EQUIVALENT BUMPER SYSTEM CRASH PULSE PERFORMANCE THROUGH THE LENS OF CRASHWORTHINESS & OCCUPANT SAFETY EXPERTS

AN EXAMINATION OF COLLISION MANAGEMENT SYSTEMS AND VEHICLE OCCUPANT SAFETY

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Functional Performance Measurement By Crashworthiness & Occupant Safety Experts

STATEMENT: The content of this document is copyrighted and proprietary to Diamond Standard Parts, LLC and may not be used or republished without our written consent. The documentation, certified test results and crashworthiness expert validations are in basis of fact, truthfully and faithfully presented. The focus is a direct comparative on functional bumper component performance between OEM service parts and Diamond Standard Brand Alternative parts only. No statements or representations may be extended to other aftermarket parts, certified or not, as to their quality or functional performance based on the equivalent test results presented here.

Diamond Standard Companies have invested extensively in dynamic, destructive and quasi-static third party testing of OEM, Diamond Standard, and parts made from Non-OEM material and forming process to advance a state-of-the-art industry understanding of quality and its affect on part performance including the examination of crash pulse and occupant head trajectory.

MGA Research of Burlington, Wisconsin, was chosen as the third party test facility due to its 33 year history of providing companies such as General Motors, Ford, Chrysler, Hyundai, Toyota and others, with dynamic IIHS protocol and crash evaluation testing. Just as the testing and certification of comparative part performance is impressive as it is expansive, Diamond Standard has utilized several prominent experts from the crash industry for purposes of designing and validating the third party testing results certified by MGA.

MGA Research Corporation Testing
www.mgaresearch.com

James R. Hackney – Widely considered by the industry as the "Father of Safety" and former Director of Crashworthiness at NHTSA. Co-Author of the paper "New Car Assessment – Five Star Crash Rating – Vehicle Safety Performance Characteristics". Jim was critical in designing Diamond Standard testing protocols and evaluating results just as he was instrumental in a majority of the safety devices now standard on vehicles throughout the world.

Dr. David Breed – The recipient of the H. H. Bliss Award as one of the inventors of the Air Bag & NHTSA Award for Safety Engineering, David's distinguished career spanning 40 years includes numerous SAE publications and approximately 200 patents in the automotive products field involving air bags and occupant sensing systems for smart Air Bag characteristics. Chairman of both Automotive Technologies International and Intelligent Technologies International of Boonton, New Jersey, David has been critical in shedding light on the industry accepted fixed barrier testing, crash pulse and occupant safety affect of comparative bumper systems and subject of this document.

George W. Neat – Former NHTSA expert and Chief of the Vehicle Crashworthiness Division, U. S. Department of Transportation/Volpe National Transportation Systems Center. George's career with DOT spanned 35 years in transportation safety and technology applicable to the automotive industry, including innovative airbag expansion devices and crash dummy instrumentation.

Rudy H. Arendt – Former VP and co-founder of MGA Research Corporation and recognized worldwide as an expert in designing vehicle crashworthiness and automotive safety testing.

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Purpose & Policy

We patently believe the individual part criteria established by OEM in its original parts created the standard to which all structural parts in collision must be held. OEM bumper system components, for example, defined as bumper fascias, high strength steel reinforcements and high density foam energy absorbers must comply with Federal Motor Vehicle Safety Standards under the NHTSA in CFR 49, part 581 for new vehicles. It is mandatory a Diamond Standard structural part must achieve and be certified as providing the same standard of functional performance vs. OEM service parts to ensure the function of vehicle collision management systems have been properly and completely restored.

Scope of Certification

Diamond Standard has engaged the services of MGA and their expertise since 2002 to provide extensive destructive, dynamic, comparative performance testing to OEM service parts within a credible, independent third party system of testing by industry experts. Tests covering all Diamond Standard front steel bumpers, high strength steel/aluminum reinforcements and full assembly step bumper systems' performance have been conducted and performance certified as equal to OEM service parts they replace. Diamond Standard high density foam absorbers have been tested by MGA to FMVSS 302 testing with performance certified as equal to OEM service part performance in functionality and non-flammability. Brackets are subjected to Rockwell material hardness, weld pull testing vs. OEM in the Diamond Standard ISO-17025 accredited research test facility.

Testing is broad as it is expansive with industry approved part and bumper system testing protocols. Tests have expanded from individual parts, to bumper systems and full frontal crashes including bumper system testing to establish crash pulse and affect on occupant head trajectory including:

IIHS FMVSS 214 side impact cart
IIHS low speed crash test into fixed barrier
Frontal Barrier Testing
Quasi-Static Pole Testing
FMVSS 302 Flammability Testing
VESC (Vehicle Equipment Safety Commission) V-5 Testing for Towability

About MGA Testing & Certification

MGA Research is an accredited, recognized worldwide leading independent provider of engineering consulting, automotive testing technologies and state-of-the-art facilities and staff of test experts. MGA's global footprint offers the automotive industry a comprehensive array of products and services related to consulting, testing and government compliance issues supported by five (5) facilities in the United States with additional facilities in South Korea, Japan, China and India.

The MGA client base includes all original equipment car manufacturers, the aerospace industry, IIHS and the U.S. Military providing services for virtually every global vehicle regulation from full-vehicle level to component-level certification of interior and exterior components. The MGA expertise in conducting safety and reliability tests in the North American markets (FMVSS and CMVSS) is unparalleled and supports other activities related to testing, validation and the documentation and certification of test results. The testing processes for Diamond Standard were conceived by James R. Hackney, who developed the industry accepted "quasi-static" comparative tests.

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Industry Accepted Frontal Barrier Testing Methodology & Protocol To Measure Crash Pulse and Deflection Through Total Velocity Change Comparatively OEM vs. Diamond Standard

New passenger vehicles must be designed to meet minimum crashworthiness standards and crash avoidance requirements as specified by the Department of Transportation, National Highway Traffic Safety Administration. These requirements are defined in the Federal Motor Vehicle Safety Standards (FMVSS) that are contained in the Code of Federal Regulations (CFR) 49. Crashworthiness standards are generally applicable to new vehicle system performance. FMVSS 208 is related to the protection that a new vehicle must provide to occupants in frontal impact crashes. " It must be emphasized that, in most cases, these standards do not apply to individual components of the vehicle or even major structural components. The major requirements of these standards specify maximum injury levels as measured on anthropomorphic test dummies in defined crash conditions. This allows the vehicle manufacturers the flexibility of different design approaches to meet these requirements" (Statement by George W. Neat, former Chief, Vehicle Crashworthiness Division of the Volpe National Transportation Systems Center).

Over the years controversy has often arisen relative to vehicle parts that are used to repair collision damaged vehicles to a complete and safe repair. This controversy is centered on the position that these aftermarket parts that are not original equipment manufacturer or manufacturer service parts will degrade the safety and damageability performance of the vehicle. Specifically, OEM bumpers and/or rebar systems MAY be designed to provide load paths and distribute crash loads in a manner that contributes to the safety performance of the vehicle and, for frontal impacts, the proper performance of air bag deployment systems. In early 2000, Reflexxion Automotive contracted with James R. Hackney to develop test procedures that could be used to provide crashworthiness and damageability data to make comparisons to OEM bumper systems that would be predictive of more severe dynamic tests. The quasi-static pole protocol was created subjecting bumper components to a 14-inch diameter rigid pole section attached to a hydraulic cylinder and pole section loaded into the bumper/rebar at a rate of one-half inch per second. In evaluating quasi-static load carrying characteristics and dynamic tests determining crash pulse and deceleration comparatives "the following conclusions can be drawn from such test series: 1) the quasi-static test appears to provide a good measure of comparison between aftermarket and OEM parts in IIHS dynamic tests, and 2) properly manufactured after market parts can provide, at least, equivalent performance to OEM parts." (Statement by James Hackney, former Director of Crashworthiness NHTSA)

This report is specific to the use of Frontal Barrier Testing in identifying the crash pulse of a vehicle which in turn is used in the design of an air bag system. The frontal barrier crash is one of the shortest duration crashes and thus one of the most severe for a given vehicle. The resulting system designed for occupant safety can be tested repeatedly using sled tests where desired crash pulses are recreated. To assist and further the understanding that Diamond Standard Brand structural parts perform in an equivalent manner to OEM service parts they replace this documents crash pulse frontal barrier testing conducted at 15KPH, the lower threshold of air bag deployment using IIHS Sled Test Methodology on an FMVSS 214 side impact cart to measure crash pulse and vehicle dummy responses including forward and vertical head movement of a 2006 Nissan Altima energy absorber/rebar structural bumper system.

"A single frontal barrier crash is sufficient for determining the vehicle crash pulse for frontal barrier impacts. The frontal barrier test is approximately equivalent to the case of two cars of same mass impacting frontally at the same speed. However, if the masses and the stiffness of the impacting vehicles are unequal, the crash pulse can be significantly shortened or lengthened. Other type of real world impacts such as with rigid moveable objects, breakaway structures and undercarriage hang ups can shorten the crash pulse by a large percentage. It is advisable, therefore, to pick a somewhat more severe sled test pulse for air bag system design: that is, one of a somewhat shorter duration than the 30 MPH frontal barrier crash pulse." (mandated by FMVSS 208 and requirement of vehicle occupant safety) (Statement by Dr. David S. Breed, Recipient of the H. H. Bliss Award as one of the inventors of the Air Bag in SAE Technical Paper Series #900548 Are Barrier Crashes Sufficient for Evaluating Air Bag Sensor Performance).

Examining the Certified Bumper System Components

High Strength Steel Reinforcement

OEM began replacing Low Strength Carbon Steel with High Strength Steel (HSS) in manufacturing bumpers and reinforcements as part of the vehicle's bumper safety system which achieved lighter weight while increasing strength and integrity of the parts in resisting impact and stress. The trend to stronger materials has continued with the use of Ultra and Advanced steels and even High Strength aluminum reinforcements today. In addition, OEM steel reinforcements are one piece roll formed which provide for repeatable dimensional stability and tolerance throughout the entire length of the part.

The Diamond Standard High Strength Steel Reinforcement (NI1006160DSN) pictured below has been precision engineered to replicate the safety and damageability criteria of the original OEM part. Quasi-static pole and dynamic crash comparative testing vs. OEM on this reinforcement has been conducted by MGA with certified results proving equivalent functional performance. The part has also been Certified by NSF meeting all dimensions of quality requirements as an acceptable replacement for the OEM service part.

NI1006160DSN
MGA, NSF CERTIFIED

As can be seen in the reinforcement beam cross section photos below, the OEM beam is made of a single piece of High Strength steel which is roll formed and seam welded on the rear of the beam in the center of the channel for maximum integrity and strength. The material and process are costly and reinforce the perspective shared earlier in a statement by crashworthiness expert George Neat that "OEM bumper and/or rebar systems may be designed to provide load paths and distribute crash loads in a manner that contributes to the safety performance of vehicles, and, for front systems, the proper performance of air bag deployment". Diamond Standard Brand reinforcement beams are formed in the same manner and incorporate OEM High Strength steel and have been tested, certified and validated to provide equivalent functional performance vs. the OEM service parts they replace.

A two piece welded structure and use of Non High Strength steel yields parts in testing which fail to resist crash energy as set forth in federal standards, the original OEM part or the Diamond Standard Brand part.

Examining the Certified Bumper System Components

High Density Foam Energy Absorber

OEM Single and Dual High Density Foam Absorbers are part of a vehicle's collision management system and designed to absorb and distribute crash energy and be non-flammable meeting FMVSS 302 test standards of flammability. OEM energy absorbers are made of ARPRO EPP Expanded Polypropylene Product used extensively in automotive applications where durability, multiple impact resistance and other demanding performance challenges must be met in energy management applications and vehicle crash requirements. ARPRO EPP material has a very high strength-to-weight ratio with load bearing structural support capable of handling significant loads with little loss of form.

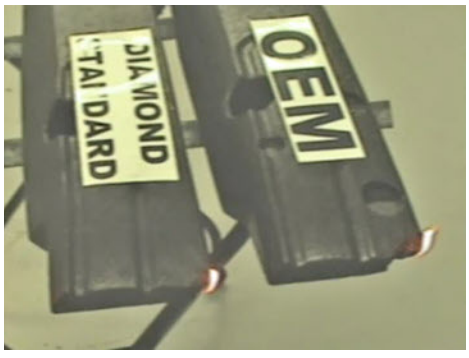
Diamond Standard High Density Absorbers are formed using the same OEM engineered closed cell plastic foam to absorb and help reduce vehicle damage in the event of an impact. In addition to its excellent energy absorption, light weight, EPP Expanded Polypropylene offers load bearing structural support, is non-flammable and recyclable at the end of the vehicle's service. The Diamond Standard High Density Foam Absorber (NI1070136DSN) pictured below has been precision engineered to replicate the safety and damageability criteria of the original OEM part. Quasi-static pole, dynamic crash testing and even flammability comparative testing vs. OEM covering this energy absorber has been conducted by MGA Research Corporation with certified results proving equivalent functional performance. The part has also been certified by NSF meeting all dimensions of quality requirements as an acceptable replacement for the OEM service part.

NI1070136DSN
MGA, NSF CERTIFIED

2006 NISSAN ALTIMA ABSORBER SPECIFICATIONS

NO.	PART	TEST	OE DATA	UNIT	DIAMOND STANDARD
1	NR7702	MATERIAL	EPP-11P		EPP-11P
2	NR7702	COLOR	BLACK		BLACK
3	NR7702	PART WT.	0.543	KG	0.545
4	NR7702	DENSITY	0.083	9/CM	0.083
5	NR7702	DUROMETER HARDNESS	71.26	HC	71.26
6	NR7702	FLAMMABILITY	NON		NON

As established, Diamond Standard Brand High Density Foam Energy Absorbers are made using OEM ARPRO EPP material and proved in FMVSS testing by MGA to be non-flammable. To show the non-flammable charcteristics, a test was conducted at the Diamond Standard Brand Management Center in Memphis, TN.



5 Second Ignition

1 Minute Elapsed Time

2 Minutes Elapsed Time

MGA Front Barrier Test 1: 2006 Altima Absorber / Rebar System @ 15 KPH

To Measure Crash Pulse and Deflection Through Velocity Change Comparatively OEM vs. Diamond Standard

For this benchmark dynamic comparative test of the Nissan Altima bumper system, conducted by MGA Research Corporation, a protocol was developed to compare the load carrying, energy absorption and deceleration characteristics of the OEM service parts system vs. the Diamond Standard Brand system consisting of the 2006 High Density EPP Foam energy absorber, and the High Strength Roll Formed Steel reinforcement. The absorber and reinforcement systems were subjected to a severe frontal barrier test at 15KPH (9.5MPH) which is a speed just below the minimum threshold of the Air Bag no-fire limit.

The reinforcement/absorber system was attached to rigid steel mounts that were attached to the face of a FMVSS 214 side impact cart/IIHS sled. For purposes of measuring energy, load carrying and velocity changes four (4) longitudinal accelerometers were attached to the components and sled. As can be seen and discussed on the opposite page, "the recorded data from each of the accelerometers was very nearly the same for each of the manufacturer's equipment" (George Neat) and the left front frame rail accelerometer was randomly chosen to illustrate the crash pulse across all four placements for comparative purposes. "In a 15KPH barrier test it is likely that half or more of the crash pulse is significantly influenced by the crushing of parts of the vehicle behind the bumper and thus perhaps only the first 30 – 35 milliseconds of the test should be used for comparison purposes" (Dr. David Breed).

FMVSS 214 Side Cart Weights

	Units	Front Axle	Rear Axle	Total
Left	kg	374.2	240.8	
Right	kg	389.5	223.2	
Ratio	%	62.2	37.8	
Totals	kg	763.7	464.0	1227.7

OEM System

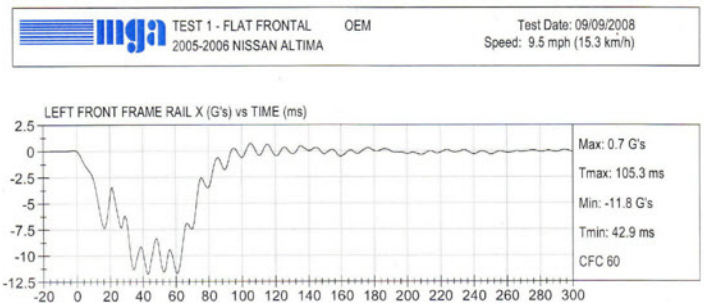
Diamond Standard System

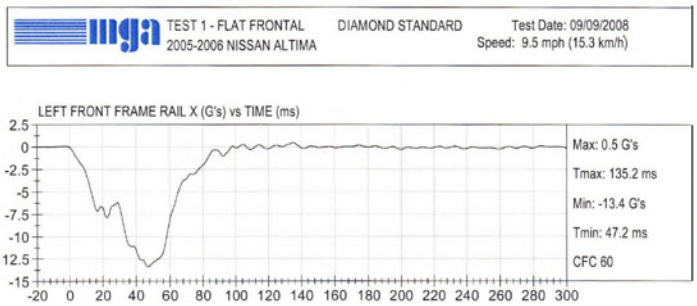
"A major function of the front bumper assembly is to absorb the energy in minor collisions and protect the rest of the vehicle structure from damage. The front rebar and absorber are designed to meet this requirement. The front structural components, including the rebar and the absorber, are designed to absorb energy in more severe crashes in order to protect the occupants. Airbags are deployed when certain conditions are met. Algorithms for this, which are proprietary, are becoming more complex, with data to accommodate occupant characteristics and to prevent inappropriate airbag deployment. Data from accelerometers and other sensors are used to determine when it is appropriate to actuate the front airbags. These algorithms are based on the characteristics of the unique front structure of the manufacturer's vehicle, INCLUDING the front rebar and absorber. Consequently, it is essential that the performance of ANY replacement rebar and absorber be comparable to the performance of the original equipment" (George Neat).

MGA Front Barrier Test 1: Examining Altima Crash Pulse, Velocity Comparatives and Conclusion

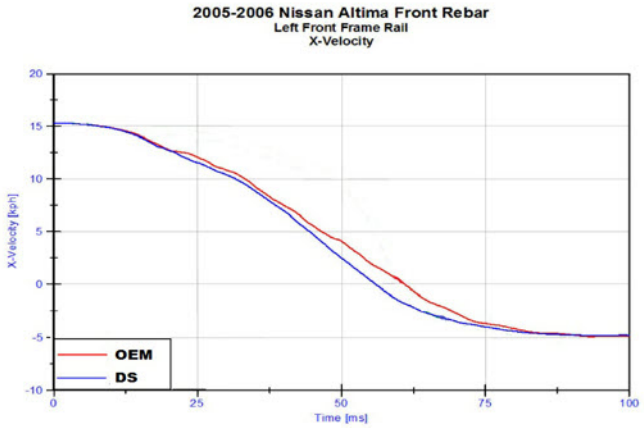
The expected performance of the rebar/absorber systems of the OEM service parts bumper system and Diamond Standard Brand Alternative system can be illustrated by observing the longitudinal velocities of the left front frame rails shown in the charts below. Keep in mind the following results are certified by MGA as accurate and complete. The velocity of the OEM rebar/absorber combination is reduced to half the initial impact speed after approximately 42.6 milliseconds whereas the time for the Diamond Standard combination is approximately 38.85 milliseconds. The Diamond Standard bumper system reaches half the impact speed approximately 1.35 milliseconds sooner than the OEM service parts system. The Diamond Standard and OEM velocity profiles are essentially identical for the next 20 milliseconds.

At that time, approximately 60 milliseconds, the Diamond Standard profile drops off slightly faster than the OEM profile for the next 20 milliseconds, consistent with the slightly higher maximum deceleration observed. Keep in mind the statement by Dr. David Breed "In a 15KPH barrier test, it is likely that half or more of the crash pulse is significantly influenced by the crushing of parts of the vehicle behind the bumper and thus perhaps only the first 30 – 35 milliseconds of the test should be used for comparison". "As such, the Diamond Standard equipment absorbs slightly more energy than the OEM equipment until the car reverses direction" (George Neat). The Diamond Standard Brand High Strength steel reinforcement and High Density EPP foam energy absorber system performance is again demonstrated to be very similar to that of the OEM system.





In comparing the Diamond Standard Brand structural bumper component system to the OEM system from the left front frame rail velocity curves, the two systems track within repeatable expectations showing they decelerate gradually and uniformly from the beginning of the impact through the first 20 milliseconds as pointed out above, and thus absorbing energy along the way. The Diamond Standard velocity curve shows the Alternative bumper system absorbs slightly more energy than the OEM service parts equipment through most of the event and certainly through the time period of the event critical to air bag deployment system performance.



CONCLUSION

"The performance of the Diamond Standard Alternative rebar/absorber can be expected to be very similar to the performance of the OEM equipment in a crash scenario" (George Neat)

MGA Front Barrier Test 2: 2006 Altima Absorber / Rebar System @ 15KPH

To Measure Part System Affect On Vehicle Occupant Head Movement Comparatively OEM vs. Diamond Standard

The benchmark comparative test of the Nissan Altima bumper systems, conducted by MGA Research Corporation comparing the OEM service parts system consisting of the 2006 High Density EPP foam energy absorber and High Strength steel reinforcement to the Diamond Standard Brand system was faithfully repeated in all respects injecting the use in this second test of an anthropomorphic test dummy to add another dimension to our evaluation of the performance of the systems. In this instance, the focus of the test centered on the affect on the head trajectory of the dummy created by the OEM service parts system vs. the Diamond Standard Brand system.

Specifically, the absorber and reinforcement systems were subjected to a severe frontal barrier test at 15KPH (9.5MPH) with the system components attached to rigid steel mounts that were attached to the face of a FMVSS 214 side impact cart/IIHS sled.

OEM System

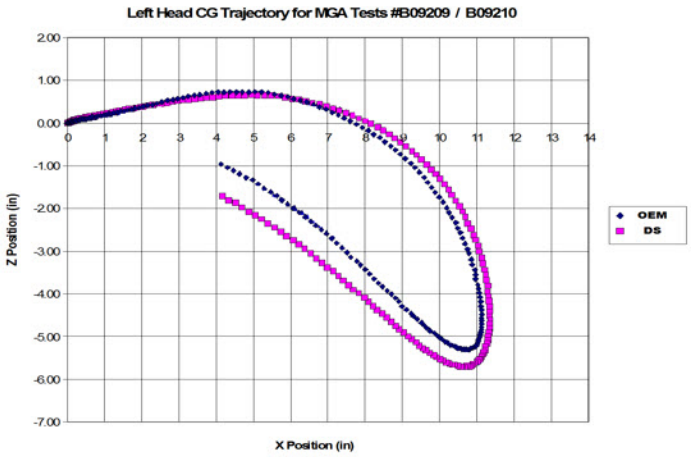
Diamond Standard System

A high speed camera was focused on the anthropomorphic dummy's head throughout the test sequence using the actual frame by frame footage of the event as the data input in terms of tracking and plotting the movement of the head in the "x" direction (forward) and "z" position (vertical). No attempt is made here to draw any conclusions relative to the dummy's interaction with an air bag as this was outside the scope of the test which was conducted to provide an added dimension to part system functional performance and the systems' affect on head trajectory.

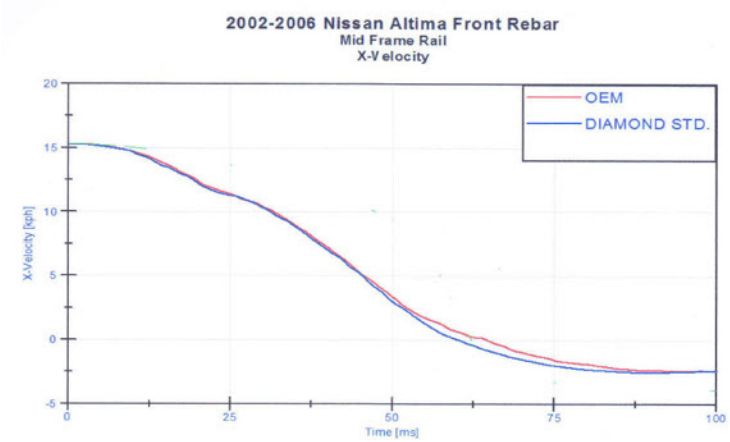
MGA Front Barrier Test 2: Examining Affect of Bumper Systems On Vehicle Head Trajectory and Conclusion

The following MGA Research Corporation created data document plots the left head CG head trajectory affect of the OEM service part system in blue and Diamond Standard Brand system in magenta for comparative purposes.

"The head trajectory for the OEM bumper test was 11.1 inches in the "x" (forward) direction and 5.3 inches in the "z" (vertical) direction. The crash pulse lasted about 70 milliseconds with a rebound velocity of 2.5KPH. The head trajectory for the Diamond Standard Brand system was 11.3 inches in the "x" direction and 5.6 inches in the "z" direction. The crash pulse lasted about 65 milliseconds with a rebound velocity of 2.5KPH. There is no logical explanation to the slightly larger "z" head trajectory in the Diamond Standard results" (Dr. David Breed).



Examining the comparison of the Diamond Standard results with the OEM service parts system in terms of the event's velocity curve from the mid frame rail, "the two bumper velocity curves track within repeatability expectations at least up to about 55 milliseconds which is beyond the realm where the test is valid. There is a slight divergence resulting in an added 5 milliseconds to the OEM crash pulse which probably explains the slightly shorter "x"head trajectory for the OEM case. The rebound velocity of the two bumper systems is identical, an indication that both absorbed about the same amount of crash energy. Perhaps, static force deflection tests can explain why the OEM bumper was a bit softer at the end of the test. It is doubtful that it is significant in real world crash tests. The crushing of the remainder of the vehicle structure undoubtedly has a much greater influence on the crash pulse than this difference in stiffness" (Dr. David Breed).



CONCLUSION

"The Diamond Standard and the OEM bumpers are for all practical purposes identical especially in the region where the bumper determines crash pulse. It is thus unlikely that they would perform differently in real world crashes where an airbag deploys" (Dr. David Breed)

DIAMOND STANDARD

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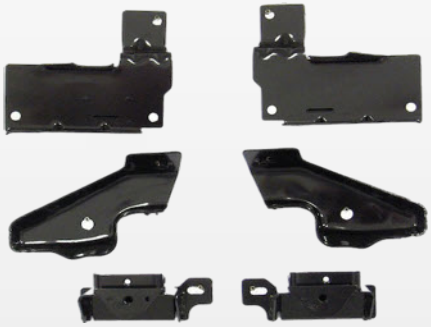
CLASS AAA SAFETY PARTS

EQUIVALENT QUALITY & FUNCTIONAL PERFORMANCE

FRONT BUMPERS - CHROME

FRONT BUMPERS - PAINTED

STEPBUMPER SYSTEMS



BUMPER BRACKETS, BRACES & SUPPORTS

ENERGY ABSORBERS

REINFORCEMENT BARS

ISO - TS16949 CERTIFIED FACILITIES

Smithers Quality Assessments, Inc.

CERTIFICATE OF APPROVAL

This is to Certify that the Quality Management System of:

REFLEXXION AUTOMOTIVE PRODUCTS, LLC

has been assessed and approved by Smithers Quality Assessments, Inc., to the following quality management system standards and requirements:

ISO 9001:2000 With Design

The Quality Management System is Applicable to:

The design, assembly and distribution of rear step bumpers, specialty hoods, bumper reinforcement, absorbers, and rubber bumper pads for the automotive aftermarket.

Approval Certificate Number: 01.290.2 *Original Approval: October 17, 2001*

Smithers Quality Assessments, Inc.

CERTIFICATE OF APPROVAL

This is to Certify that the Quality Management System of:

Production Bumper Stampings

has been assessed and approved by Smithers Quality Assessments, Inc., to the following quality management system standards and requirements:

ISO 9001:2000 with Design

The Quality Management System is Applicable to:

The design, manufacture and distribution of independently produced aftermarket replacement parts for the collision repair market.

Approval Certificate Number: 05.104.5 *Original Approval: April 14, 2005*