middle Container, Driver Resultant Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTMI0000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.02 g at -4.20 ms

Max. Value
28.11 g at 14.40 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

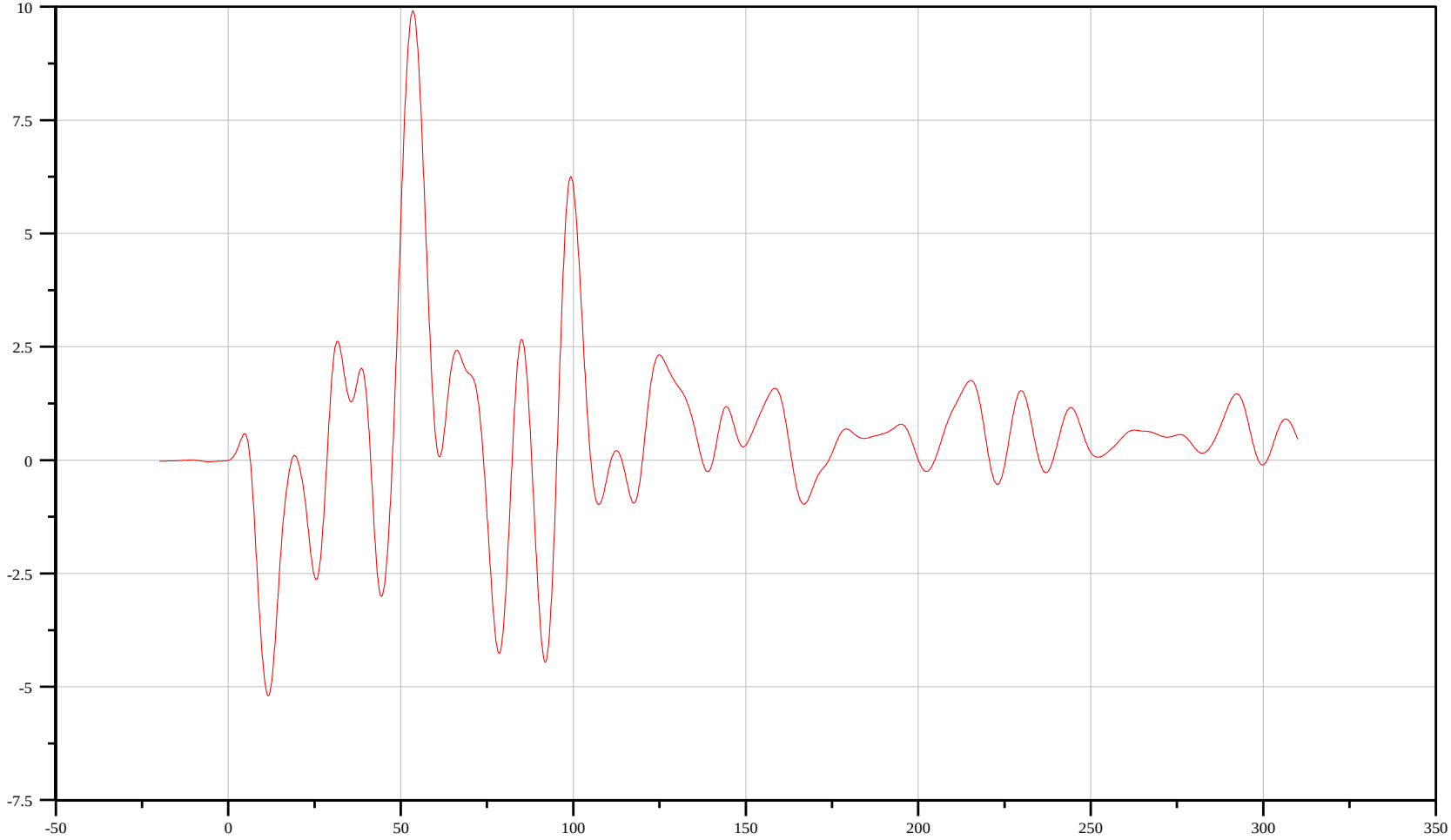
Rear Container, Passenger X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTRE0000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-5.20 g at 11.60 ms

Max. Value
9.91 g at 53.50 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

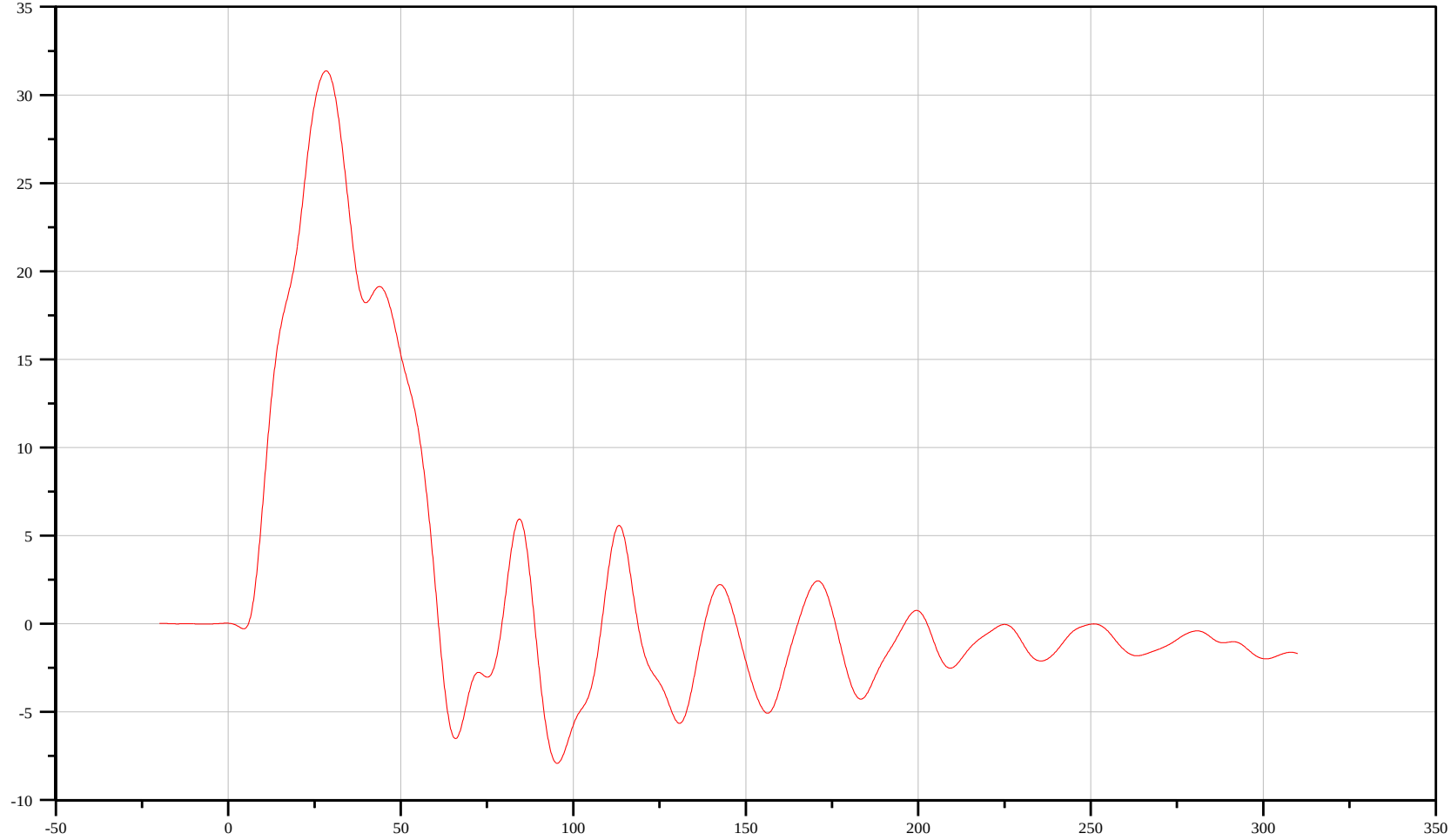
Rear Container, Passenger Y-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTRE0000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-7.92 g at 95.30 ms

Max. Value
31.37 g at 28.40 ms

Time [ms]

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

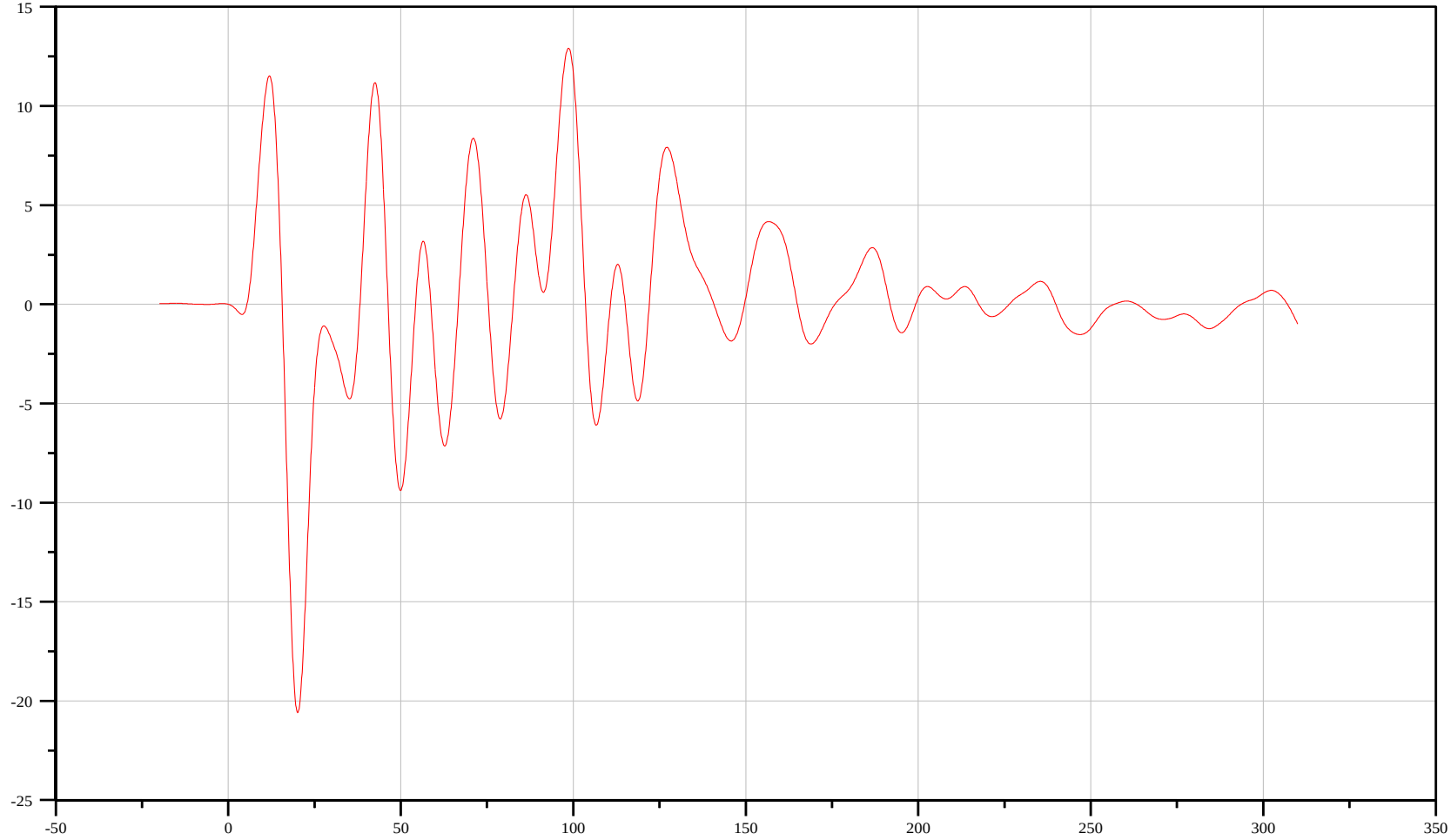
Rear Container, Passenger Z-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTRE0000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-20.59 g at 20.10 ms

Max. Value
12.92 g at 98.60 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

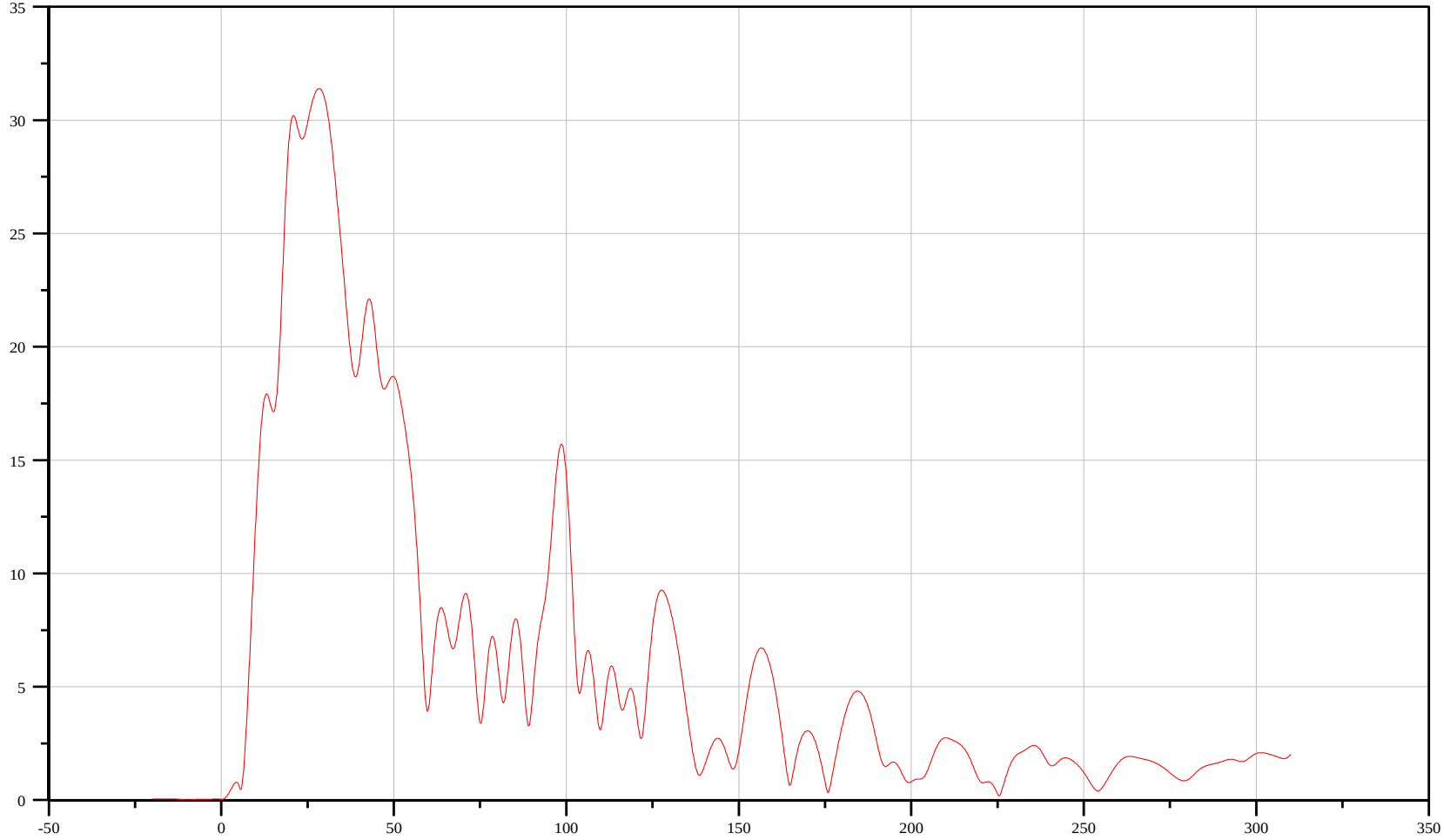
Rear Container, Passenger Resultant Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTRE0000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.01 g at -9.40 ms

Max. Value
31.39 g at 28.40 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

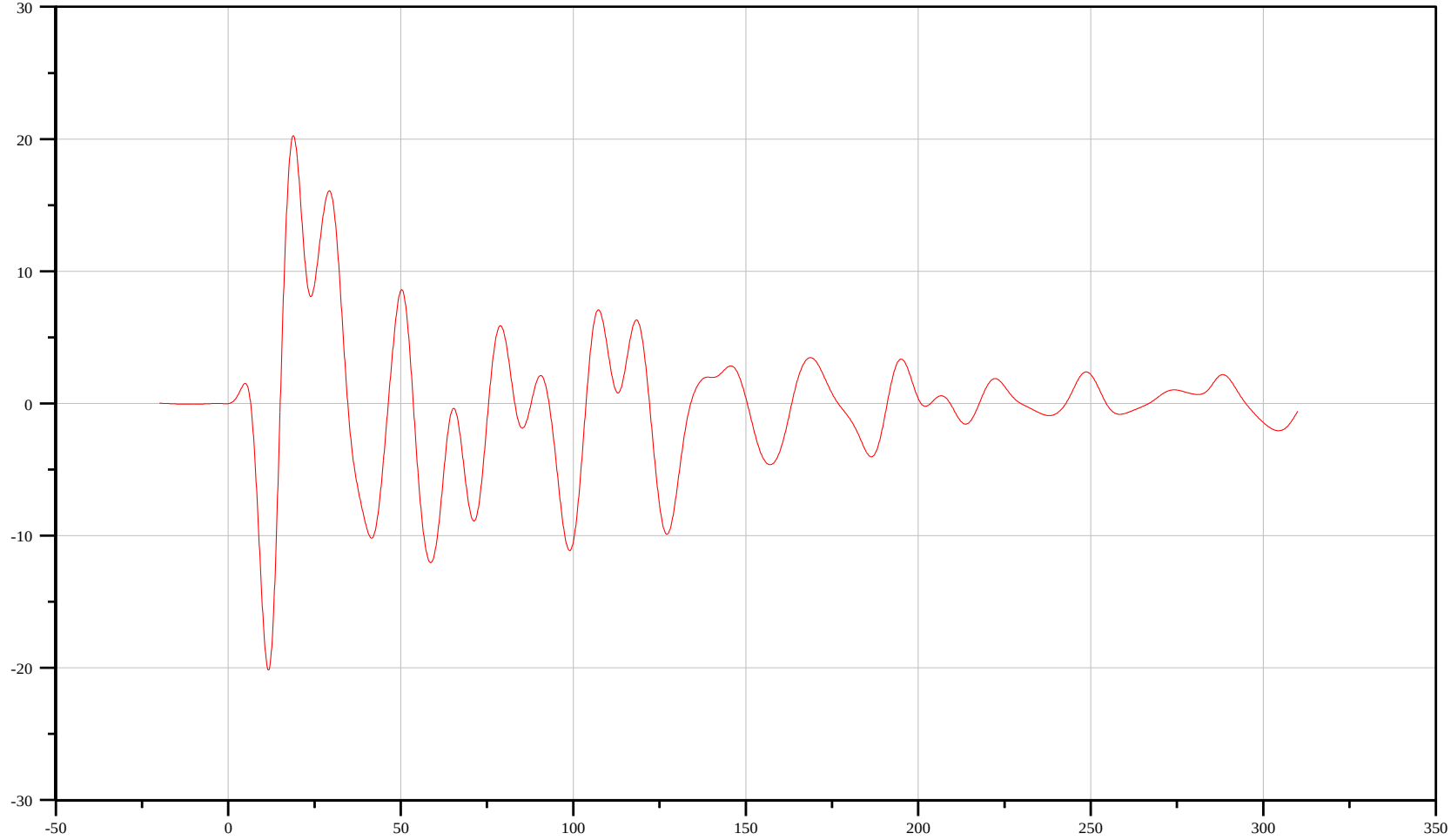
Rear Container, Driver X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTRE0000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-20.17 g at 11.70 ms

Max. Value
20.26 g at 18.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

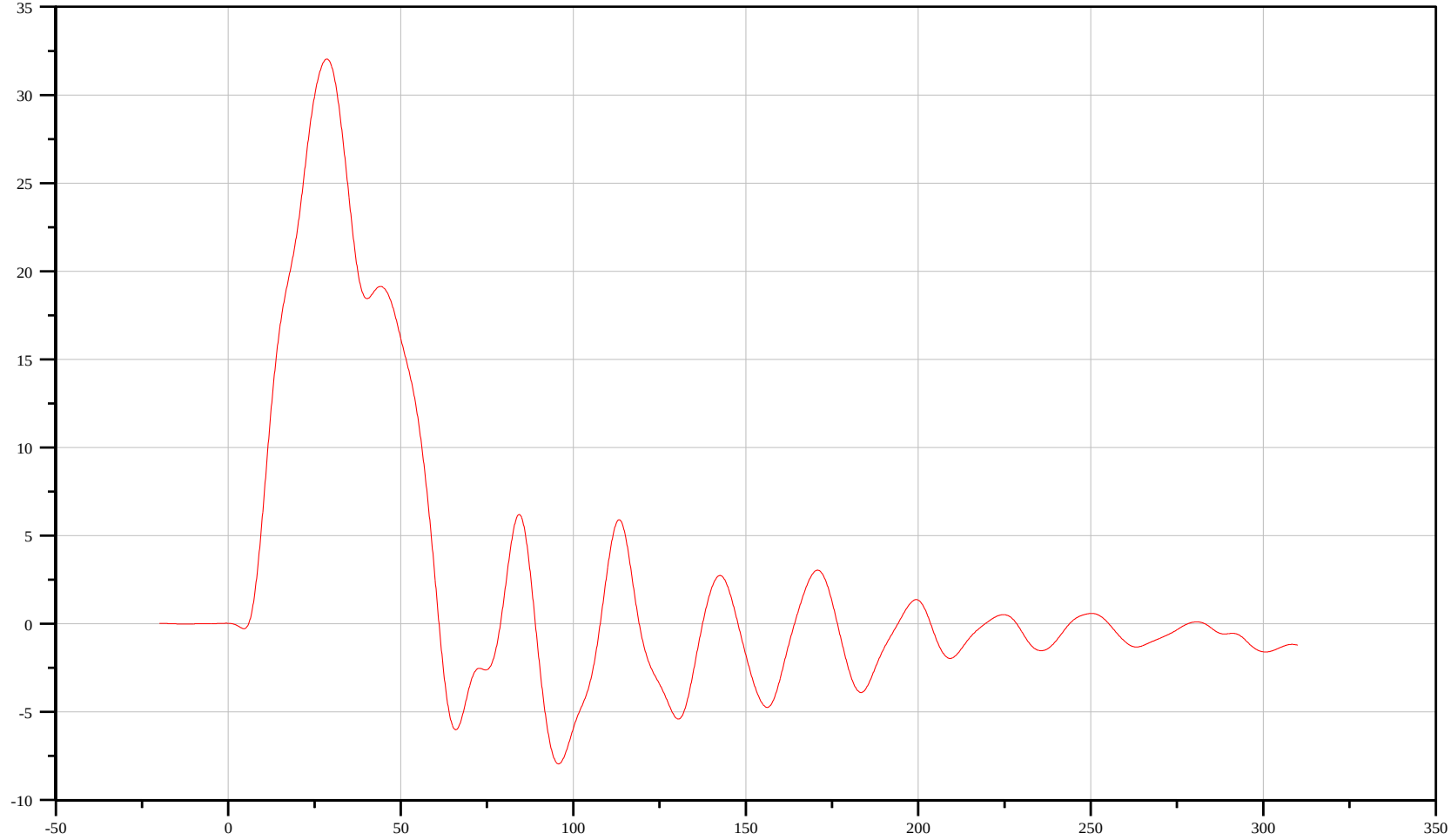
Rear Container, Driver Y-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTRE0000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-7.95 g at 95.70 ms

Max. Value
32.04 g at 28.60 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

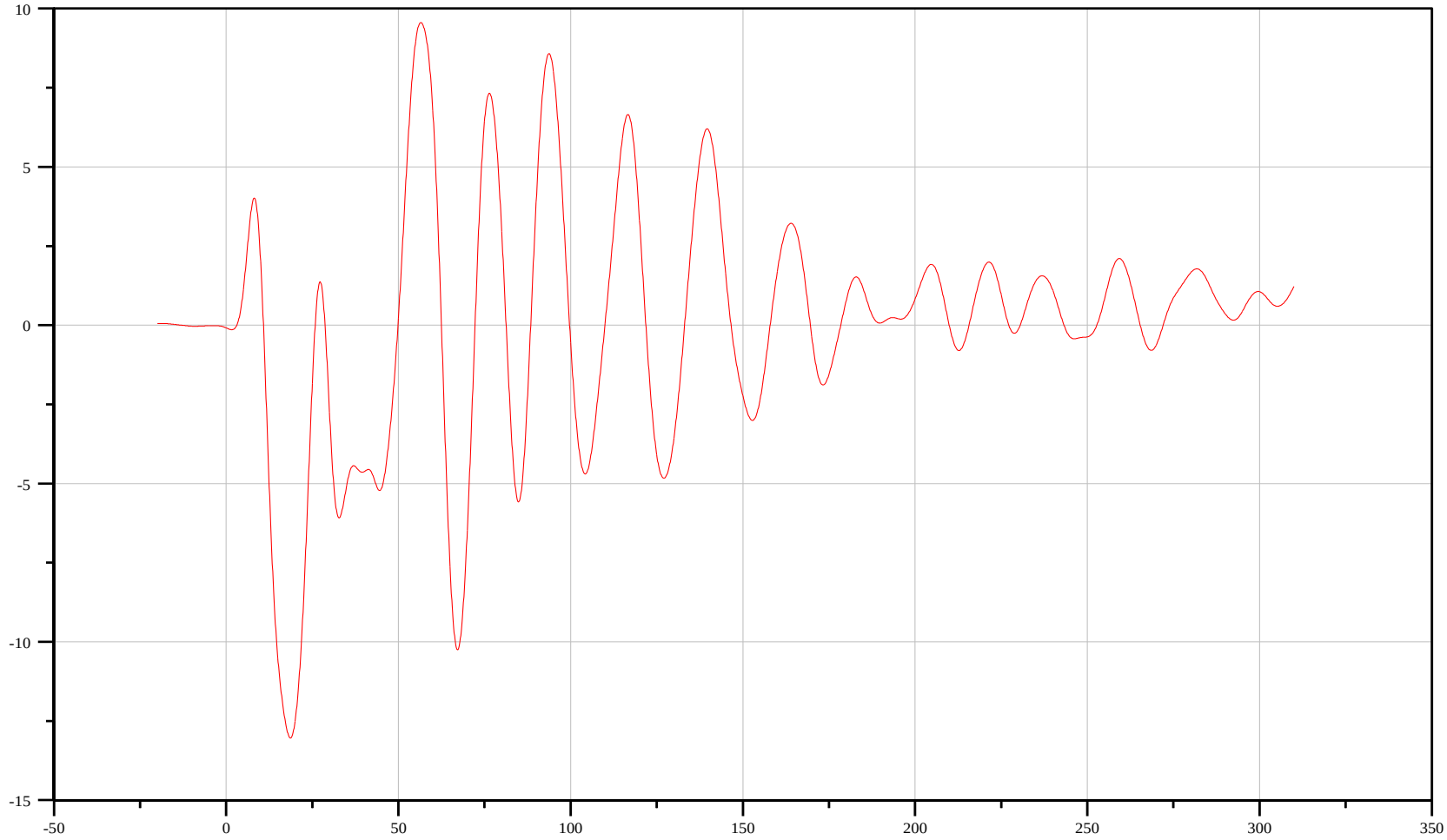
Rear Container, Driver Z-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTRE0000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-13.04 g at 18.70 ms

Max. Value
9.56 g at 56.50 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

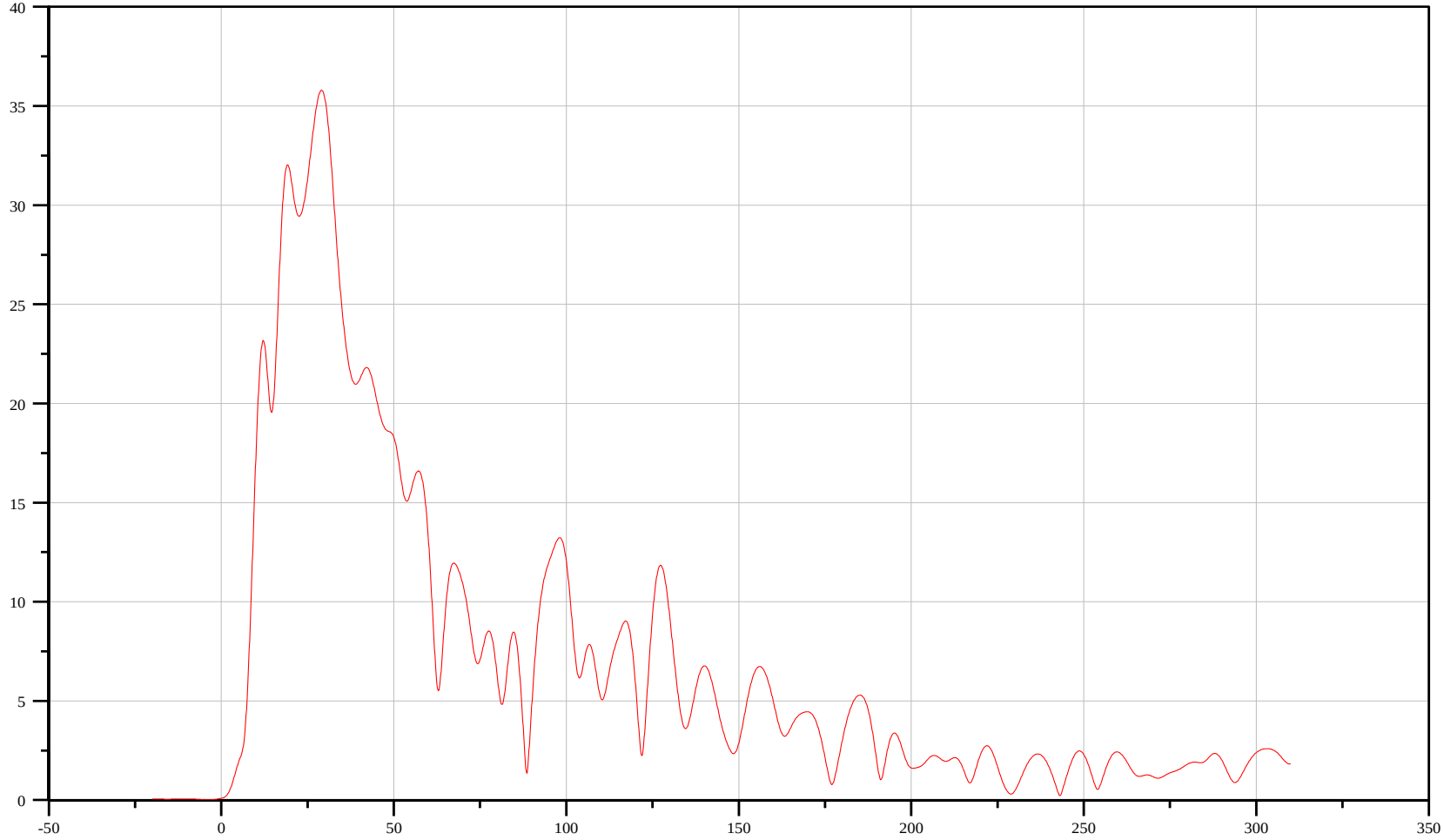
Date: 04/16/2012
Time: 08:34

Rear Container, Driver Resultant Acceleration

Customer: Battelle

11CONTRE0000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.02 g at -4.20 ms

Max. Value
35.80 g at 29.10 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

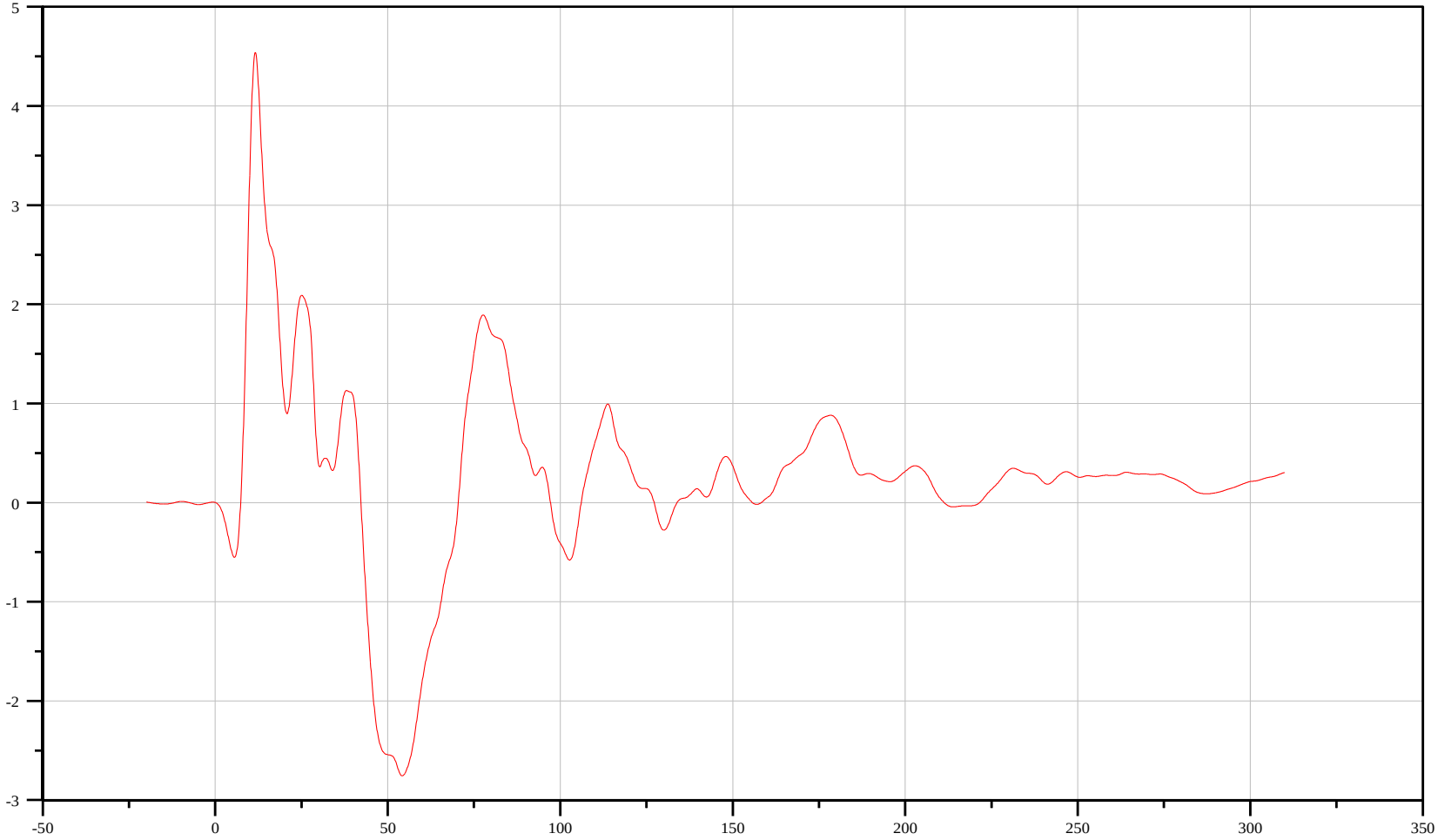
Engine X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10ENGN000000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-2.76 g at 54.20 ms

Max. Value
4.54 g at 11.60 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

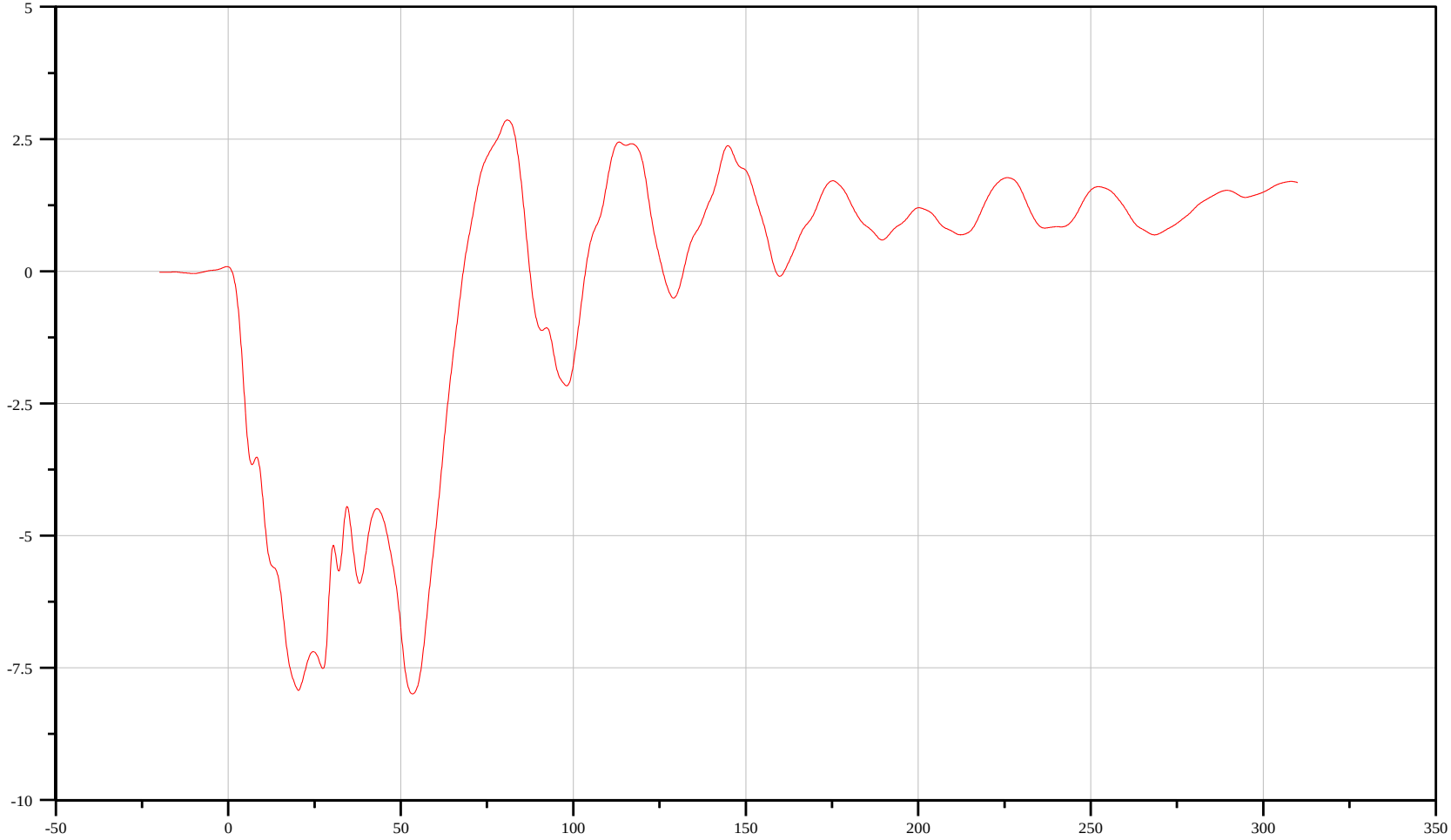
Engine Y-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10ENGN000000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-7.99 g at 53.40 ms

Max. Value
2.86 g at 80.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

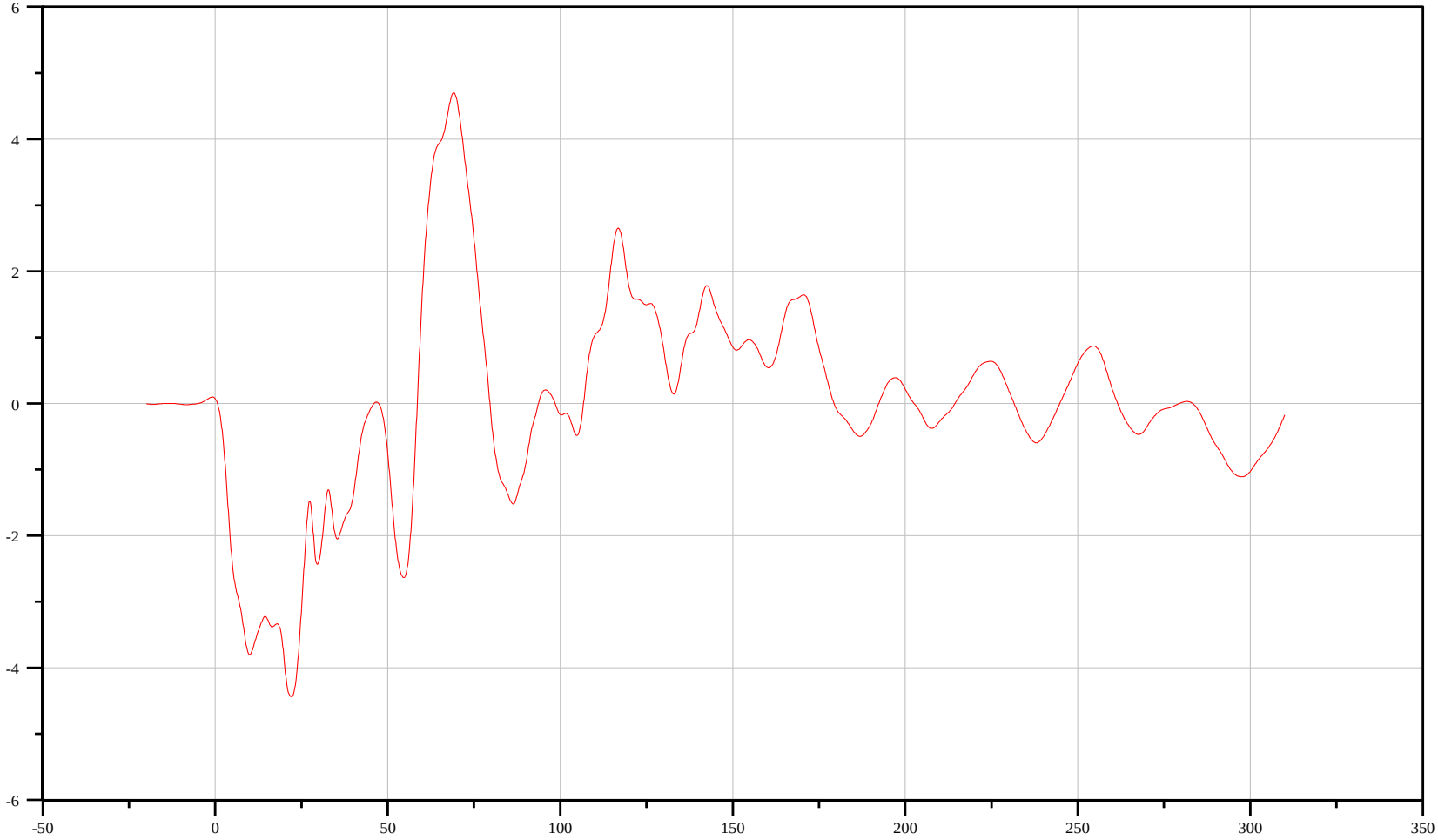
Engine Z-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10ENGN000000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-4.44 g at 22.10 ms

Max. Value
4.70 g at 69.10 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

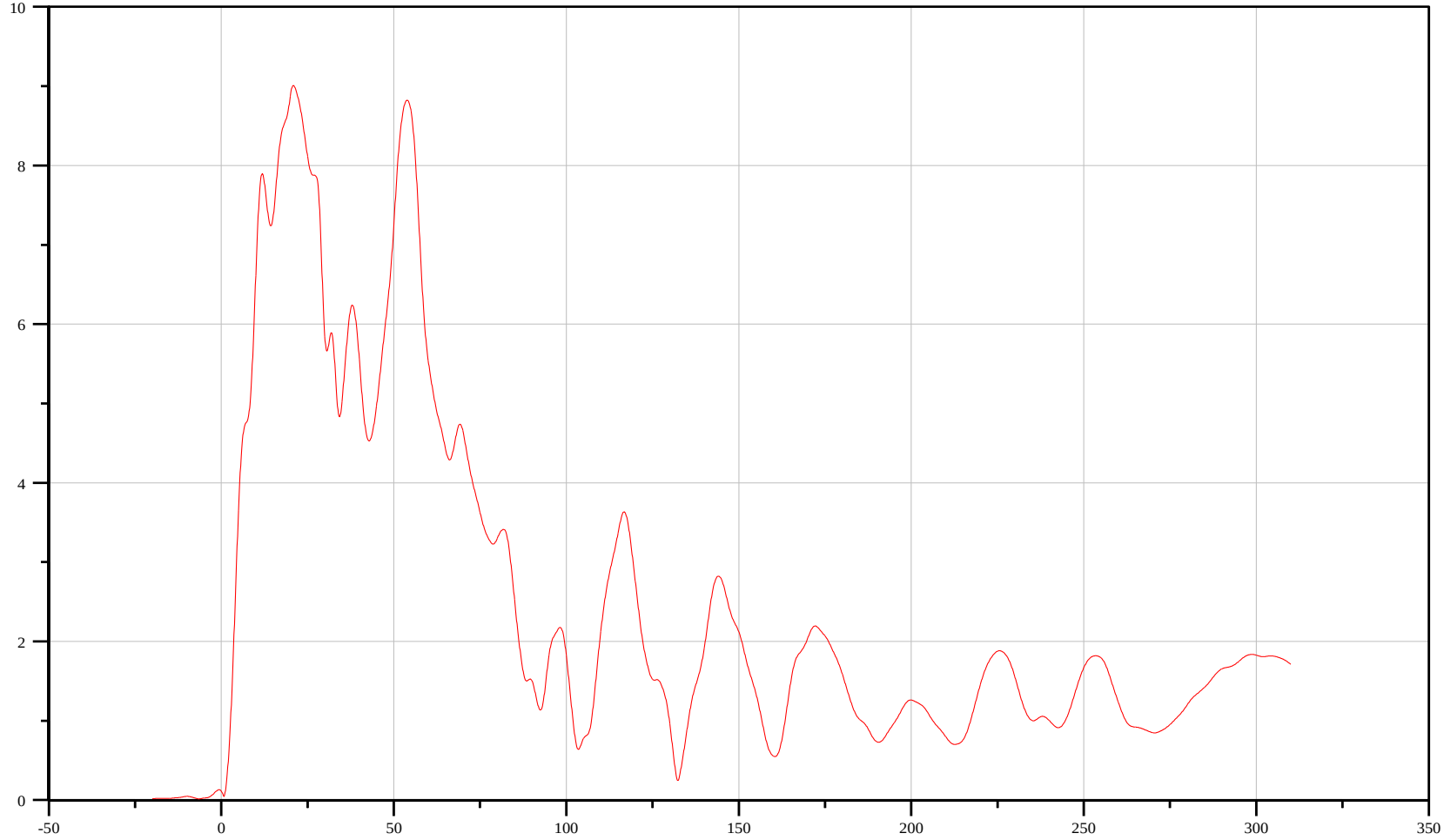
Engine Resultant Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

10ENGN000000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.02 g at -6.50 ms

Max. Value
9.01 g at 20.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

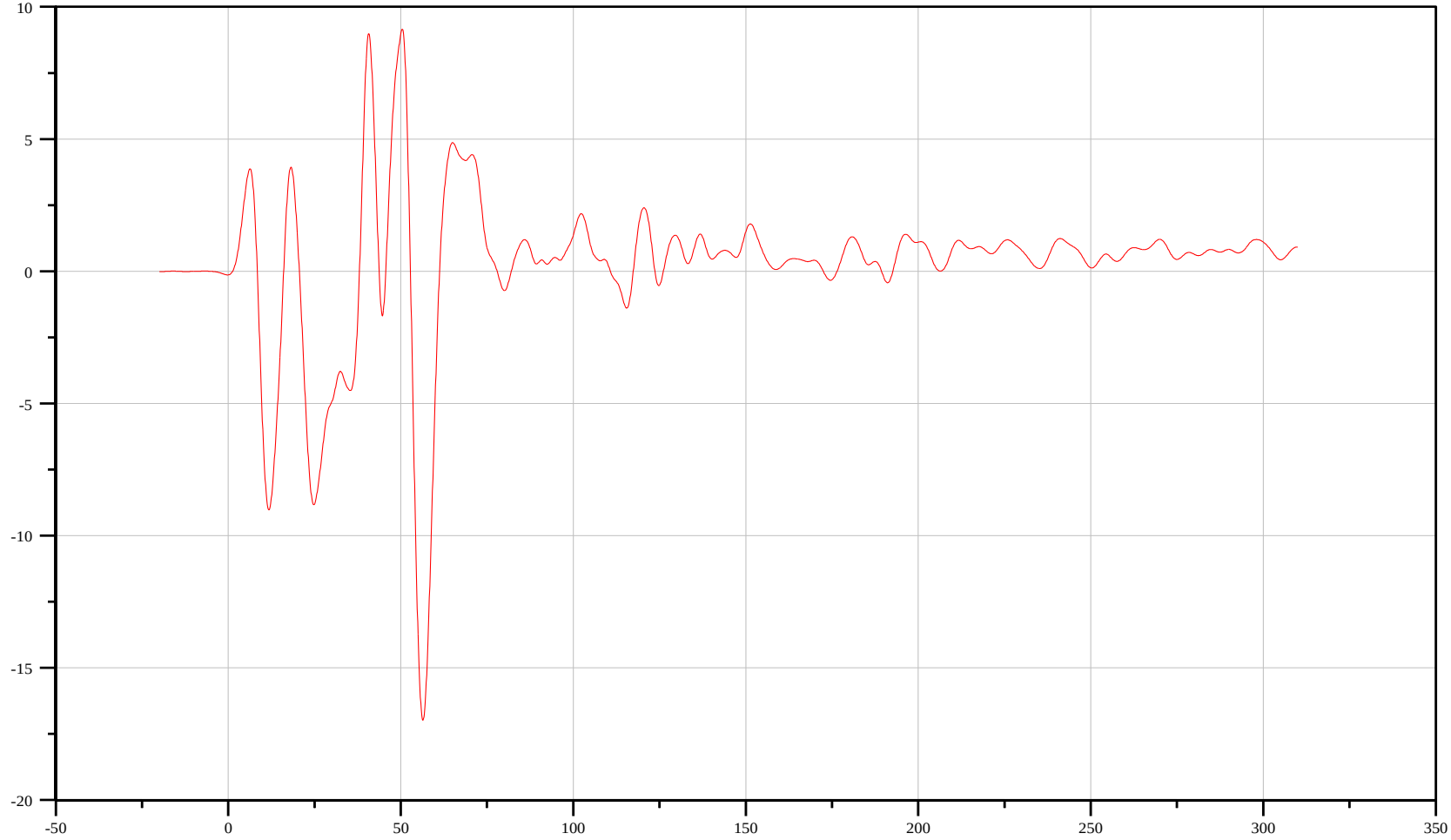
Date: 04/16/2012
Time: 08:34

Battery, Driver X-Axis Acceleration

Customer: Battelle

11BATT000000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-16.98 g at 56.40 ms

Max. Value
9.15 g at 50.40 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

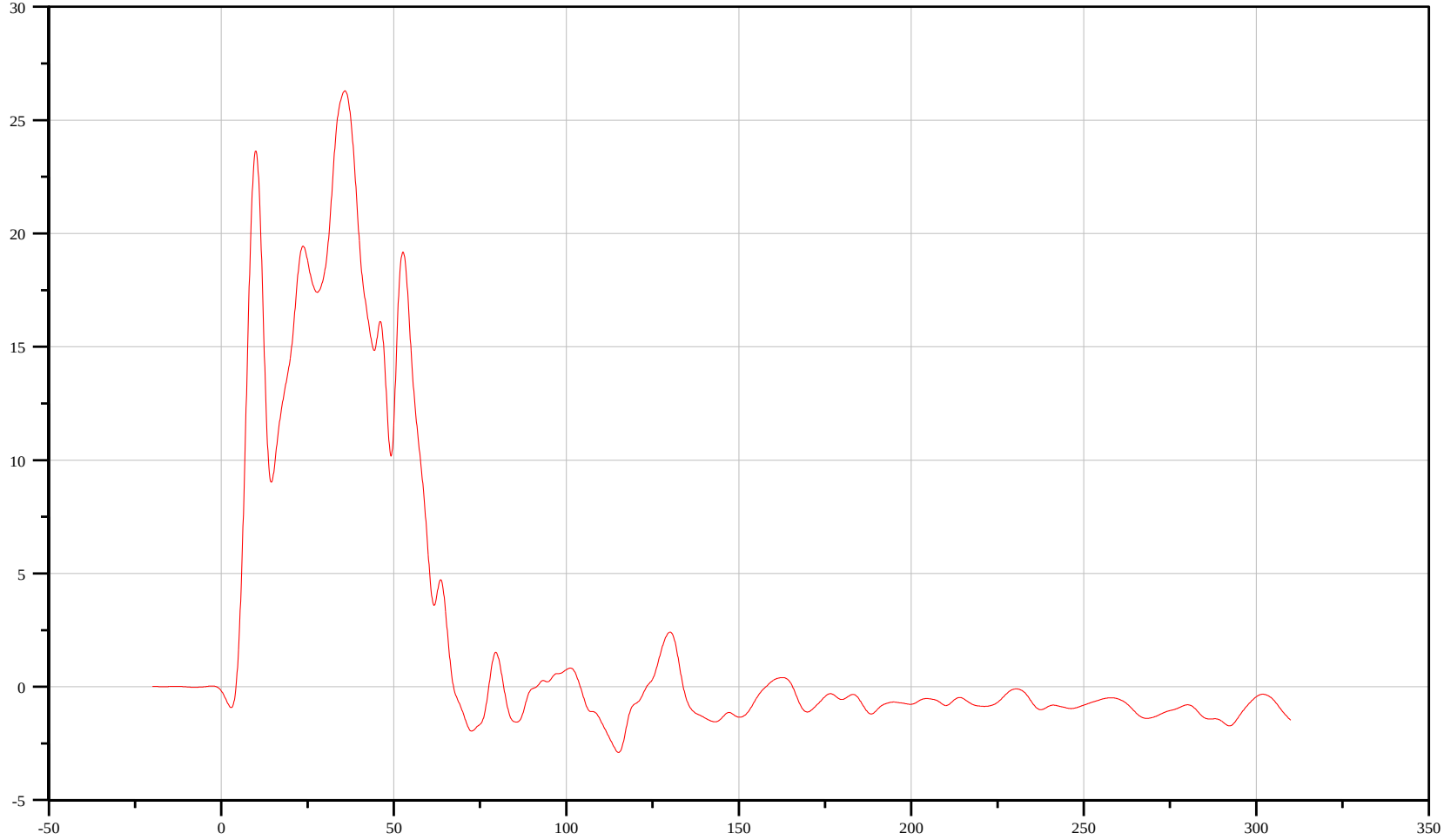
Date: 04/16/2012
Time: 08:34

Battery, Driver Y-Axis Acceleration

Customer: Battelle

11BATT000000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-2.90 g at 115.10 ms

Max. Value
26.30 g at 35.80 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

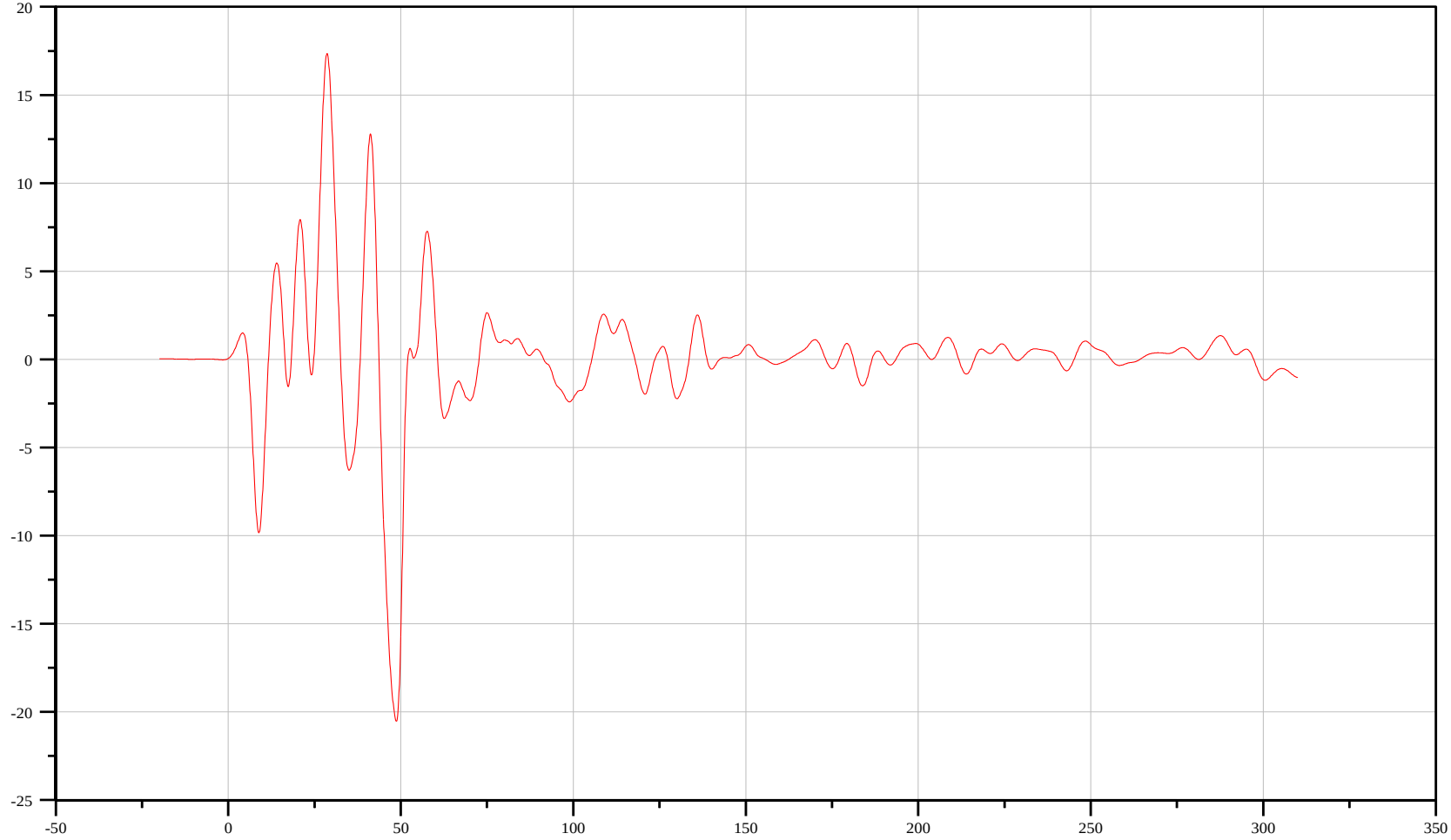
Date: 04/16/2012
Time: 08:34

Battery, Driver Z-Axis Acceleration

Customer: Battelle

11BATT000000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-20.53 g at 48.70 ms

Max. Value
17.35 g at 28.60 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

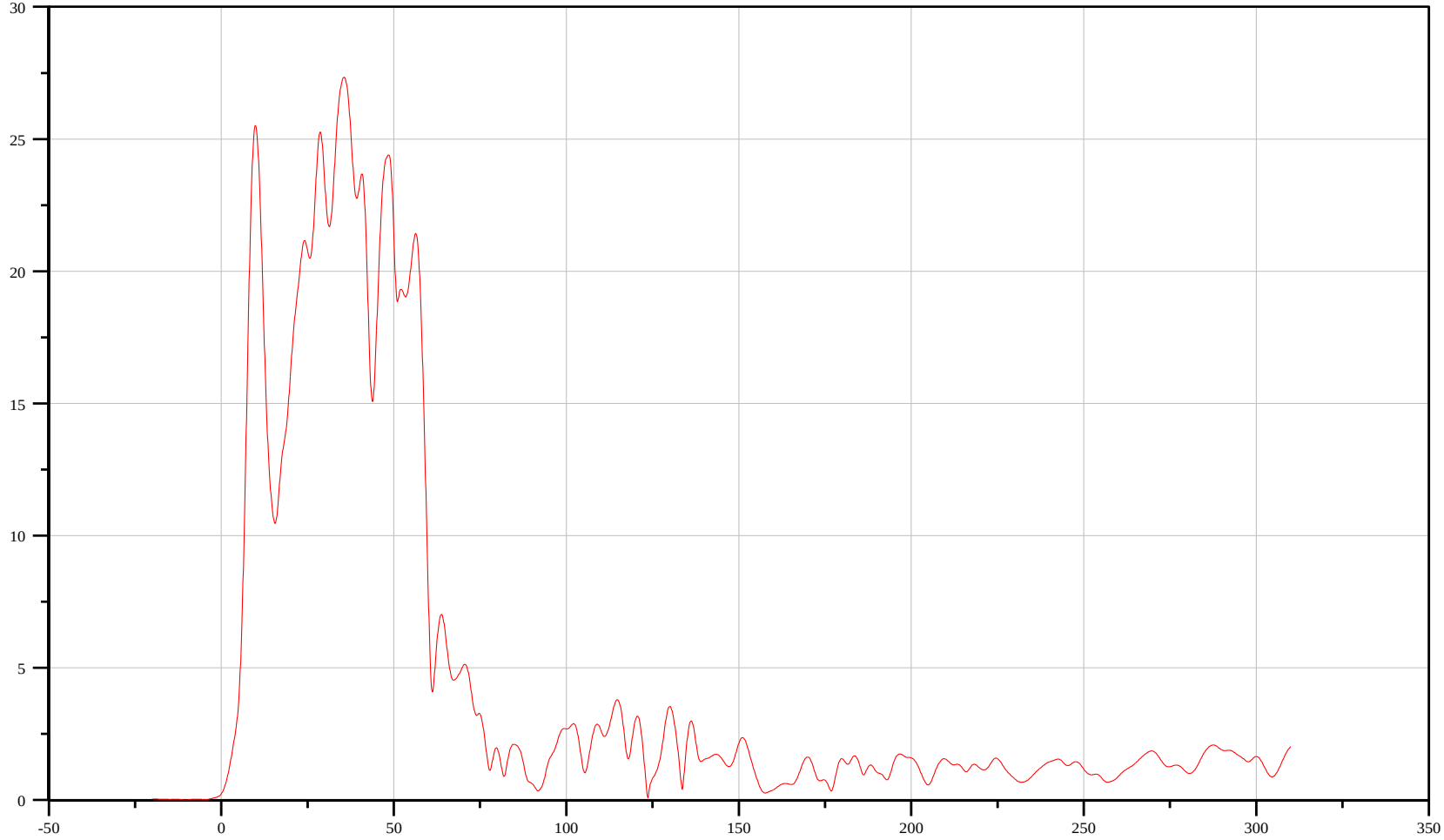
Date: 04/16/2012
Time: 08:34

Battery, Driver Resultant Acceleration

Customer: Battelle

11BATT000000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.01 g at -10.40 ms

Max. Value
27.34 g at 35.60 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

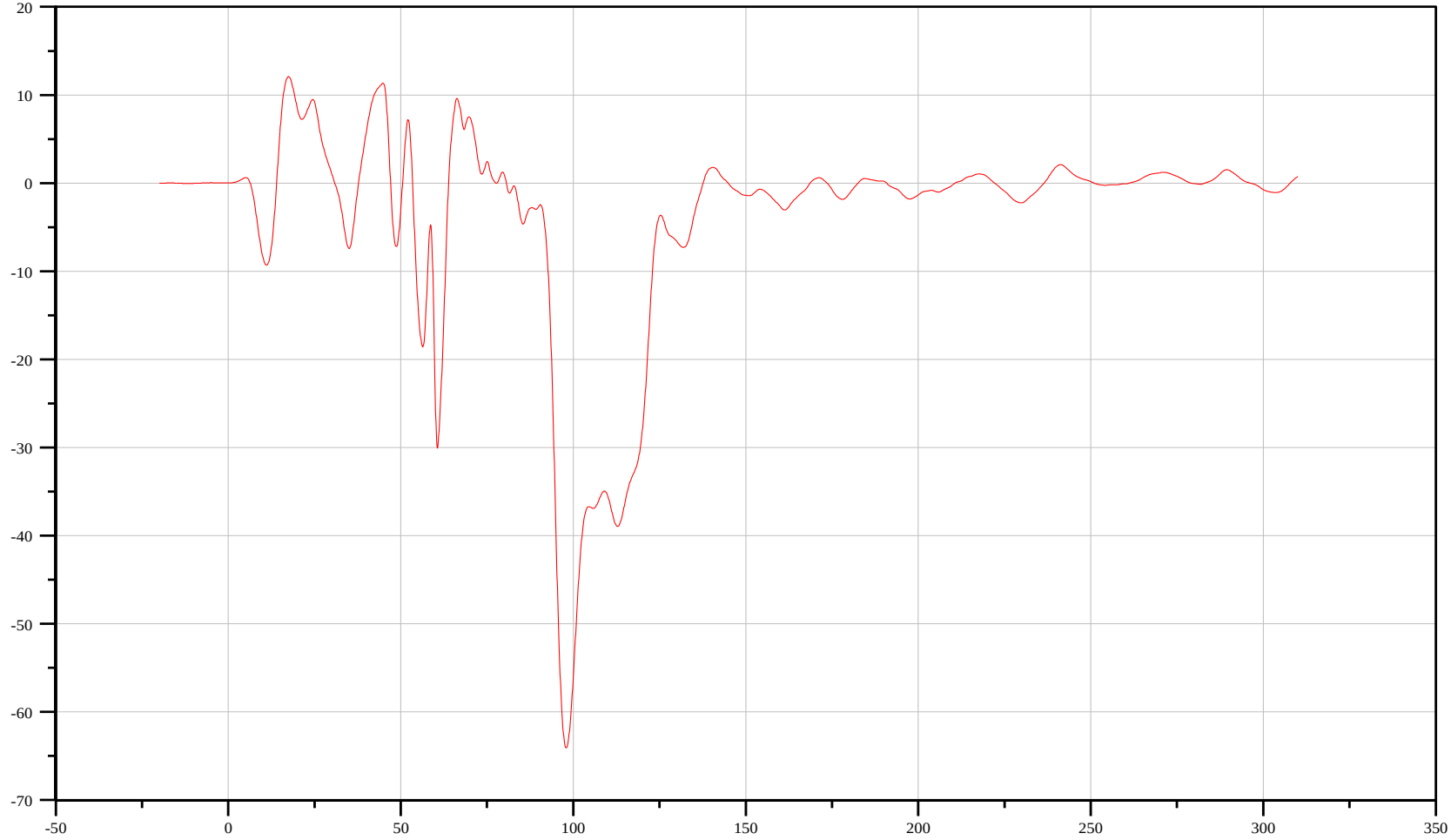
Date: 04/16/2012
Time: 08:34

Battery, Passenger X-Axis Acceleration

Customer: Battelle

13BATT000000ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-64.09 g at 98.00 ms

Max. Value
12.09 g at 17.50 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

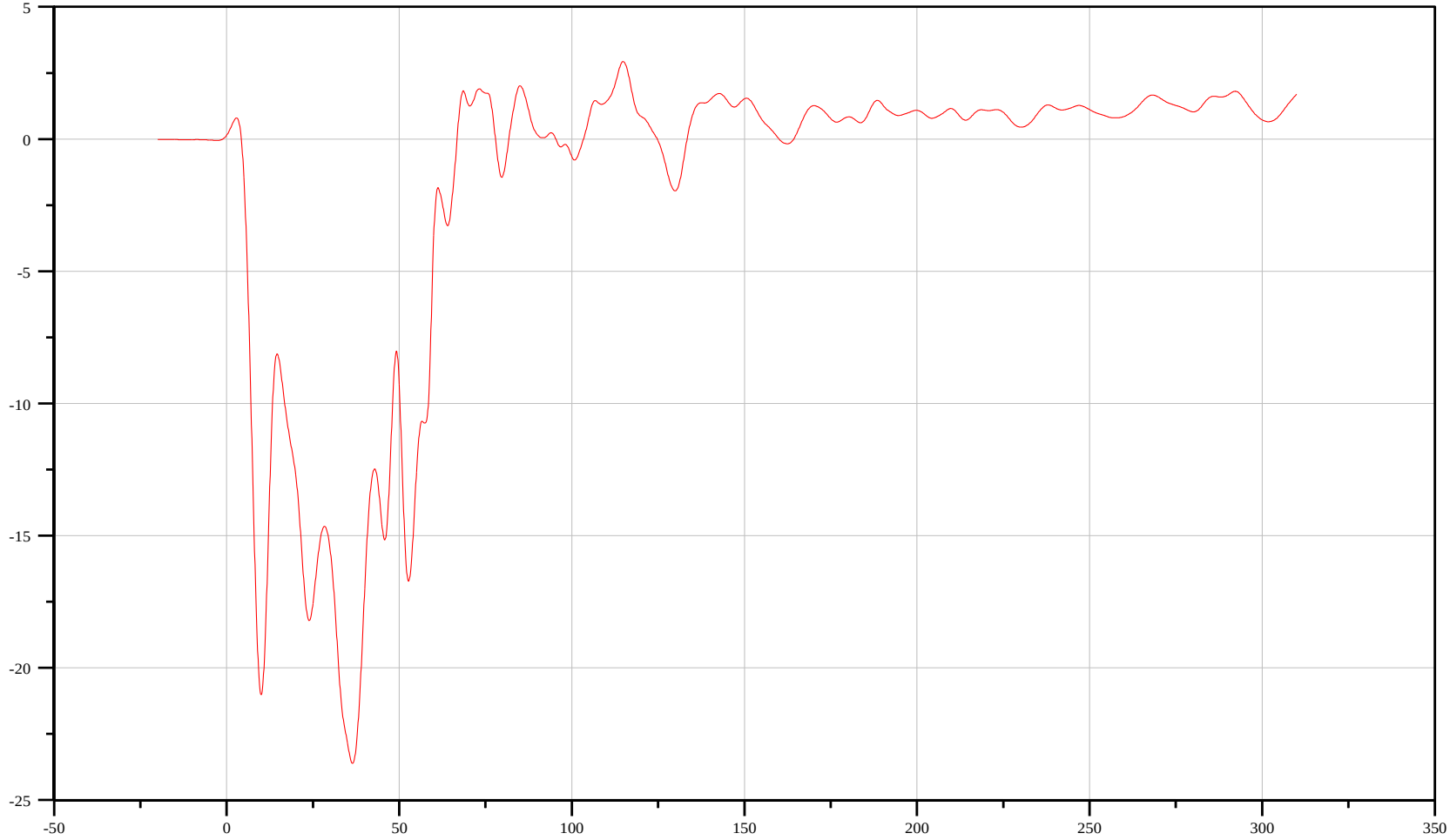
Date: 04/16/2012
Time: 08:34

Battery, Passenger Y-Axis Acceleration

Customer: Battelle

13BATT000000ACYD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-23.61 g at 36.50 ms

Max. Value
2.93 g at 114.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

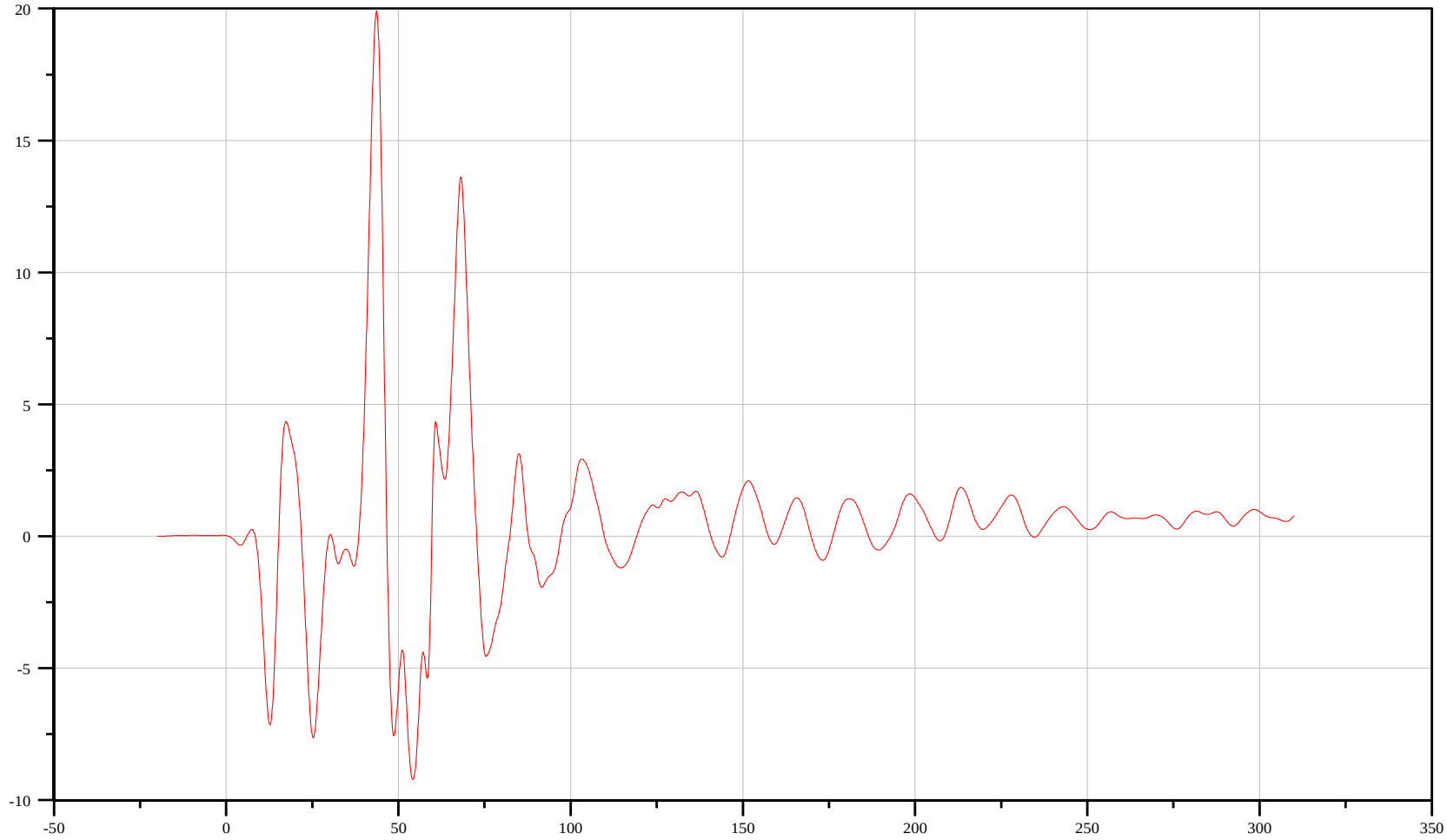
Date: 04/16/2012
Time: 08:34

Battery, Passenger Z-Axis Acceleration

Customer: Battelle

13BATT000000ACZD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-9.22 g at 54.20 ms

Max. Value
19.91 g at 43.70 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

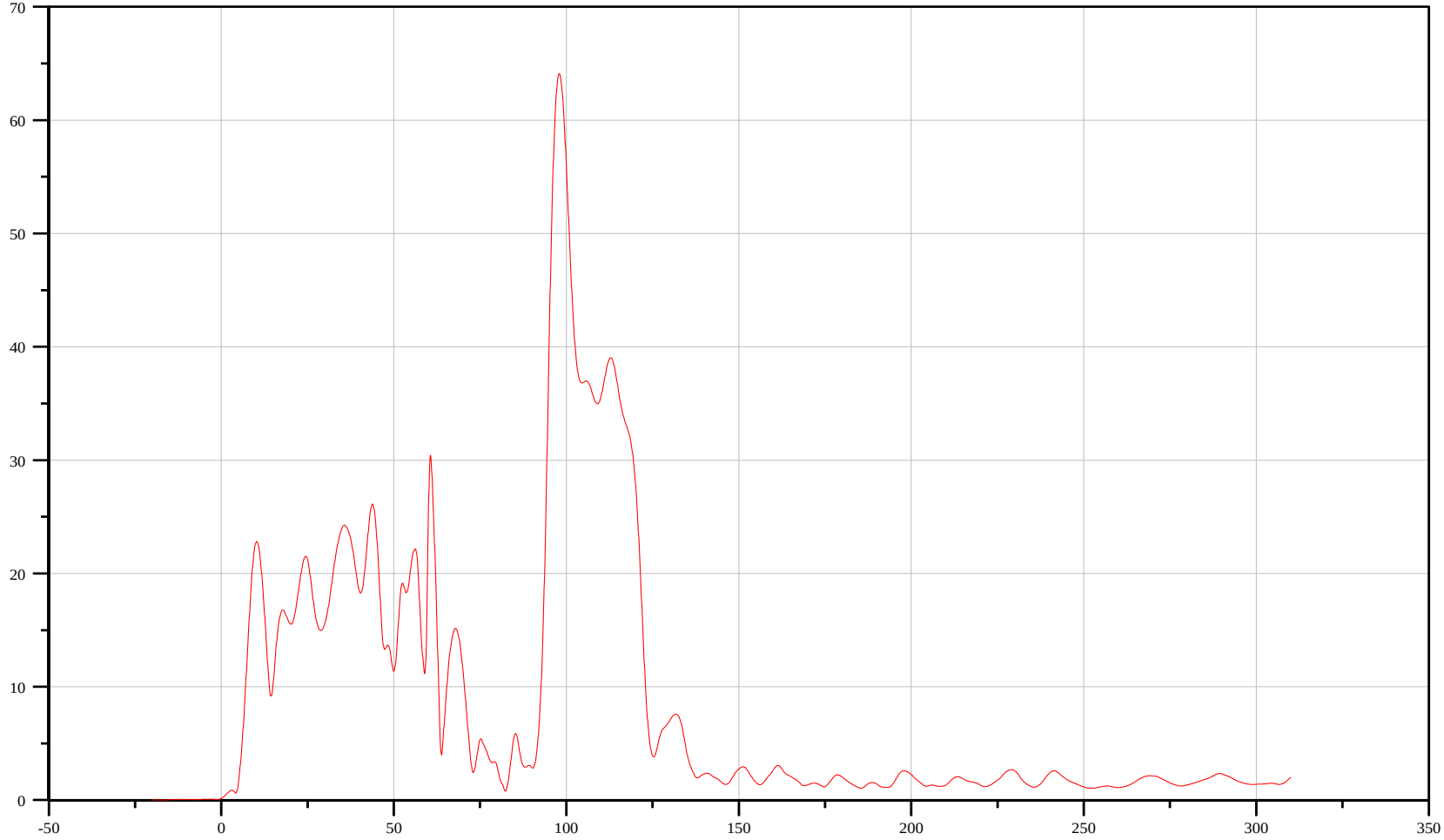
Date: 04/16/2012
Time: 08:34

Battery, Passenger Resultant Acceleration

Customer: Battelle

13BATT000000ACRD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
0.01 g at -20.00 ms

Max. Value
64.09 g at 98.00 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

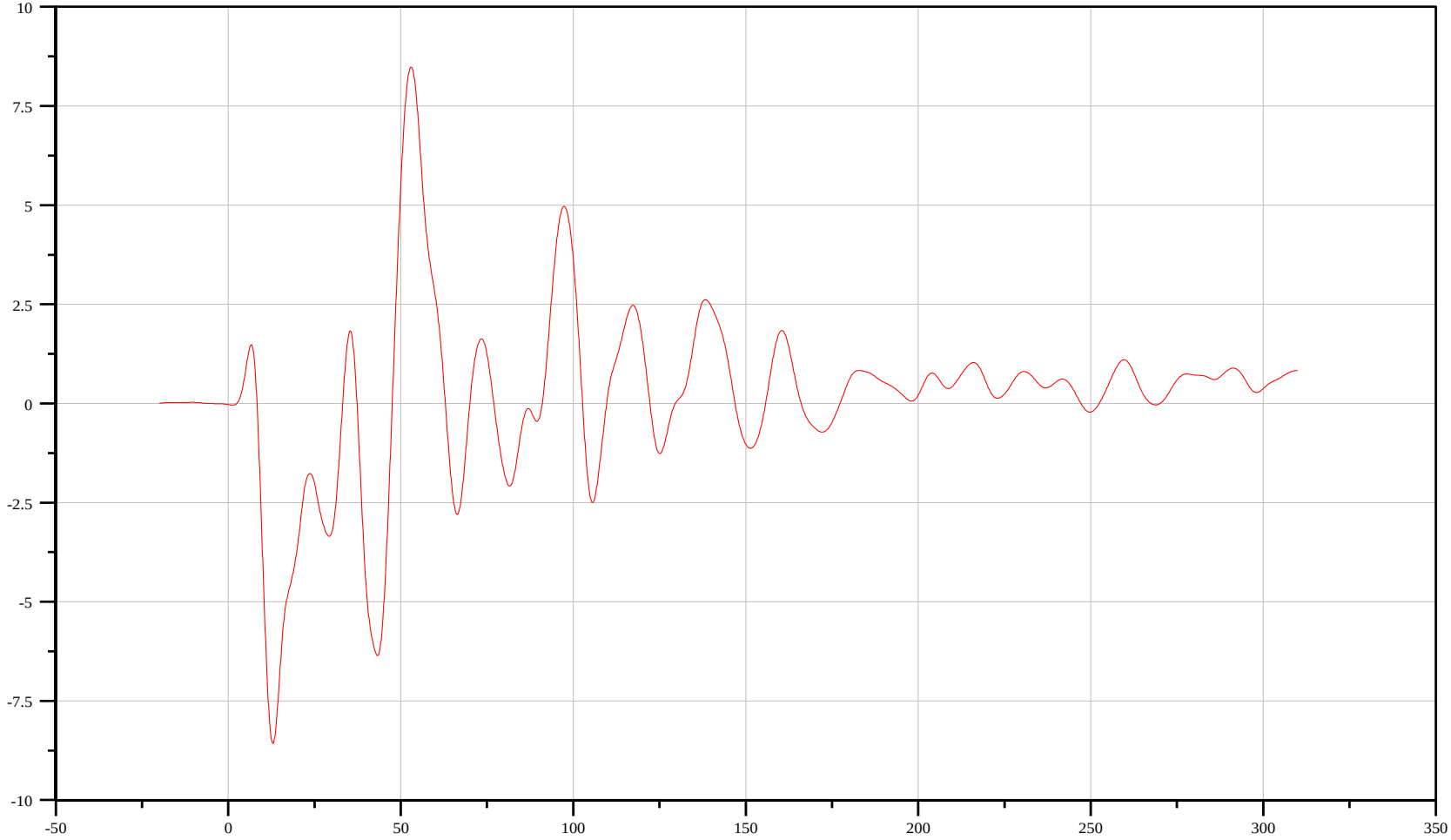
Front Container, Pitch X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTFRPI00ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-8.58 g at 12.90 ms

Max. Value
8.48 g at 53.00 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

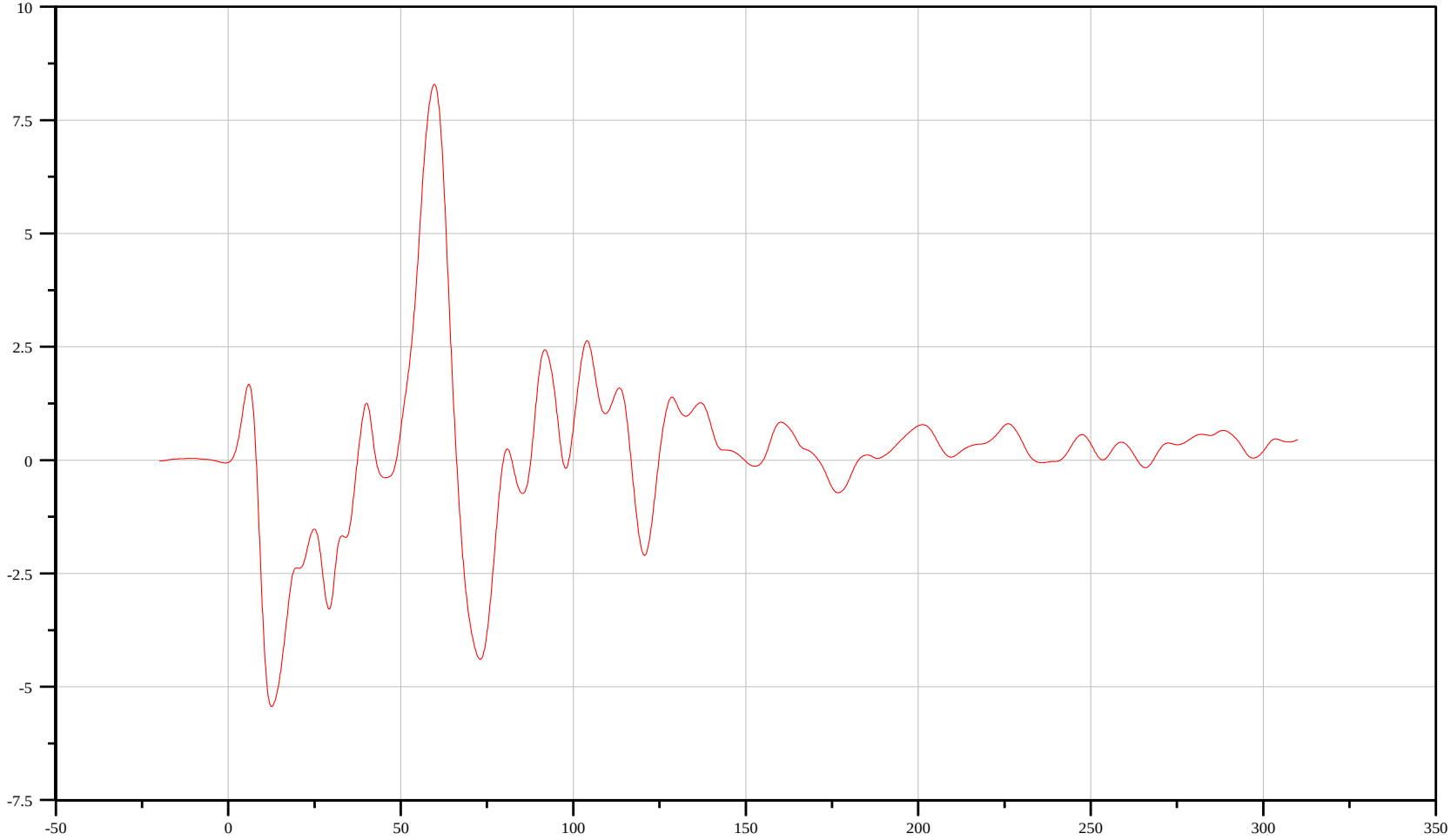
Middle Container, Pitch X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTMIPE00ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-5.44 g at 12.60 ms

Max. Value
8.29 g at 59.80 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

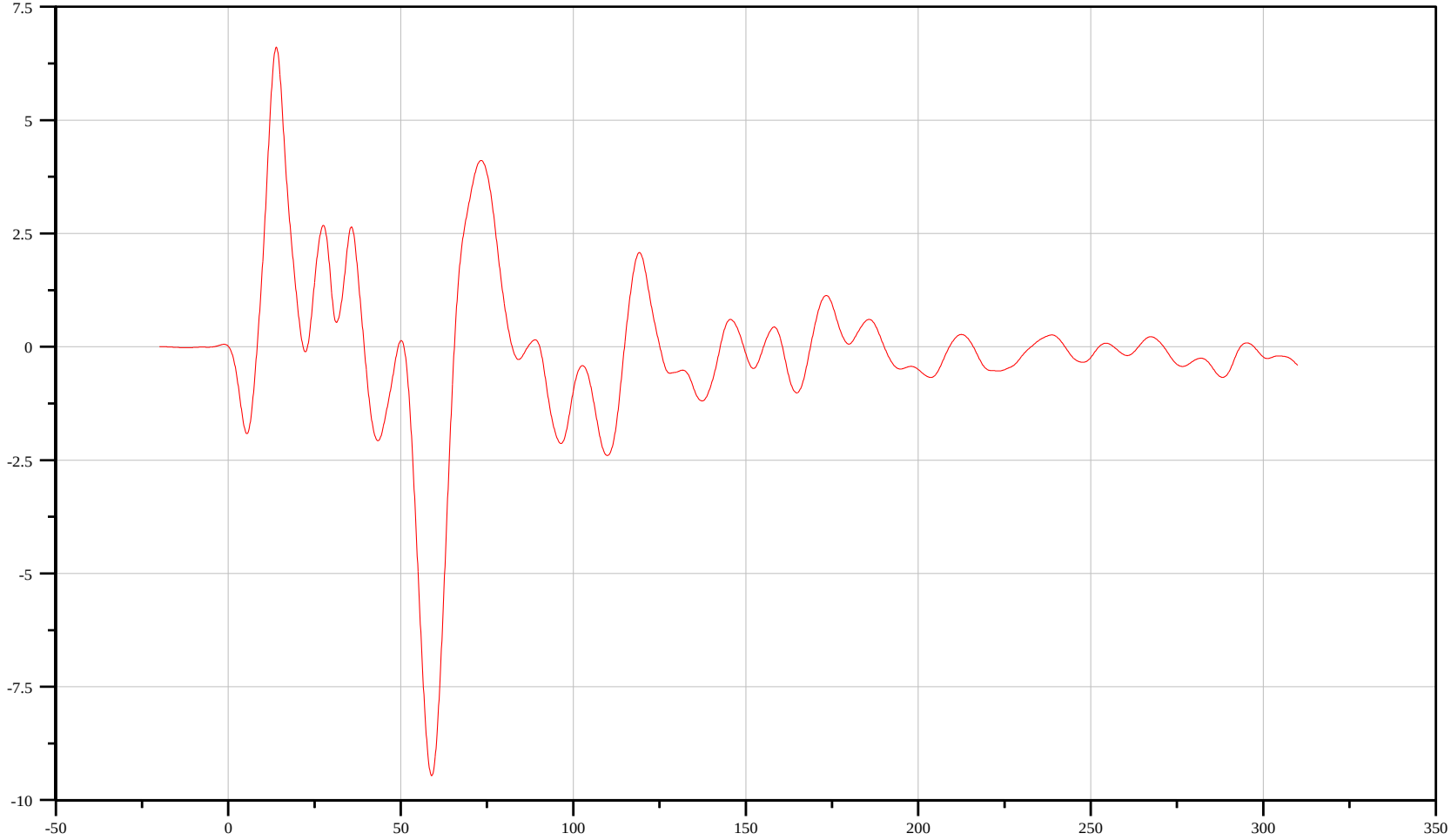
Rear Container, Pitch X-Axis Acceleration

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTREPI00ACXD

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_60

Min. Value
-9.46 g at 59.00 ms

Max. Value
6.61 g at 13.90 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

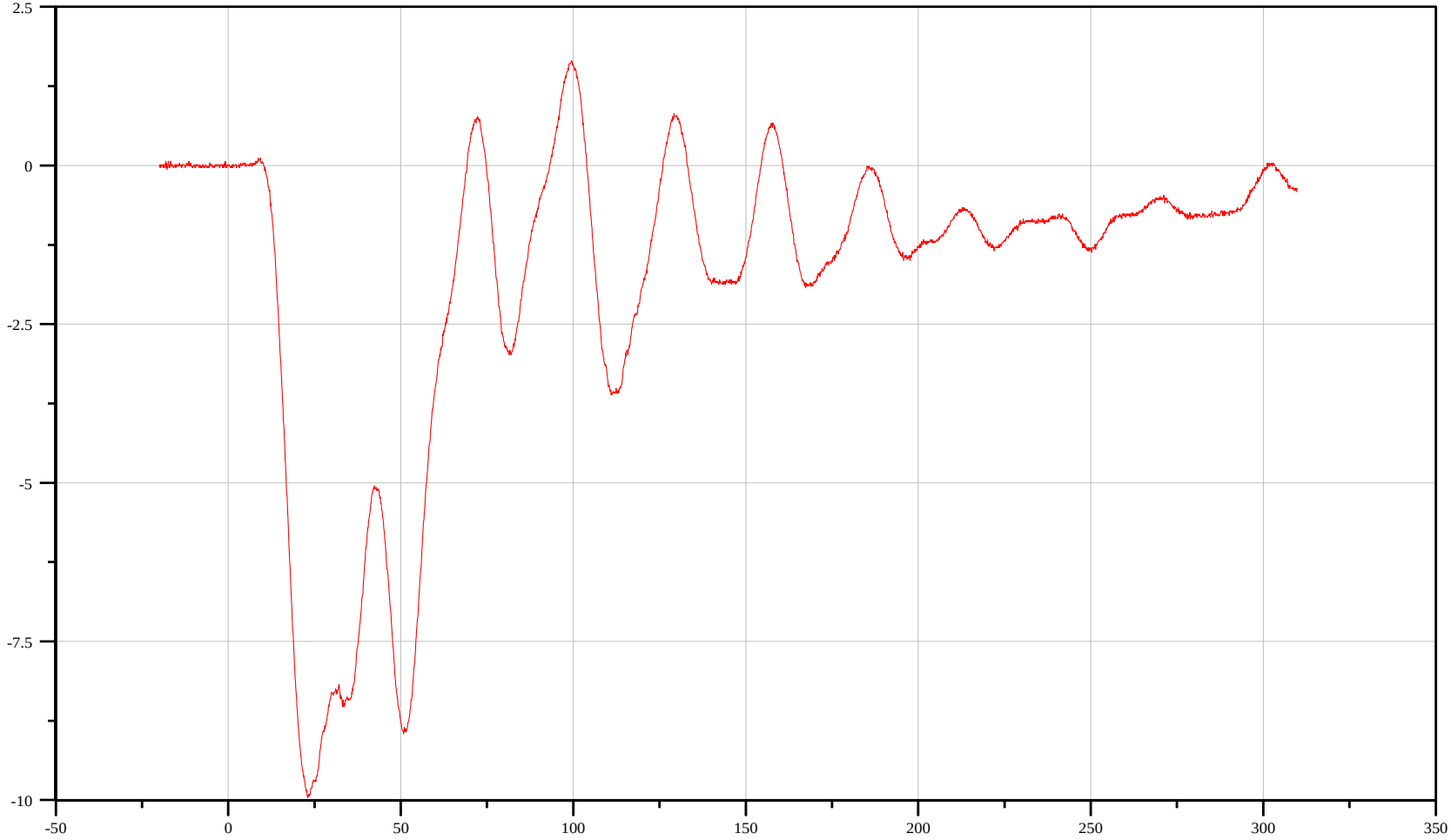
Date: 04/16/2012
Time: 08:34

Container Rear Y-Axis Displacement

Customer: Battelle

11CONTFR0000DSYA

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_1000

Min. Value
-9.96 mm at 23.10 ms

Max. Value
1.65 mm at 99.60 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

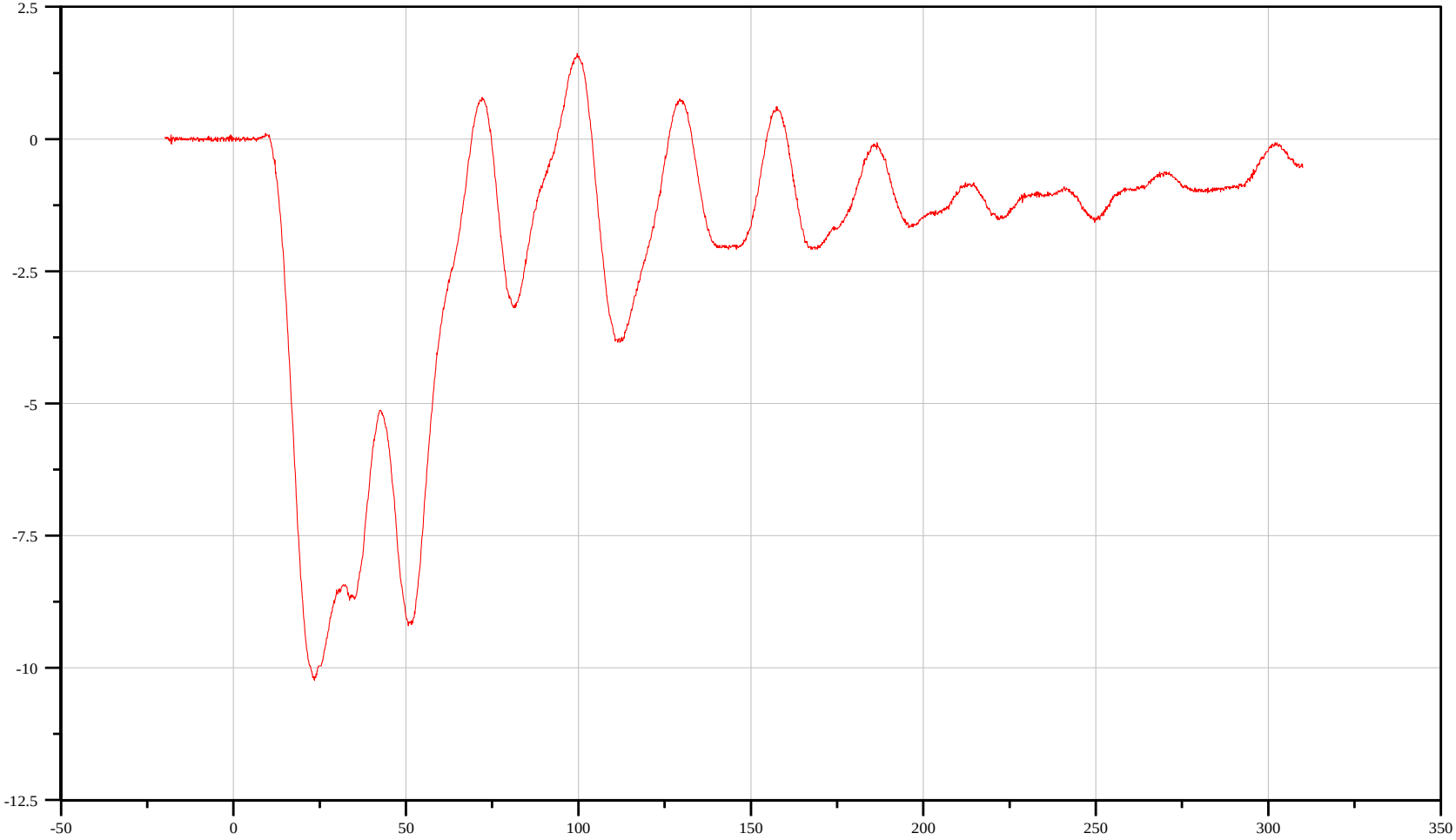
Date: 04/16/2012
Time: 08:34

Frame Rear Y-Axis Displacement

Customer: Battelle

13CONTFR0000DSYA

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_1000

Min. Value
-10.24 mm at 23.50 ms

Max. Value
1.62 mm at 99.70 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

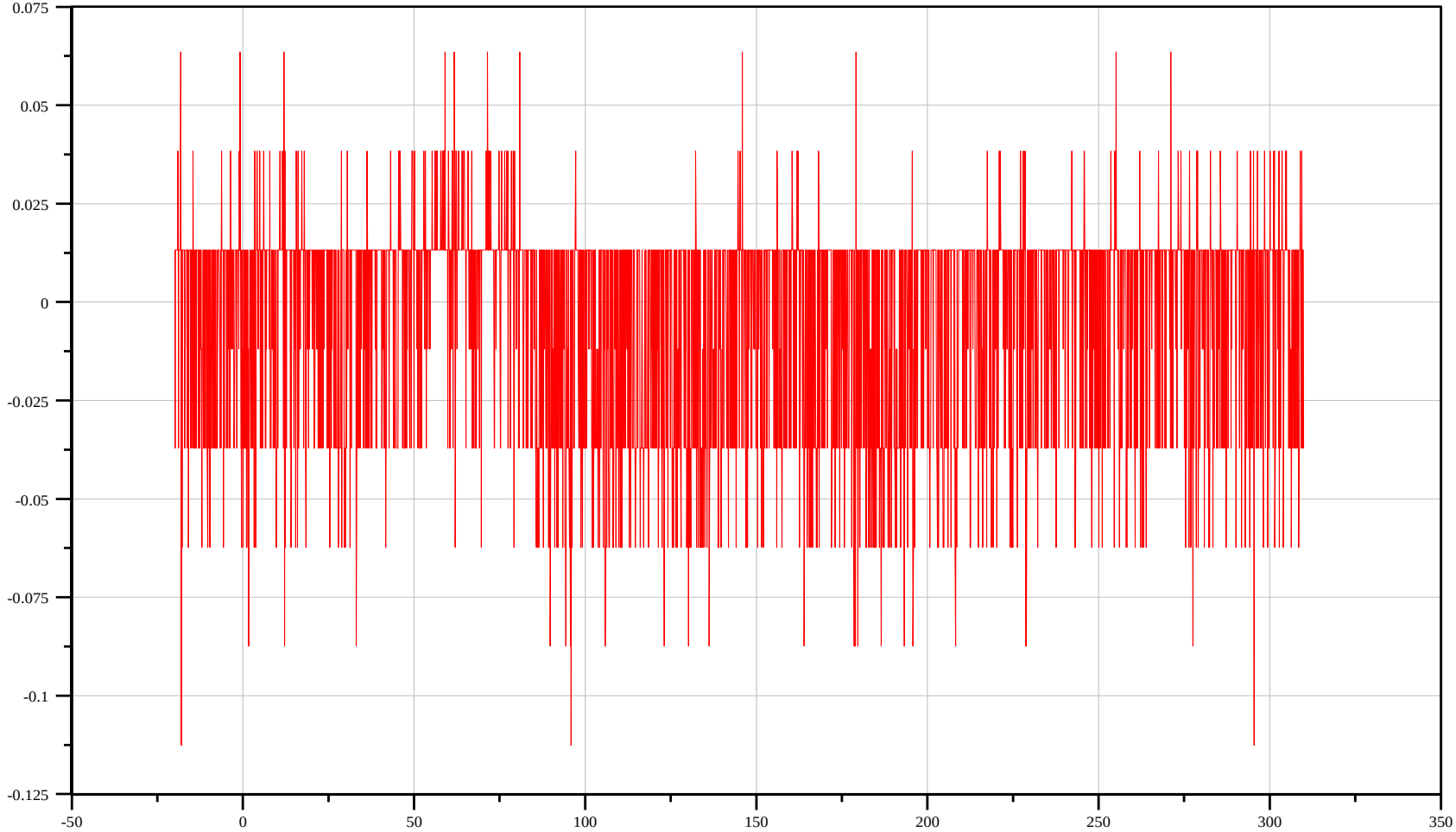
Container Mid Y-Axis Displacement

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTMI0000DSYA

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_1000

Min. Value
-0.11 mm at -18.00 ms

Max. Value
0.06 mm at -18.20 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

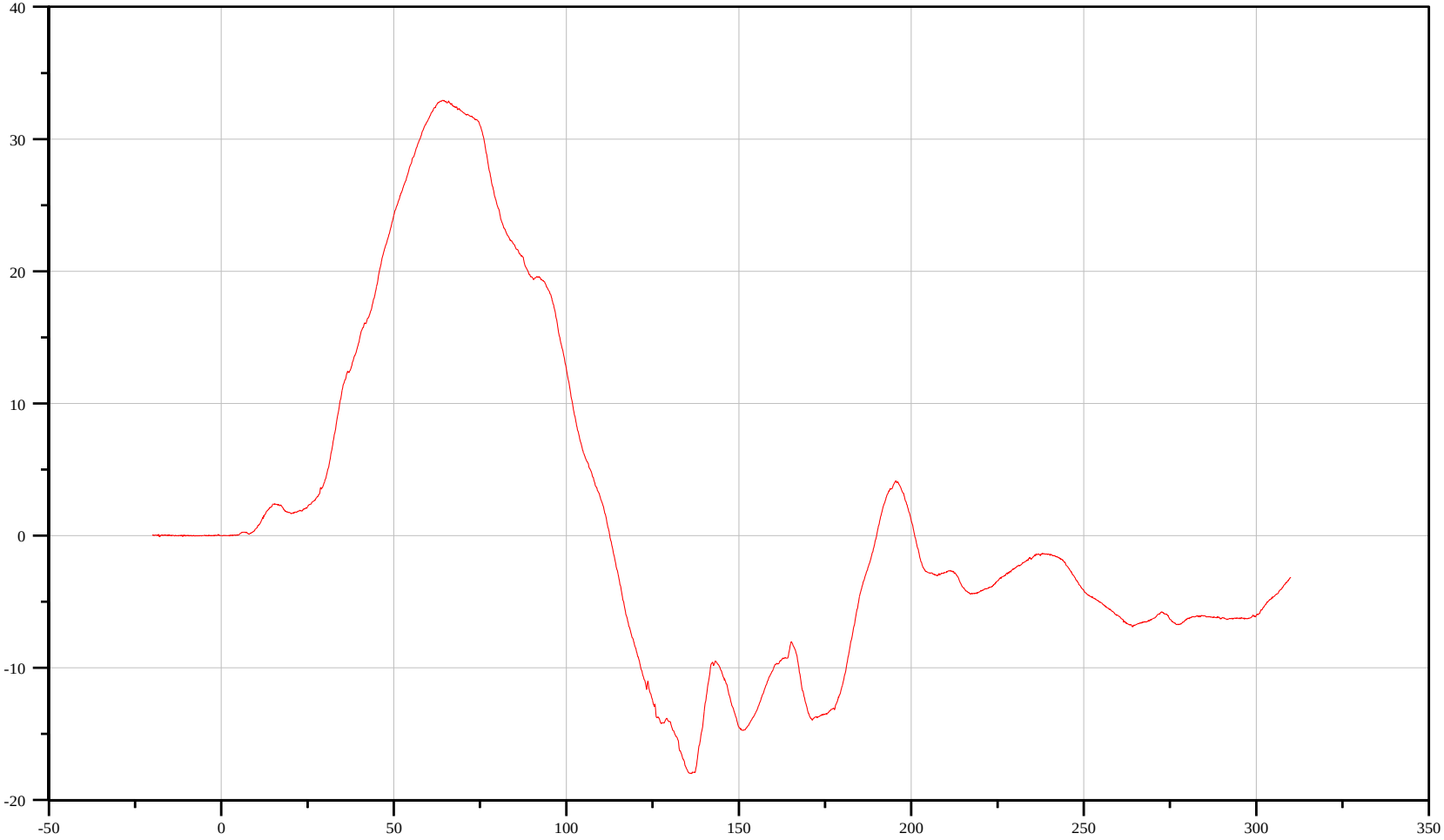
Frame Mid Y-Axis Displacement

Date: 04/16/2012
Time: 08:34

Customer: Battelle

13CONTMI0000DSYA

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_1000

Min. Value
-17.99 mm at 136.10 ms

Max. Value
32.93 mm at 64.00 ms

Deformable Moving Barrier into Left Side of Hydrogen Fuel Cell Vehicle

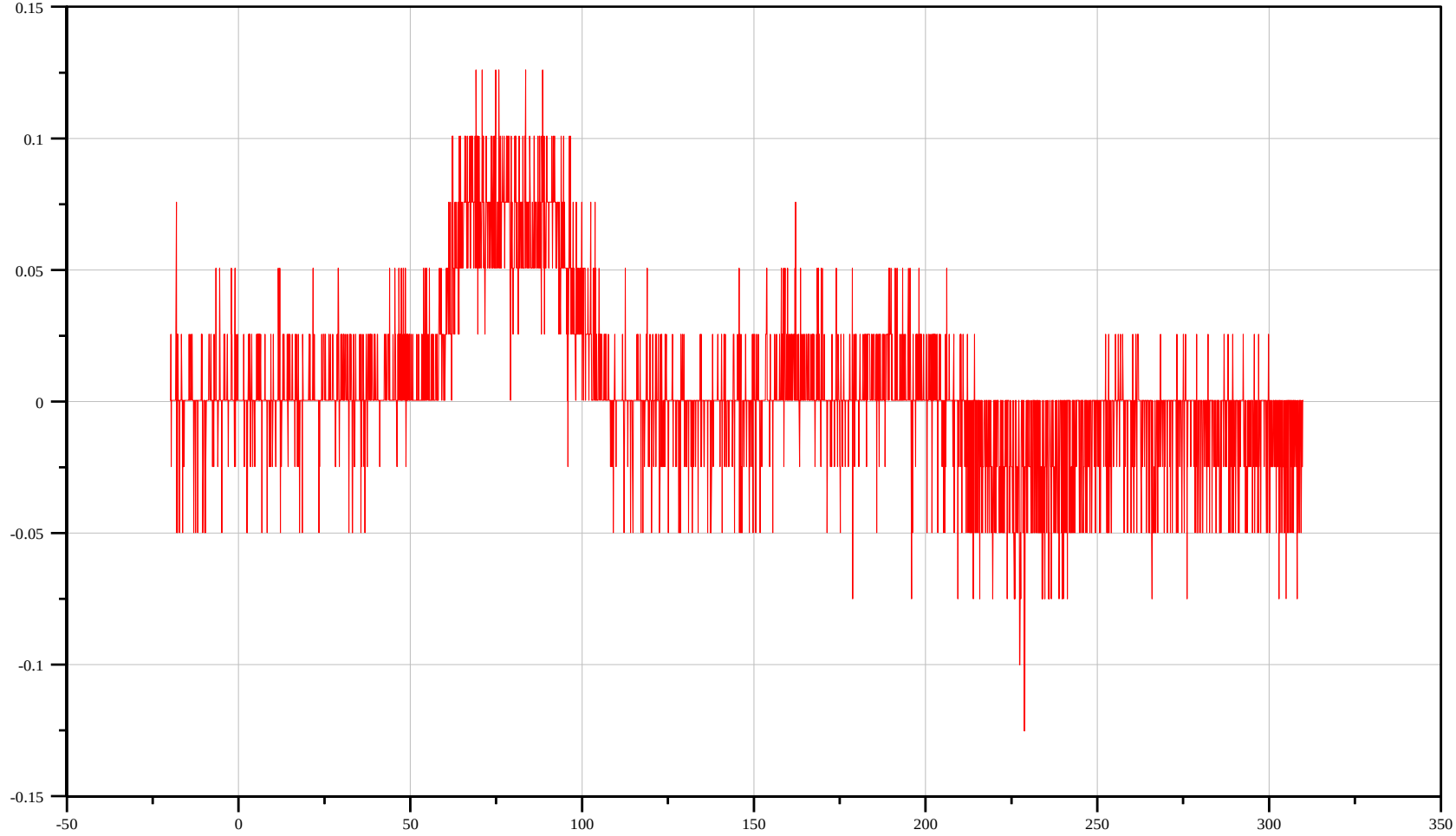
Container Front Y-Axis Displacement

Date: 04/16/2012
Time: 08:34

Customer: Battelle

11CONTRE0000DSYA

TRC Inc. Test Lab: CTF
Test Number: 120414



Filter: CFC_1000

Min. Value
-0.13 mm at 228.70 ms

Max. Value
0.13 mm at 69.10 ms

Appendix C

Barrier Certification

CERTIFICATE OF CONFORMITY

CELLBOND

Serial No. 30034 Certificate No. 44874

Description	FMVSS 214 - 1750x740x550mm Spec with 1.6 3/8 5052 Painted Grey
Cellbond Part No.	70NHTSASIUS G

	Test Results	GR No.	Blk No.
1	63554-8	29873	N/A
2	62459-8	28713	N/A

Declaration.

The above moving deformable barrier has been manufactured in accordance with the provisions of FMVSS 214 and FMVSS 301.

Additional Information...

Cellbond
5 Stukeley Business Centre
Blackstone Road
Huntingdon
Cambridgeshire
PE29 6EF
United Kingdom

T: +44 (0)1480 435302
F: +44 (0)1480 450181
E: sales@cellbond.com
www.cellbond.com

Cellbond is a division of Encocam Ltd.

Company Registration
England 1944904

Registered Office
5 Stukeley Business Centre
Blackstone Road
Huntingdon
Cambridgeshire
PE29 6EF
United Kingdom

This Certificate is valid without signature or printed date.

Printouts of the test results are available on request. Even small measures help to save resources and protect the environment. Please contact us if you would like to receive test results for a specific barrier, referencing the serial number.

Aluminium ist wiederverwertbar
Aluminium is recyclable

BATTELLE 120414

Appendix D

FARO Measurements

120414 FARO Measurements										
	Pre-Test			Post-Test			Difference			
	X	Y	Z	X	Y	Z	X	Y	Z	
Mid Wheelbase	2190	-850	-370	N/A	N/A	N/A	N/A	N/A	N/A	
Left Front Axle	874	-855	-372	N/A	N/A	N/A	N/A	N/A	N/A	
Vehicle Body	2417	608	-307	2417	610	-311	0	-2	4	
Vehicle CG (IP)	1382	38	467	1386	41	467	-4	-3	0	
Left Rear Axle	3506	-844	-367	N/A	N/A	N/A	N/A	N/A	N/A	
Battery Driver	3786	-202	13	3774	-209	26	12	7	-13	
Battery Passenger	3786	419	12	3774	413	32	12	6	-20	
Front Container Driver	2890	-490	-287	2884	-493	-288	6	3	1	
Front Container Passenger	2930	476	-273	2925	472	-266	5	4	-7	
Front Container Pitch	2907	-15	-487	2903	-17	-485	4	2	-2	
Mid Container Driver	3285	-497	-354	3281	-500	-348	4	3	-6	
Mid Container Passenger	3283	492	-334	3279	489	-325	4	3	-9	
Mid Container Pitch	3289	25	-480	3285	24	-473	4	1	-7	
Rear Container Driver	3859	-515	-330	3855	-521	-315	4	6	-15	
Rear Container Passenger	3863	476	-311	3857	472	-300	6	4	-11	
Rear Container Pitch	3855	-10	-457	3851	-17	-444	4	7	-13	
Fuel Inlet Tube	3846	-784	282	3825	-795	305	21	11	-23	

120414 Deformable Barrier Face Crush Measurements																		
		Distance Right of Center (mm)									Distance Left of Center (mm)							
Location	Height At CL	800	700	600	500	400	300	200	100	0	100	200	300	400	500	600	700	800
Top Stack Level - Level D	813	-55	-17	3	4	3	-8	-15	-5	-4	-4	-7	-11	-17	-28	-40	-71	-130
Mid Level Level C	686	-25	-11	-3	-2	-8	-11	-14	-16	-11	-8	-8	-9	-12	-21	-40	-54	-74
Top Bumper Level-Level B[1]	533	-36	-32	-30	---	---	---	-28	-28	-29	-30	-32	-34	-37	-40	-41	-48	-59
Mid Bumper Level - Level A	432	-109	-100	-101	-102	-103	-105	-105	-105	-106	-108	-111	-113	-115	-117	-119	-126	-126

All measurements were recorded using TRC Inc.'s FARO Arm with a tolerance of ± 0.1 mm.

[1] Top Bumper measurements are collected at 560 mm to eliminate post-test measurement point obstruction by the bumper element.