Towable Trailer Mounted Attenuator (TTMA-100)

Safety Trailer's new Towable Trailer Mounted Attenuator (TTMA-100) is set to revolutionize the truck mounted attenuator (TMA) market. The TTMA-100 is an attenuation trailer that attaches directly to a standard pintle-hook and trailer wiring harness. This simple connection allows the trailer to be attached or removed from a tow-vehicle in minutes and, equipped with an optional arrow panel or VMS sign mount, the TTMA-100 eliminates the need for a dedicated support vehicle. This simple attachment allows the TTMA-100 to be quickly attached directly to work vehicles, such as snowplows, sanding trucks, as well as striping and sweeping trucks, thereby eliminating the need for costly shadow vehicles. Because no vehicle modification is required, practically any vehicle with a 8-ton pintle-hook in your fleet can utilize the TTMA-100, improving safety for your workers, vehicles, and the motoring public.

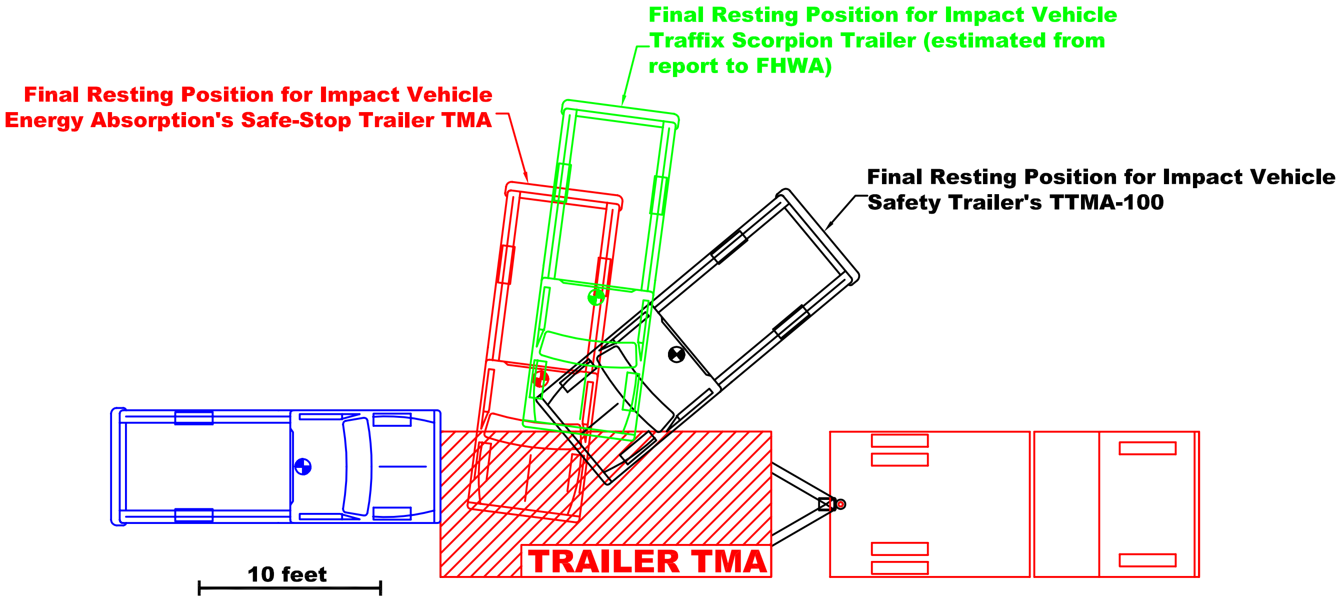
The patented feature that makes a simple pintle-hook connection work so well is the way the TTMA-100 engages a vehicle. The TTMA-100's rear impact plate is designed to capture the front of a vehicle such that, the trailer becomes locked between the impacting vehicle and the support truck. The pintle-hook connection allows the trailer to rotate to remain aligned with the impacting vehicle. Hence, the trailer and pintle-hook connection eliminates the need for costly TMA mounting and actuation equipment and allow the trailer to align itself to an impact from any direction to maximize energy dissipation (*see attached figure, showing the final vehicle resting positions for the various trailer TMA's*). Thus, the TTMA-100 both greatly simplifies TMA installation, and provides significantly improved safety performance for all tow vehicles.

When a motorist strikes a TMA, the support truck to which it is mounted will roll ahead, reducing the severity of the crash. Light support trucks allow greater roll ahead and minimize the severity of a crash. Until now, all TMA's relied on this roll ahead to reduce the severity of large passenger car impacts. For this reason, users should never attach a TMA to a truck that is heavier than that used during full-scale crash testing.

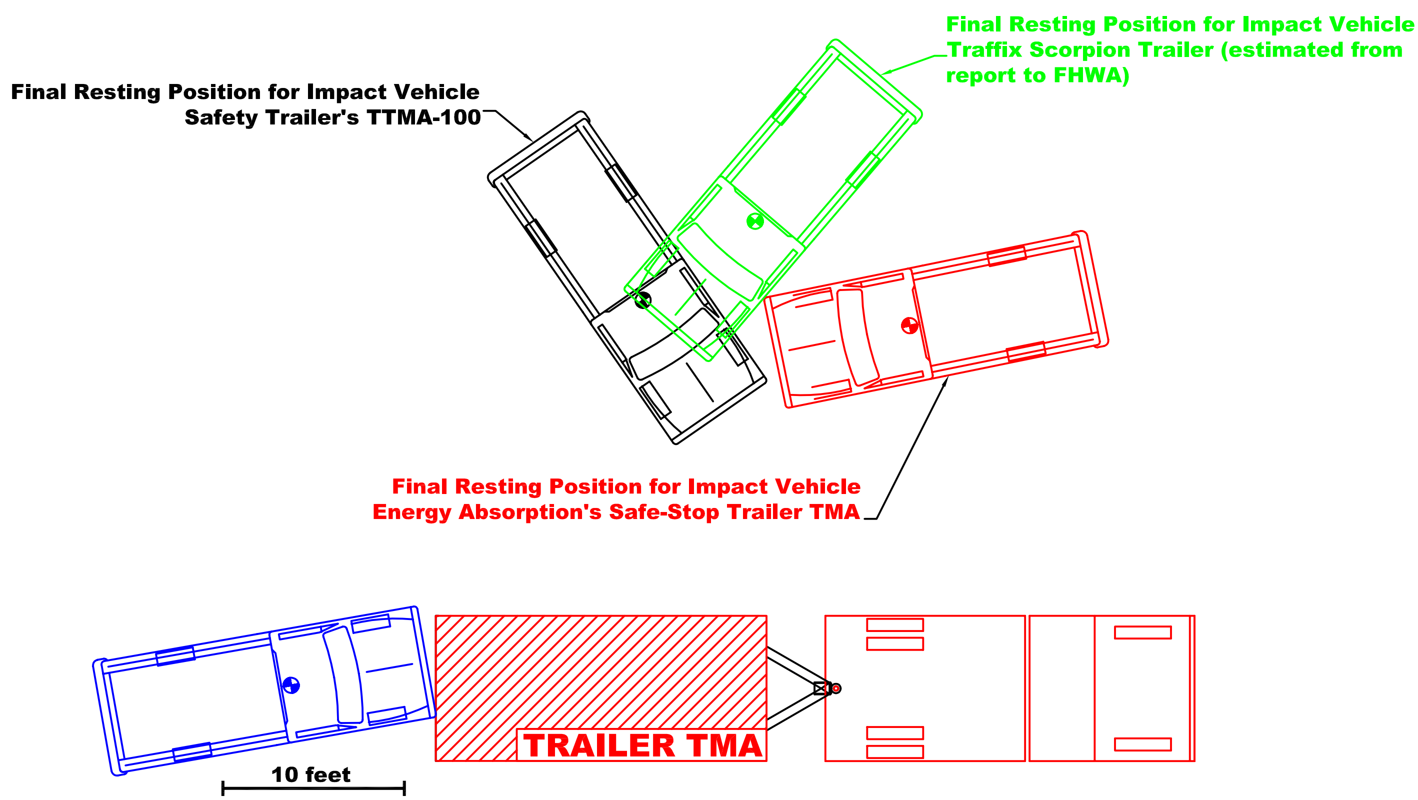
The <u>TTMA-100 is the only truck mounted attenuator</u> to successfully pass all required and optional Report 350 crash tests with the support truck blocked to prevent vehicle roll ahead - simulating an infinitely heavy truck Although other TMA systems have passed the required tests from Report 350 with a blocked truck, optional tests involving low angle and offset impacts have been conducted with a 20,000 lb support truck. Therefore, only the TTMA-100 has been proven to be truly safe using a support truck weighing more than 20,000 lb. In fact, there is no upper limit on the weight of the support truck used with the TTMA-100.

The TTMA-100 utilizes tube bursting technology to allow the trailer's frame elements to be used as the primary energy absorbers. As a result, the entire attenuator is manufactured from heavy gage steel to prevent fatigue. Further, the entire trailer steel is galvanized to eliminate corrosion problems. This durable construction and easy attachment allow the TTMA-100 to be safely used with snow plows as well as sanding, salting, and chemical treatment operations.

In summary, the TTMA-100 offers a major improvement in work zone safety, while at the same time reducing the cost and inconvenience associated with conventional TMA's.



NCHRP Report 350 Optional Test 3-52



NCHRP Report 350 Optional Test 3-53

Technical Summary of the TTMA-100

The TTMA-100 is an attenuation trailer that functions as a truck mounted attenuator. The trailer attaches to a standard 8-ton pintle hitch and can be towed at any speed, from stopped to full highway speeds. The only operational difference between towing a trailer and using a conventional TMA is that the trailer never needs to be raised when operating at higher speeds like conventional TMA. Hence, there is no delay while the cushion is raised or lowered and there is no risk of damaging the unit because the operator forgot to raise it. Further, there are no overhead clearance issues that can arise with a conventional TMA in the raised position. The only possible disadvantage of a trailer TMA is that the trailer tongue makes it somewhat longer than a conventional design. Otherwise, the TTMA-100 performs all the duties of a truck mounted attenuator, whether it is used in a slow moving work zone or on a blocking vehicle, parked to prevent errant vehicles from entering a workzone. The TTMA-100 has been fully tested and is FHWA approved as meeting NCHRP Report 350 Test Level 3 requirements. The primary advantages of using the TTMA-100 over conventional TMA's are summarized below.

Eliminates Dedicated Support Truck - Because it doesn't need special mounting hardware the TTMA-100 eliminates the "dedicated support truck." The TTMA-100 can attach to virtually any vehicle in your fleet, provided it has an 8-ton pintle hook and is wired to tow a trailer.

Attaches in Minutes - The TTMA-100 attaches or detaches in just a few minutes. Mounting or dismounting a conventional TMA takes many times longer, wasting valuable worker and equipment time.

Eliminates Shadow Vehicle - The TTMA-100 can be attached directly to any work truck, such as striping or sweeping equipment, provided the vehicle weighs 10,000 lbs or more. With the optional arrow board or variable message sign board attached to the trailer, there is no need for a separate shadow vehicle.

Safe with Heavy Trucks - All of the required and optional full-scale crash tests recommended by NCHRP Report 350 were run with a blocked support truck to simulate an infinitely heavy vehicle. All other TMA systems have been tested, at least in part, with a support truck weighing less than 20,000 lb. Hence, the TTMA-100 is the only TMA system, trailer or otherwise, proven to be safe under all NCHRP Report 350 test conditions when attached to a support truck that weighs more than 20,000 lb.

Innovative Engagement System - The TTMA-100 is designed to capture the front of an impacting vehicle to prevent it from sliding along the face of the trailers' impact plate. This capturing mechanism prevents a vehicle from knocking the trailer out of its path and allows the simple pintle hook attachment to function.

Maximizes Energy Dissipation - When the impact plate captures the front of a vehicle, it will actually pull the vehicle into the cushion. Further, free rotation at the pintle hook allows the trailer to align itself with the impact to maximize energy dissipation.

Cost - By eliminating the need for special attachment hardware, reducing labor required to mount and dismount the unit, and often eliminating the need for a separate shadow vehicle, the TTMA-100 is much less costly to own and operate than a conventional TMA.

FREQUENTLY ASKED QUESTIONS

1. Does the TTMA-100 meet NCHRP Report 350 requirements?

YES. The TTMA-100 has passed all NCHRP Report 350 Test Level 3 recommended crash tests, including both the required and the optional tests as documented by FHWA approval letters CC- 90 and CC-90a (www.safetytrailers.com). The TTMA-100 is the only truck mounted attenuation system to pass all full-scale crash tests with the tow vehicle blocked against forward motion to simulate an infinitely heavy tow vehicle. Only the TTMA-100 has been proven to be effective with a tow vehicle weighing more than 20,000 lb.

2. Is the rotation of the TTMA-100 a benefit to its safety performance?

YES. The TTMA-100's ability to rotate represents a major improvement in TMA safety technology. The patented innovation that makes this simple pintle-hook connection function is the way the TTMA-100 engages an impacting vehicle. The TTMA-100's impact plate is designed to capture the front of a vehicle to lock the trailer between the impacting vehicle and the tow vehicle. The mechanical interlock between the trailer and the impacting vehicle prevents the trailer from being pushed out of the path of the impacting vehicle. In fact, the combination of the simple pintle hook attachment and the trailer's connection with the vehicle, forces the trailer to rotate and align itself with the impact in order to maximize energy dissipation. **Hence the TTMA-100 provides maximum energy dissipation for impacts at any angle to provide maximum safety to both motorists and construction workers.**

3. Can the TTMA-100 safely accommodate angular impacts?

YES. As described above, the TTMA-100's impact plate is designed to capture the front of an impacting vehicle. The connection between the front of a vehicle and the rear of the trailer pulls impacting vehicles into the trailer. Further, the connection allows the trailer to rotate to align itself with the impact in order to maximize energy dissipation. **In this way, the TTMA-100 provides maximum energy dissipation for all vehicles, regardless of the angle of impact.**

4. Is TTMA-100 is safe to tow at freeway speeds?

YES. The TTMA-100's rugged construction makes it durable enough to be towed at freeway speeds. There is never any reason to stow the trailer.

5. Can the TTMA-100 be attached directly to work trucks?

YES. With a simple pintle hook hitch and a standard trailer wiring harness, any work truck, including striping or sweeping trucks, can be equipped with the TTMA-100. The TTMA-100 can eliminate the need for shadow vehicles in most moving work zone operations.

6. Doesn’t the TTMA-100’s rotation push an impacting vehicle further into traffic than other “restrained” trailer TMA’s?

NO. When the TTMA-100 captures the front of an impacting vehicle, it actually begins to pull the vehicle into the cushion. Further, by aligning itself with the impact, the TTMA-100 is able to maximize energy dissipation and avoid pushing the vehicle into adjacent traffic lanes. Comparison of vehicle rest locations after offset and angular crash tests (Tests 3-52 & 3-53) with other TMA systems shows that the TTMA-100 has no greater tendency to push vehicles into adjacent traffic lanes than other attenuator designs. Further, the TTMA-100 was tested with a blocked tow vehicle while all other systems were tested with relatively light support vehicles. A light tow vehicle rolls ahead as much as 5 meters during an impact to significantly increase the effectiveness of an attenuation system. Hence, the TTMA-100 performed just as well as the other TMA and trailer systems, even though it was tested under much more stringent conditions. **Therefore, it must be concluded that the TTMA-100 is less prone to pushing impacting vehicles into adjacent traffic lanes than its competitors.**

7. Can the TTMA-100 be used on snow plows?

YES. The TTMA-100 can be attached directly to a standard pintle hitch and a normal trailer wiring harness. Further, the trailer is constructed with heavy gage steel and is galvanized to prevent corrosion. This combination of simple attachment, durable construction and corrosion resistance make the TTMA-100 the first practical solution for safety protection of snow plows.

8. What modifications are required to attach a TTMA-100 to a sanding or salting truck?

NONE. The TTMA-100 can be attached without any modification directly to all sanding, salting, and brining trucks, that allow direct access to their pintle hook.

9. Is the TTMA-100 capable of meeting the safety performance evaluation guidelines in the update to NCHRP Report 350?

YES. The TTMA-100 has been designed with sufficient reserve capacity to meet the increased test severity required by the new testing guidelines as currently proposed.

10. Does the tow vehicle weight affect the performance of a TMA?

YES. When an automobile strikes the back of a TMA it begins to push the tow vehicle forward. Lighter tow vehicles are pushed farther forward and at a higher speed than are heavy tow vehicles. Tow vehicle roll ahead has a beneficial effect. Every foot that the truck rolls ahead before the impacting vehicle is brought to rest with respect to the tow vehicle reduces the amount of energy that must be absorbed by the TMA. Thus, lighter tow vehicles roll ahead further reducing the total amount of energy that must be absorbed by the cushion. No TMA system other than the TTMA-100 has been able to pass all NCHRP Report 350 with the tow vehicle blocked against roll ahead. Hence, only the TTMA-100 has been proven to be truly safe when attached to a truck weighing more than 20,000 lb.

11. What tow vehicle weight limits are associated with the TTMA-100?

10,000 lbs. and HIGHER. The TTMA-100 is recommended for use with any tow vehicle 10,000 lb or more. The TTMA-100 is the only TMA design that has utilized a blocked tow vehicle to simulate an infinitely heavy vehicle in all of the NCHRP Report 350 required and optional crash tests. All other TMA systems have utilized a 20,000 lb truck in at least some of their crash tests. Therefore, the TTMA-100 is the only system that can be safely used on tow vehicles weighing more than 20,000 lb. Note that FHWA does not recommend the use of any TMA system with any tow vehicle weighing less than 10,000 lb.

12. Does NCHRP Report 350 recommend testing with a 20,000 lb tow vehicle?

YES. Prior to the writing of NCHRP Report 350, there were no objective criteria for evaluating the safety performance of truck mounted attenuators. Most agencies conducting testing during this period used tow vehicles in the 10,000-20,000 lb range. The authors of the NCHRP Report 350 attempted to establish uniform testing criteria that could be used to evaluate the safety performance of competing designs. Unfortunately, by fixing the tow vehicle weight at 20,000 lb, the testing criteria created potential liability problems for TMA users and restricted advancement of the state-of-the-practice in TMA design. Agencies that needed to mount TMA's on heavy tow vehicles found that all available designs had been tested when attached to a relatively light, 20,000 lb truck. Hence, there was no device available that had been tested with a truly heavy tow vehicle and further, because the guidelines required a very light tow vehicle be used during full-scale crash testing, manufacturers had no motivation to develop designs for heavier vehicles.

13. Will the Update to Report 350 recommend testing with a 20,000 lb tow vehicle?

MAYBE. The update to NCHRP Report 350 is nearing completion and, if approved, will make the two optional tests required as well as add one additional optional test with a mid-sized automobile. The new guidelines will require manufacturers to define the maximum and minimum allowable tow vehicle weight for each TMA design. Three of the four required and the optional full-scale crash tests will be required to be conducted with the maximum allowable tow vehicle weight. One required test will be conducted with the minimum allowable tow vehicle weight to evaluate roll ahead.

14. Has the TTMA-100 been designed for long-term fatigue resistance?

YES. The basic construction of the Trailer TMA eliminates the fatigue prone components of a conventional TMA system. Further the TTMA-100 utilizes heavy gage tubular construction to provide additional fatigue resistance.

15. Can the TTMA-100 safely attenuate impacts with a loaded tractor-trailer truck?

NO. All truck mounted and trailer attenuators are designed to safely attenuate impacts with passenger vehicles and as such do not have sufficient energy dissipation capacity to fully attenuate high-speed, heavy truck impacts. However, some real world crashes have shown that TMA's can mitigate the severity of some heavy truck impacts with tow vehicles. TTMA-100 is the only truck mounted attenuation system to have passed all required and optional crash tests with a blocked tow vehicle. Hence, it is safe to assume that the TTMA-100 has greater energy dissipation capacity than any other TMA system. A simplified impact analysis of an 80,000 lb truck impacting tow vehicles traveling 15 mph was conducted to evaluate possible impact situations. The analysis showed that the TTMA-100 would have the energy dissipation capacity to reduce the truck to truck impact speed to 20 mph or less for the following crash conditions.

Tow Vehicle Weight, lb	80,000 lb Truck Impact Speed mph
10,000	54
20,000	45
40,000	39
60,000	37
80,000	36

16. Can the TTMA-100 be safely used with a tractor-trailer combination.

YES. All full-scale crash tests on the TTMA-100 were conducted with the tow vehicle blocked against forward movement or rotation. This test condition was specifically used to simulate the trailer being attached to a tow vehicle weighing 80,000 lb or more, and as a result the FHWA has approved use of the TTMA-100 with tow vehicles of unlimited mass. **Hence, it is safe to use the TTMA-100 attached to any tractor-trailer combination.**

17. Does the TTMA-100 have any attenuator components that may detach in an accident?

NO. The TTMA-100 is designed to retain all of its components during a high speed impact and the tube bursting system is designed to deflect the sides of the bursted tube out of the path of the impacting vehicle. Further, the tube side walls remain firmly attached to the trailer and do not become flying projectiles during high speed impacts. Numerous tests have been conducted with the tube bursting technology used in both construction and permanent roadside safety hardware and the tube bursting components have never been shown to pose a risk of entering the occupant compartment of an impacting vehicle. It should be noted that a significant amount of vehicle debris, such as plastic grill components, lens covers, etc., are generated during any full-scale crash testing and some videos of TTMA-100 testing shows these light weight components traveling away from the point of impact. This debris from the impacting vehicle is not unique to the TTMA-100 and, for the most part, it is blocked by the tow vehicle. **Hence, the TTMA-100 does not produce flying debris that would pose a danger to occupants of an impacting vehicle or nearby road workers.**

18. <u>Can the trailer remain attached during impact to the tow vehicle with a simple pintle hook attachment?</u>

YES. A pintle hook attachment may become detached from a tow vehicle during some high energy impacts. However, when used with the recommended safety chains, the TTMA-100 will remain attached to its tow vehicle, even under severe impact conditions. Hence, the trailer will remain attached to the rear of the tow vehicle and not pose a problem to construction workers or adjacent traffic.

19. <u>Does the TTMA-100 accommodate impacts on the side of the cushion differently that other TMA's?</u>

NO. All truck mounted attenuators are designed to safely accommodate vehicles striking the rear of the tow vehicle. No TMA system can accommodate even a modest impact on the side of the cushion. The TTMA-100 is no exception to this universal rule.

MAINTENANCE GUIDELINES

Proper maintenance of the Trailer TMA is critical to assure continuing safe operation and long-term durability of the system. The outside of the Trailer TMA should be washed periodically, particularly during winter usage, to eliminate salt and other road contaminants. The inside of the frame should also be washed annually. The end caps (Item G) can be removed to allow rinsing the inside of the frame. Care should be taken with the wiring for the side marker lights during this process. Note that all critical parts of the Trailer TMA are hot-dip galvanized, thus requiring minimal maintenance.

The following preventive maintenance schedule is recommended:

Item	Function Required	Before Each Use	Weekly	3 Months/ or 3,000 Miles	12 Months or 12,000 Miles
Lighting System	Test that they are operational	••			
Pintle Hook	Check for adequate capacity and that the retaining pin is properly inserted	••			
Safety Chains	Check that they are properly attached	••			
Tire Inflation	Set to manufacturer specification		••		
Tire Condition	Inspect for cuts, wear, bulging, etc.			••	
Wheels	Inspect for cracks, dents or distortion			••	
Bolts and Wheel Nuts	Tighten to specified torque values			••	
Wheel Bearings and Cups	Inspect for corrosion or wear. Clean and repack				••
Frame Welds	Check for cracks				••

REPAIR OF DAMAGED TRAILER

Impact by Errant Vehicle

When the TTMA-100 is impacted by an errant vehicle, the following sequence of events will occur:

1. The impact head and the mandrels are pushed forward by the impacting vehicle.

2. For impacts of 5 mph (8 km/h) or less, which are termed nuisance hits, crash testing has shown that there is no damage to the energy absorption assembly of the TTMA-100. Damages will likely be confined to bending or shearing of the shear bolts holding the first stage energy absorbing tubes and minor scratches and dents to the impact head.

3. For impacts with higher impact speed, the shear bolts holding the mandrels to the first stage energy absorbing tubes are sheared off.

4. The mandrels are pushed forward and engage the first stage energy absorbing tubes.

5. Bursting of the first stage energy absorbing tubes begins to dissipate the energy from the impacting vehicle.

6. Bursting of the first stage energy absorbing tubes continues. The next sequence of events depends on the severity of the impact.

   Low-speed impact:
   a. Vehicle comes to a complete stop prior to the mandrels reaching the breakaway axle.

   Medium-speed impact:
   a. The mandrels contact the shear blocks for the breakaway axle and shear off the bolts attaching the breakaway axle to the first stage energy absorbing tubes.
   b. The impact head contacts the axle push rods and moves the axle forward as the bursting process continues.
   e. Vehicle comes to a complete stop prior to the mandrels reaching the splice connecting the first and second stage energy absorbing tubes.

   High-speed impact:
   a. The mandrels contact the shear blocks for the breakaway axle and shear off the bolts attaching the breakaway axle to the first stage energy absorbing tubes.
   b. The impact head contacts the axle push rods and moves the axle forward as the bursting process continues.
   c. The bursting process continues past the splice connecting the first and second stage energy absorbing tubes.
   d. Vehicle comes to a complete stop or spins out to a safe stop.

TTMA-100 Repair

For impacts requiring replacement of major components on the TTMA-100, Safety Trailers, Inc. offers different parts packages depending on the damage assessment of the unit. These parts packages come with specific instructions regarding assessment of trailer conditions and for repair of your damaged trailer. These parts packages are available through STI or a designated distributor in your area

To facilitate our evaluation of the in-service performance of the TTMA-100, we offer these repair parts packages at significant discounts if records of the incident are forwarded to STI or one of our designated distributors. These records may include one or more of the following items: photographs of damaged trailer, photographs of the impact and support vehicles, police accident report if available, and phone interviews with involved parties.

These parts packages are also available for purchase by the end user to keep in stock. In the case where repair parts are taken from the stock, STI will issue rebates if the incident requiring replacement of the parts is reported to STI or one of our designated distributors.

When the TTMA-100 is impacted by an errant vehicle, the degree of damage and the resulting level of repair and replacement is a function of the severity of the impact. In turn, the impact severity is a function of many factors, including the weight of the tow vehicle and whether it is stationery or moving, the weight of the impacting vehicle and its impact speed and angle. As discussed above, the impact severity and associated level of repair and replacement can be generally grouped into the following four categories, in order of ascending severity:

- Nuisance hit,
- Low-speed impact,
- Medium-speed impact, and
- High-speed impact.

Nuisance Hits

Nuisance hits are typically 5 mph or less. Crash testing has shown that there is no damage to the energy absorption assembly of the TTMA-100 when impacted at a speed of 5 mph. Thus, for such nuisance hits, the key activities are:

- Inspect shear bolts holding mandrels in place with the energy absorbing tubes. If the shear bolts are bent or broken, replace the bolts.
- Inspect trailer lights for damage, replace if necessary.

Order the appropriate parts in accordance with the damage sustained by the trailer. The parts typically needed for such nuisance impacts are shown in the following table:

Part	Part No.	Items in Package
Shear Bolts	NHRC	Shear bolts, nuts and washers
Light Bar	T100-LB	New rear light bar and wiring harness

Low-Speed Impacts

Low-speed impacts are those resulting in bursting of the first stage energy absorbing tubes, but the vehicles come to a complete stop before the breakaway axle is detached. For such low-speed impact, the key activities are:

- Replace first stage energy absorbing tubes.
- Inspect trailer lights for damage, replace if necessary.
- Inspect impact head for damage.
- Make sure that the impact head maintains proper alignment for the mandrels.
- Inspect the mandrels for damage.
- Inspect lunette ring, pintle hook, and safety assembly for damage. Repair/replace components as appropriate.

Order the appropriate parts in accordance with the damage sustained by the trailer. The parts typically needed for such low-speed impacts are shown in the following table:

Part	Part No.	Items in Package
First Stage Energy Absorbing Tubes	LSRC	2 energy absorbing tubes and all associated hardware required for repair
Light Bar	T100-LB	New rear light bar and wiring harness

<u>Medium-Speed Impacts</u>

Medium-speed impacts also result in bursting of the first stage energy absorbing tubes, but the mandrels reach the shear blocks to break off the axle from the first tubes and push the axle forward. However, the vehicle comes to a complete stop prior to reaching the splice connecting the first and second stage energy absorbing tubes. For such medium-speed impact, the key activities are:

- Replace first stage energy absorbing tubes.
- Inspect the breakaway axle assembly for damage. Replace axle if visibly bent.
- Inspect trailer lights for damage, replace if necessary.
- Inspect impact head for damage.
- Inspect the mandrels for damage.
- Inspect the lunette ring, pintle hook, and safety assembly for damage.

Order the appropriate parts in accordance with the damage sustained by the trailer. The parts typically needed for such medium-speed impacts are shown in the following table:

Part	Part No.	Items in Package
First Stage Energy Absorbing Tubes	MSRC	2 first stage energy absorbing tubes and all associated hardware required for repair
Axle Assembly	T100-AA	Axle, push rods and fenders
Light Bar	T100-LB	New rear light bar and wiring harness

High-Speed Impacts

High-speed impacts are those resulting in the bursting of the first stage energy absorbing tubes through the splice and into the second stage energy absorber. For high speed impacts, the key activities are:

- Replace first stage energy absorbing tubes.
- Replace the second stage energy absorbing tubes.
- Inspect the breakaway axle assembly for damage. Replace axle if visibly bent.
- Inspect trailer lights for damage, replace if necessary.
- Inspect impact head for damage.
- Inspect the mandrels for damage.
- Inspect the lunette ring, pintle hook, and safety assembly for damage.

For most high-speed impacts, damage to the trailer is too extensive to be repaired and it may be more cost-effective to purchase a new trailer. In the event that damage sustained by the trailer is repairable, the parts typically needed for such high-speed impacts are shown in the following table:

Part	Part No.	Items in Package
Energy Absorbing Tubes	HSRC	2 first stage energy absorbing tubes, trailer frame, and all associated hardware required for repair
Axle Assembly	T100-AA	Axle, push rods and fenders
Light Bar	T100-LB	New rear light bar and wiring harness

TTMA-100 -- TRAILER TMA
GENERAL SPECIFICATIONS

I. Scope

This specification presents product information for the Trailer TMA manufactured and distributed by Safety Trailers, Inc. The specification includes the following sections:

- Intended applications
- Support truck guidelines
- Product description
- Product approvals
- Product durability
- Mounting of optional equipment
- Dimensions and weight

II. Intended Applications

The Trailer TMA is designed to protect motorists and workers in both moving shadow vehicle and stationary barrier vehicle applications. The TTMA has been successfully crash tested with both small sedan and light truck vehicles impacting at speeds up to 100 km/hr (62 mph). When properly deployed, the Trailer TMA will:

1. Reduce the severity of impact for occupants of errant vehicles that collide with the rear of a shadow or barrier vehicle.
2. Reduce crash severity for occupants of shadow vehicles.
3. Minimize or prevent damage to the barrier or shadow vehicle.
4. Reduce the time required to clear the accident scene and restore traffic flow.

The Trailer TMA, by Safety Trailers, Inc., utilizes tube bursting technology to attenuate vehicular impacts. The structural tube rail members of the trailer function as energy absorbers. The energy dissipation occurs as steel mandrels, attached to the impact head, are driven into the trailer frame members.

III. Support Truck Guidelines

Support trucks used to tow the Trailer TMA should have a minimum weight of 4,500 kg (9,900 lb). Support truck drivers should utilize an adequate head rest, lap belt, and shoulder harness. Heavier support trucks reduce the risk to shadow vehicle operators and reduce vehicle roll ahead during an impact. However, because all full-scale crash tests were conducted with the support truck blocked to prevent roll ahead, there is no upper limit on the acceptable support truck weight.

The distance between the shadow vehicle and work zone activities should be maintained at acceptable minimums to prevent the support truck from rolling into workers or other construction equipment. Support truck roll-ahead distance is a function of the weight and speed of both the shadow truck and the impacting vehicle. Table 1 shows calculated shadow vehicle roll-ahead distances for a variety of shadow and impacting vehicle weights and impact speeds. Roll-ahead calculation procedures were adapted to include the weight of the Trailer TMA and are based upon a shadow vehicle speed of 15 mph.

When the Trailer TMA is attached to a stationary barrier vehicle, the support truck should be placed in second gear with the parking brake fully engaged. In order to minimize barrier truck roll-ahead distance, the vehicle's parking brake should be maintained in good operating condition. Calculated roll-ahead distances for stationary barrier vehicles utilizing a Trailer TMA are shown in Table 2. Data shown in Tables 1 and 2 were developed using procedures presented in a paper entitled "Use of Truck Mounted Attenuators in Work Zones," by Jack B. Humphreys and T. Darcy Sullivan.

The Trailer TMA is attached to the support truck using to standard pintle hook with a minimum towing rating of 7250 kg (8 tons). The pintle hook must be securely mounted to an appropriately strong structural component on the frame of the support truck. The pintle hook height needs to be in a range between 500 and 800 mm (19.5 and 32 in.). For pintle hooks ranging from 500 to 610 mm (19.5 to 24") the lower lunette ring mounting position must be utilized. For pintle hooks ranging from 700 to 800 mm (27.5 and 32 in.) the upper mounting position for the lunette ring is required. In between these ranges either location for the lunette ring is acceptable. It is recommended that both the current ballast and the anticipated ballasting of the support truck be considered when selecting the appropriate lunette ring location. The support truck must be equipped with a standard four pin linear connector to power the Trailer TMA markers and brake lights. The trailer is also supplied with an adapter to accommodate tow vehicles with a round pin connector.

A trailer jack is located on the forward most cross member of the Trailer TMA. Connecting the Trailer TMA to a tow vehicle is as simple as placing the lunette ring in the truck's pintle hook, attaching the trailer lighting connector and safety chains, and raising the trailer jack to a horizontal position for towing. The light weight of the Trailer TMA and its very low tongue weight of approximately 900 N (200 lb) make the connection process very quick and easy.

IV. Product Description

A. Major Components

The Trailer TMA incorporates the following major components

1. Trailer Frame Assembly
2. Two (2) Bursting Tubes
3. Axle Assembly with Axle Push Tubes
4. Torsion Axle
5. Two (2) Tube Bursting Mandrels
6. Impact Head

B. General Assembly

The Trailer Frame Assembly includes a lunette ring for attachment to a standard 8 ton or larger pintle hook. The two bursting tubes are attached to the trailer frame assembly and provide the primary energy dissipation system. The two bursting tubes also serve as the primary longitudinal frame elements. The axle and push tube assembly are attached to the two bursting tubes. The Impact head is mounted to the two Tube Bursting Mandrels which are inserted into the bursting tubes.

C. Trailer TMA Function

The Trailer TMA is designed to safely attenuate passenger vehicle impacts on the rear of the trailer. When a vehicle strikes the rear of the trailer, the impact head is forced forward and it drives the tube bursting mandrels into the bursting tubes. Energy dissipation by the bursting tubes provides a controlled deceleration of the impacting vehicle. As the tube bursting mandrels continue forward, they contact axle shear connectors and fracture the bolts holding the trailer axle to the bursting tubes. Shortly thereafter, trailer's impact head contacts the axle push tubes and moves the axle toward the front of the trailer. For high energy impacts near the design limits, the impact head will continue forward until the bursting tubes are completely ruptured. If needed, the side rails of the trailer frame assembly will then begin to burst and the energy dissipation will continue until the impacting vehicle is brought to a safe stop.

During high energy impact testing near the design limits, the Trailer TMA proved to be capable of attenuating all of the impact energy without producing any damage to undercarriage, suspension, or tires of the tow vehicle. No structural components of the Trailer TMA were forced under the support vehicle.

During minor impacts, trailer damage should be limited to the two bursting tubes which can be easily replaced. This process involves removing the impact head, tube bursting mandrels, and the axle assembly from the trailer by removing four bolts and pulling the system apart. The damaged bursting tubes will be replaced and the axle, tube bursting mandrels, and impact head will then be re-attached. Note that the trailer wiring and light system must be carefully inspected and any needed repairs made before placing the restored trailer back into service. Complete repair should be accomplished with simple hand tools and the appropriate replacement parts.

D. Lights and Visibility

The Trailer TMA is shipped with a lighting assembly that conforms to FMVSS No. 108, "Lamps, Reflective Devices, and Associated Equipment." Any modification to the lighting, marker, and reflectivity should conform to these specifications. FMVSS 108 represents a minimum requirement. Users can add additional lights, markers, and reflective strips without fear of violating this standard.

E. Corrosion Protection

All components of the energy dissipation system, including the impact head, tube bursting mandrels, bursting tubes, and trailer frame assembly shall be hot-dip galvanized to prevent corrosion. Bolts and other exposed attachment hardware should also be galvanized where possible to prevent corrosion.

V. Product Approvals

The Trailer TMA by Safety Trailers, Inc. was approved by the Federal Highway Administration (FHWA) as a Test Level-3 Truck Mounted Attenuator in a letter dated April 15th, 2005. It has also been recognized by FHWA as meeting the TL-3 Optional Tests recommended by NCHRP Report 350 in a letter dated September 18th, 2006. Many states do not require individual approval of TMA systems and rely only on FHWA approval. The Trailer TMA is now fully qualified for use in all of those states.

Safety Trailers Inc. is pursuing approval in every state where a separate approval process is required. If your state requires individual approval of TMA's and the Trailer TMA is not listed on the appropriate approved product list, please call **Safety Trailers Inc.** at **(970)-819-1741** for information regarding approval status in your state.

VI. Product Durability

The Trailer TMA has been subjected to extensive road testing at both high and low speed operations on both paved and unpaved roadways. This testing has shown no evidence of fatigue failure of any components of the Trailer TMA. Safety Trailers Inc. is continuing to conduct long term testing to assure that no fatigue problems develop. If your state requires special testing of TMA durability, please contact Safety Trailers Inc. for help in testing the new Trailer TMA to meet any state standards and gaining the needed state approval.

VII. Optional Equipment

The Trailer TMA is designed to accommodate light weight flashing arrow boards or other optional equipment attached to the front of the trailer. Two pairs of mounting holes have been placed in the trailer frame cross member and another pair is placed in trailer hitch gusset. These mounting holes should be sufficient for supporting a light weight arrow board or other optional warning devices. The support structure for these optional devices must be designed to withstand a 20 g acceleration without collapse. Note that the wiring harness supplied with the Trailer TMA may need to be supplemented in order to power a flashing arrow board or other warning device. Users interested in attaching optional equipment to the Trailer TMA are encouraged to contact Safety Trailers Inc. for additional advice.

VIII. Dimensions and Weight

The Trailer TMA has a very low profile, with a maximum height of only 788 mm (31 in.). This low profile allows excellent visibility for any optional equipment, such as a flashing arrow board attached to the front of the trailer. The maximum trailer width, measured at the impact head, is 2440 mm (96 in.) and its overall length is 7.2 m (23'-6"). The total mass of the basic Trailer TMA without any optional equipment is approximately 635 kg (1400 lb).

Table1. Calculated Roll-Ahead Distances for Shadow Vehicles.

Support Truck Weight, lb	Traffic Operating Speed, mph	Impact Vehicle Weight, lb			
		4500	10000	15000	24000
10,000	65	119′	205′	261′	333′
	55	97′	158′	198′	247′
	45	77′	118′	143′	174′
15,000	65	93′	161′	211′	278′
	55	78′	127′	162′	209′
	45	65′	97′	120′	150′
24,000	65	71′	118′	157′	215′
	55	62′	97′	124′	165′
	45	54′	77′	96′	122′

Table 2. Calculated Roll-Ahead Distances for Barrier Vehicles.

Support Truck Weight, lb	Traffic Operating Speed, mph	Impact Vehicle Weight, lb			
		4500	10000	15000	24000
10,000	65	38′	103′	152′	216′
	55	27′	74′	109′	155′
	45	18′	50′	73′	104′
15,000	65	22′	68′	108′	166′
	55	16′	49′	77′	119′
	45	11′	33′	52′	80′
24,000	65	11′	38′	65′	111′
	55	8′	27′	47′	80′
	45	6′	18′	32′	54′

SUMMARY OF CRASH TEST RESULTS
TTMA-100

Guidelines set forth in National Cooperative Highway Research Program (NCHRP) Report 350 specify two (2) required crash tests for evaluation of a truck-mounted attenuator (TMA) under test level 3 (TL-3) conditions:

1. Test Designation 3-50. An 820-kg (1,800-lb) passenger car impacting the center of the TMA at a speed and angle of 100 km/h (62 mph) and 0 degree.

2. Test Designation 3-51. A 2000-kg (4,400-lb) pickup truck impacting the center of the TMA at a speed and angle of 100 km/h (62 mph) and 0 degree.

In addition, *NCHRP Report 350* recommends two (2) optional crash tests for further evaluation of a truck-mounted attenuator under TL-3 conditions:

3. Test Designation 3-52. A 2000-kg (4,400-lb) pickup truck impacting the TMA at a speed and angle of 100 km/h (62 mph) and 0 degree with the centerline of the vehicle offset by one-third of the width of the TMA.

4. Test Designation 3-53. A 2000-kg (4,400-lb) pickup truck impacting the center of the TMA at a speed and angle of 100 km/h (62 mph) and 10 degrees with the centerline of the vehicle offset by one-quarter of the width of the TMA.

The two required tests (3-50 and 3-51) assess the impact performance of the TMA in end-on impacts while the two optional tests evaluate off-center and oblique impacts. All four (two required and two optional) crash tests were successfully conducted for the Trailer TMA. In addition, test 3-53 was repeated with the support truck rigidly restrained to eliminate lateral and vertical movements in addition to forward movement.

A 1973 Ford dump truck, weighing 4,390 kg (9,700 lb), was used as a support vehicle for the Trailer TMA system in these tests. The front of the support vehicle was set against a rigid concrete block to prevent any forward motion of the support vehicle during the impact event. The reason for eliminating the forward motion of the support truck is to allow the Trailer TMA to be used with a support truck of any weight, i.e., there is no upper limit on the weight of the support truck that the Trailer TMA can be used with.

Summaries of the test results and the sequential photographs for each of these crash tests are shown in Figures 1 through 5, respectively. Detailed information on these crash tests are provided in the test reports included on the CD-ROM.

- Test Number TTMA-3 (3-30)
- Date 8/04/04
- Test Article
  - Type .... Trailer TMA
  - Key Elements .... Trailer TMA impact head
    - Tubular steel frame
    - Trailer wheel and axle assembly
  - Orientation .... center of vehicle with center of TMA
- Soil Type .... NA
- Vehicle Model .... 1999 Geo Metro
  - Curb .... 743 kg
  - Test Inertial .... 821 kg
  - Gross Static .... 897 kg
- Vehicle Speed
  - Impact .... 96.0 km/h
  - Exit .... 0.0 km/h
- Vehicle Angle
  - Impact (trajectory) ..... 0.13 deg
  - Exit (trajectory) .... NA
- Vehicle Stability .... Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal .... 11.86 g's < 20 g's
  - Lateral .... 2.11 g's < 20 g's
- Occupant Impact Velocity
  - Longitudinal .... 11.42 m/s < 12 m/s
  - Lateral .... 0.02 m/s < 12 m/s
- Post-Impact Head Deceleration and Theoretical Head Impact Velocity
  - THIV .... 11.41 m/s < 12 m/s (not req.)
  - PHD .... 11.89 g's < 20 g's (not req.)
- Vehicle Damage .... Moderate
  - TAD[7] 12-FD-4
  - SAE[8] 12FDEW2
- Vehicle Stopping Distance .... 2.58 m downstream
- Test Article Damage .... Moderate
- Maximum Deflection
  - Permanent Set .... 3,102 mm
  - Dynamic .... 3,077 mm
- Working Width .... 6.97-m long by 5.05-m wide

FIGURE 1: Test TTMA-3 results (NCHRP test 3-50).

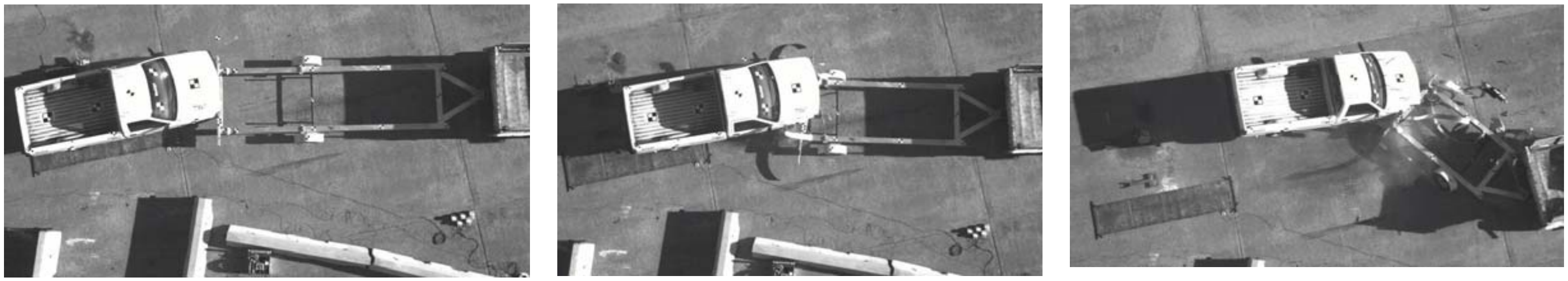
- Test Number TTMA-4 (3-51)
- Date 12/14/04
- Test Article
  - Type .... Trailer TMA
  - Key Elements .... Trailer TMA impact head
    Tubular steel frame
    Trailer wheel and axle assembly
  - Orientation .... center of vehicle with center of TMA
- Soil Type .... NA
- Vehicle Model .... 1999 GMC 2500
  - Curb .... 1,955 kg
  - Test Inertial .... 2,012 kg
  - Gross Static .... 2,012 kg
- Vehicle Speed
  - Impact .... 99.5 km/h
  - Exit .... 0.0 km/h
- Vehicle Angle
  - Impact (trajectory) ..... 0.63 deg
  - Exit (trajectory) .... NA

- Vehicle Stability .... Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal .... 17.69 g's < 20 g's
  - Lateral .... 4.11 g's < 20 g's
- Occupant Impact Velocity
  - Longitudinal .... 8.59 m/s < 12 m/s
  - Lateral .... 0.21 m/s < 12 m/s
- Post-Impact Head Deceleration and Theoretical Head Impact Velocity
  - THIV .... 8.58 m/s < 12 m/s (not req.)
  - PHD .... 17.72 g's < 20 g's (not req.)
- Vehicle Damage .... Moderate
  - TAD[7] 12-FD-3
  - SAE[8] 12FDEW2
- Vehicle Stopping Distance .... 3.89 m downstream
- Test Article Damage .... Moderate
- Maximum Deflection
  - Permanent Set .... 4,632 mm
  - Dynamic .... 5,132 mm
- Working Width .... 6.97-m long by 7.21-m wide

FIGURE 2: Test TTMA-4 results (NCHRP test 3-51).

- Test Number TTMA-5 (3-52)
- Date 7/29/05
- Test Article
  - Type .... Trailer TMA
  - Key Elements .... Trailer TMA impact head
  - .... Tubular steel frame
  - .... Trailer wheel and axle assembly
  - Orientation .... Centerline offset by one-third of width
- Soil Type .... NA
- Vehicle Model .... 2000 Chevrolet C2500
  - Curb .... 2,021 kg
  - Test Inertial .... 2,024 kg
  - Gross Static .... 2,024 kg
- Vehicle Speed
  - Impact .... 102.1 km/h
  - Exit (not required) .... NA
- Vehicle Angle
  - Impact (trajectory) .... 1.3 deg
  - Exit (not required) .... NA
- Vehicle Stability .... Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal .... 14.30 g's < 20 g's
  - Lateral .... 6.68 g's < 20 g's
- Occupant Impact Velocity
  - Longitudinal .... 10.66 m/s < 12 m/s
  - Lateral .... 1.04 m/s < 12 m/s
- Post-Impact Head Deceleration and Theoretical Head Impact Velocity
  - THIV .... 10.75 m/s < 12 m/s (not req.)
  - PHD .... 18.07 g's < 20 g's (not req.)
- Vehicle Damage .... Moderate
  - TAD[8] 12-FR-4
  - SAE[9] 12FYEW3
  - OCDI F000000000
- Vehicle Stopping Distance .... 5.03 m downstream
- Test Article Damage .... Moderate
- Maximum Deflection
  - Permanent Set .... NA
  - Dynamic .... NA
- Working Width .... 7.86-m long by 12.78-m wide

FIGURE 3: Test TTMA-5 results (NCHRP test 3-52).



- Test Number TTMA-7 (3-53)
- Date 12/20/05
- Test Article
  - Type .... Trailer TMA
  - Key Elements .... Trailer TMA impact head
    Tubular steel frame
    Trailer wheel and axle assembly
  - Orientation .... Centerline offset by one-fourth of width
- Soil Type .... NA
- Vehicle Model .... 1999 Chevrolet C2500
  - Curb .... 1,956 kg
  - Test Inertial .... 2,013 kg
  - Gross Static .... 2,013 kg
- Vehicle Speed
  - Impact .... 99.9 km/h
  - Exit .... NA
- Vehicle Angle
  - Impact (trajectory) .... 11.0 deg
  - Exit (trajectory) .... NA
- Vehicle Stability .... Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal .... 12.83 g's < 20 g's
  - Lateral .... 9.15 g's < 20 g's
- Occupant Impact Velocity
  - Longitudinal .... 10.80 m/s < 12 m/s
  - Lateral .... 1.50 m/s < 12 m/s
- Post-Impact Head Deceleration and Theoretical Head Impact Velocity
  - THIV .... 11.10 m/s < 12 m/s (not req.)
  - PHD .... 14.31 g's < 20 g's (not req.)
- Vehicle Damage .... Moderate
  - TAD[9] 12-FR-4
  - SAE[10] 12FZEW4
  - OCDI F000000000
- Vehicle Stopping Distance ..... 7.38 m downstream
- Test Article Damage .... Moderate
- Maximum Deflection
  - Permanent Set .... NA
  - Dynamic .... NA
- Working Width .... 9.04 m long by 13.00 m wide

FIGURE 4: Test TTMA-7 results (NCHRP test 3-53).

- Test Number TTMA-9 (3-53)
- Date 8/18/06
- Test Article
  - Type .... Trailer TMA
  - Key Elements .... Trailer TMA impact head
    - Tubular steel frame
    - Trailer wheel and axle assembly
  - Orientation .... Centerline offset by one-fourth of width
  - Shadow Vehicle .... Right-rear tire blocked against lateral movement
    - Ballasted to total weight of 10,433 kg
- Soil Type .... NA
- Vehicle Model .... 1999 Chevrolet C2500
  - Curb .... 2,105 kg
  - Test Inertial .... 2,023 kg
  - Gross Static .... 2,023 kg
- Vehicle Speed
  - Impact .... 100.4 km/h
  - Exit .... NA
- Vehicle Angle
  - Impact (trajectory) .... 9.3 deg
  - Exit (trajectory) .... NA
- Vehicle Stability .... Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal .... -11.27 g's < 20 g's
  - Lateral .... -6.43 g's < 20 g's
- Occupant Impact Velocity
  - Longitudinal .... -9.21 m/s < 12 m/s
  - Lateral .... -0.65 m/s < 12 m/s
- Vehicle Damage .... Moderate
  - TAD[9] 12-FD-4
  - SAE[10] 12FDEW4
  - OCDI F000000000
- Vehicle Stopping Distance .... 15.24 m downstream
  - 2.44 m toward the left
- Test Article Damage .... Moderate
- Maximum Deflection
  - Permanent Set .... NA
  - Dynamic .... NA
- Working Width .... 18.33 m long by 14.93 m wide

FIGURE 5: Test TTMA-9 results (Repeat of NCHRP test 3-53).

As mentioned previously, the Trailer TMA was determined to have satisfactorily met all evaluation criteria set forth in NCHRP Report 350 for all five tests. The Trailer TMA performed as designed, dissipating the impact energy by bursting the energy-absorbing tubes into strips of steel. For the two head-on tests (tests 3-50 and 3-51), the vehicles were brought to a controlled and safe stop in line with the support truck. The lengths of bursting were functions of the impact energy. For the oblique impacts (tests 3-52 and 3-53), the bursting process slowed down the vehicles until the vehicle yawed out due to the eccentricity and oblique angle of impact. The bursting process then continued with one of the energy absorbing tubes until the vehicles were brought to a controlled and safe stop. Due to yawing of the vehicle, the vehicle's trajectory may intrude into adjacent traffic lanes depending on the location and specific application of its use. However, any intrusion would be minimal and for a short duration of time.