

Safe-Stop Trailer (SST) TMA™

GENERAL SPECIFICATIONS

I. GENERAL:

Scope: This specification describes a truck-mounted attenuator (TMA) system for 'mobile work zone' shadow vehicles and 'stationary work zone' barrier vehicles.

The system provides impact protection during collisions into the rear of a truck in work zone operations. The system design dissipates the collision energy of standard passenger vehicles traveling at speeds up to 100 km/h (62mph).

The following primary benefits are projected:

1. Reduce impact severity for occupants of the barrier or shadow vehicle.
2. Reduce or eliminate damage to barrier or shadow vehicle.
3. Reduce incident management time.
4. Increase survival rate for the occupants of impacting vehicles.
5. Lower injury rate for the occupants of impacting vehicles.

II. PRODUCT:

All SST Truck Mounted Attenuators [TMA's] shall be designed and manufactured by Energy Absorption Systems, Incorporated, a Quixote Company, of Chicago, Illinois, in accordance with this specification.

The SST TMA, when properly mounted, shall meet NCHRP (National Cooperative Highway Research Program) Report 350, Test Level 3 (TL-3) criteria.

The SST TMA equipped truck shall have a maximum skid distance of 8 m (25ft) when impacted at NCHRP Report 350 TL-3, test 3-51 impact conditions. The forward skid distance is dependent on the truck's weight, the truck's transmission being in second gear, and the parking brake set with the truck situated on clean, dry pavement.

The SST TMA can be used with any weight vehicle over 4500 kg (9,920 lbs). FHWA has acknowledged the infinite weight test and the use of the Safe-Stop 180 TMA with heavier support vehicles at the discretion of the contracting authority. The SST is a modified version of the Safe-Stop 180 TMA.

The SST TMA uses a hydraulic cylinder dampener system to minimize rotation during an offset impact, thus helping to minimize possible secondary accidents. This system will allow the trailer to act like a normal trailer when trailering and resist rotation when impacted.

The SST has the capabilities of being used with lighter shadow and barrier vehicles. The roll-ahead distance is affected by the total weight of the shadow or barrier vehicle plus the SST TMA weight.

See the Calculated Roll-Ahead chart below:

**Table T-4 Roll-Ahead Distance for Shadow Vehicles*

Weight of Shadow Vehicle (moving)	Prevailing speed (mph)	Weight of Impacting Vehicle to be Contained*			
		4,500 lbs	10,000 lbs	15,000 lbs	24,000 lbs
10,000 lbs	60-65	100 ft	175 ft	225 ft	275 ft
	50-55	100 ft	150 ft	175 ft	200 ft
	45	75 ft	100 ft	125 ft	150 ft
15,000 lbs	60-65	75 ft	150 ft	175 ft	225 ft
	50-55	75 ft	125 ft	150 ft	175 ft
	45	50 ft	100 ft	100 ft	100 ft
24,000 lbs	60-65	75 ft	100 ft	150 ft	175 ft
	50-55	50 ft	75 ft	100 ft	150 ft
	45	50 ft	75 ft	75 ft	100 ft

Note: Distances are appropriate for shadow vehicles speeds up to 15 mph.

**Table T-5 Roll-Ahead Distance for Barrier Vehicles*

Weight of Barrier Vehicle (stationery)	Prevailing speed (mph)	Weight of Impacting Vehicle to be Contained*			
		4,500 lbs	10,000 lbs	15,000 lbs	24,000 lbs
10,000 lbs	60-65	50 ft	100 ft	150 ft	200 ft
	50-55	25 ft	75 ft	100 ft	150 ft
	45	25 ft	50 ft	75 ft	100 ft
15,000 lbs	60-65	25 ft	75 ft	100 ft	150 ft
	50-55	25 ft	50 ft	75 ft	100 ft
	45	25 ft	25 ft	50 ft	75 ft
24,000 lbs	60-65	25 ft	50 ft	75 ft	100 ft
	50-55	25 ft	25 ft	50 ft	75 ft
	45	25 ft	25 ft	25 ft	50 ft

**Source: "Use of Truck Mounted Attenuators in Work Zones" by Jack B. Humphreys, P.E. and T. Darcy Sullivan, P.E., University of Tennessee.*

***Weights of typical vehicles:**

- Mid-size automobile — 2,250 lbs
- Full-size automobile — 3,500 lbs
- Loaded 3/4-ton pickup truck — 6,000 lbs
- Loaded 1-ton cargo truck — 10,000 lbs
- Loaded 4-yard dump truck — 24,000 lbs

Shadow or Barrier Recommended Vehicle Weight

Recommended minimum vehicle weight ó 4,500 Kg (9,920 lbs.)

Recommended maximum vehicle weight ó No Limitation

III. DESCRIPTION OF SYSTEM:

A. General Assembly

The complete SST TMA shall be designed to make attachment or detachment from the truck simple and fast. The major components (listed in III. B.) stay together when detached from the support vehicle.

The TMA frame shall be capable of collapsing when impacted by an errant vehicle. No portion of the TMA shall protrude forward under the truck damaging its vital elements during an impact.

The TMA shall not protrude over, into or under the truck. Further, the TMA shall not impede the line-of-site of an Arrowboard or Message board mounted on the truck, installed per MUTCD (Manual on Uniform Traffic Control Devices) guidelines at a height of 2135mm (7'-0") to the bottom of board.

Following a design impact under NCHRP Report Test Level 3 conditions, the TMA shall remain less than 3650mm (12'-0") wide and retain its structure. This shall permit short distance transport off the road after impacts. The TMA shall be capable of being refurbished using simple hand tools and replacement parts. After design speed impacts, approximately 70% of the components and framework shall be reusable.

B. Major Components:

The SST TMA shall consist of the following components:

1. Support Structure with Articulating Arms
2. Safe-Stop 180/SST Type A and Type B Cartridges
Note: Both of the cartridges shall be contained within the framework created by the arms.
3. Impact Frame
4. Cylinder Hitch Assembly (Trailer hitch with cylinder dampener system)
5. Intermediate Frame
6. Suspension, Axle, Wheels & Tires

C. Lights & Visibility

The SST TMA shall have a trailer lighting assembly per FMVSS No. 108 (Lamps, Reflective Devices, and Associated Equipment). All components shall be appropriate for their intended purpose under any adoptions issued by the NHTSA, SAE and FMVSS. This is standard practice for electrical lighting. The SST TMA shall include brake lights, taillights, turn signals and an ICC bar light. Wires shall be routed in a protective, jacketed

cable. The cable shall be routed and secured to the frames at 450 (18") maximum intervals. For repair or replacement, individual circuits shall be easily identified and accessible. Molded connectors shall be used where individual wires would otherwise be exposed to the elements. A standard, single, 7 pin trailer connector shall make the connection for all lights to the back of the truck. Conspicuity tape and reflectors shall be installed following the same established standards as the lighting.

D. Jack

One hand crank jack with swivel caster with a total rated load capacity of at least 544 kg (1200 lbs.) shall be supplied with the TMA to facilitate removing it from a truck for storage.

E. Striping

The surface of the Impact Frame facing oncoming traffic, shall display a black on yellow inverted chevron pattern with 100mm (4 in.) wide color bands. The colors shall meet the value and tolerance limits established by MUTCD.

F. Welding

All welding shall be done by, or under the direction of, a certified welder. Metal-work shall be made in America.

G. Paint

All exposed steel surfaces on the TMA shall be painted black. Paint shall be applied after the proper preparation of all steel and aluminum components. The metal preparation shall include cleaning, degreasing and abrading the metal surface. Primer shall be used if not powder coated.

H. Hardware

The TMA shall be assembled with Commercial Quality bolts, nuts, and washers conforming to ANSI (American National Standard) specifications unless otherwise specified.

I. Hydraulic System

The hydraulic system shall consist of cylinders, hoses, tank and subcomponents. The hydraulic system allows the system to articulate like a normal trailer behind the support vehicle, but locks to prevent the trailer from rotating during off-set or angled impacts.

J. Break-Away System

A system designed to automatically lock the trailer brakes in the event of a hitch failure and the trailer breaks away from the tow vehicle.

IV. WEIGHT AND DIMENSIONS:

	Max Height From Ground	Max Width (Impact Face)	Length	Weight
English Units	45"	7'-9"	19ø3"	2650 lb.
Metric Units	1.27m	2.36m	5.867m	1202 kg

Tongue weight: 194 kg (427 lbs.) included in total weight
Road Clearance: 9 ½"

V. CRASH TEST CRITERIA:

The SST TMA has successfully passed, both the required and optional tests that fall under the guidelines of NCHRP Report 350 Test Level 3 for truck mounted attenuators. NCHRP Report 350 specifications for Test Level 3 TMA impact conditions and results are as follows:

NCHRP 350 Test 3-50 - Vehicles with a mass of 820 kg (1,808 lb.) impacting straight into the rear of the TMA at 100 km/h (62 mph) shall remain upright with a theoretical occupant impact velocity of 12 m/s (39 fps) or less and the nominal occupant ridedown acceleration of 20 g's or less per NCHRP Report 350, Test 3-50 evaluation criteria. The front of the truck shall be restricted from forward movement by positioning it against a solid wall or concrete block for this test.

NCHRP 350 Test 3-51 - Vehicles with a mass of 2000 kg (4,410 lb.), impacting straight into the rear of the TMA at 100 km/h (62 mph) shall remain upright with a theoretical occupant impact velocity of 12 m/s (39 fps) or less, and the nominal occupant ridedown acceleration of 20 g's or less per NCHRP Report 350, Test 3-51 evaluation criteria.

NCHRP 350 Test 3-52 - Vehicles with a mass of 2000 kg (4,410 lb.), impacting straight into the rear of the TMA with an offset of W/3 with respect to the TMA centerline at 100 km/h (62 mph) shall remain upright with a theoretical occupant impact velocity of 12 m/s (39 fps) or less, and the nominal occupant ridedown acceleration of 20 g's or less per NCHRP Report 350, Test 3-52 evaluation criteria.

NCHRP 350 Test 3-53 - Vehicles with a mass of 2000 kg (4,410 lb.) impacting at 10 degrees into the rear of the TMA at 100 km/h (62 mph), and an offset of W/4 at an angle of 10 degrees with respect to the TMA centerline, shall remain upright with the theoretical occupant impact velocity of 12 m/s (39 fps) or less and the occupant ridedown acceleration of 20 g's or less per NCHRP Report 350, optional Test 3-53 evaluation criteria.

NCHRP 350 Test 3-51 Modified - Vehicles with mass of 2000 kg. (4,410 lb.) impacting straight into the rear of the TMA at 100 km/h (62 mph), shall remain upright. The test is a modified test 3-51 with the truck restricted from movement by positioning it against a solid wall or concrete block to simulate a truck of very heavy or infinite weight. This test had a theoretical occupant impact velocity of 12 m/s (39 fps) or less and the occupant ride down acceleration of 20.7 g performance. The FHWA has acknowledged the Infinite weight test and the use of the SST with heavier support vehicles at the discretion of the contracting authority.

During NCHRP test 3-52 and 3-53, notice the trailer did not swing laterally away from the alignment of the shadow vehicle to occupy more than 15% of the width of the adjacent traffic lane.

The SST TMA shall be designed and constructed so no solid debris is present from the system that can create a hazard on the roadway after an impact.

To minimize potential damage to the truck, no portion of the TMA's energy absorbing elements shall protrude forward damaging the vital elements of the truck's underride during an impact.

Certified test results and associated test reports and films produced in compliance with NCHRP Report 350 procedures shall be submitted, upon request, showing that the TMA conforms to the performance criteria in this specification.

VI. DURABILITY TESTING:

A. Nuisance Impact Test:

The SST TMA shall be subjected to simulated nuisance impacts at 10 km/h (6 mph) minimum. The TMA shall be capable of withstanding these impacts without

crushing any of the energy absorbing elements. The TMA shall retain all impact performance characteristics following these impacts.

B. Road Test:

The SST TMA shall be subjected to accelerated durability testing that simulates actual in-service use. Differences between the tested TMA and production units shall be noted in the report. The road tests shall cover a minimum of 4000 km (2,500 miles) on actual roadways in normal traffic. The testing shall be performed on a variety of roadways with an emphasis on poorly maintained 2 lane roads having design speeds of 80-100 km/h (50-60 mph). The record of the actual testing conditions shall provide evidence of intent to expose the system to maximized, demanding, real-world conditions. Portions of the road testing shall be video taped from another vehicle to show the interaction of the truck and TMA combination to the roadway and typical intersection conditions. Still photos of the truck and TMA during the course of the testing shall be included. The system shall be installed on an unloaded (i.e. no ballast permitted), large, dump truck with a Gross Vehicle Weight (GVW) rating of at least 18,000 kg (40,000lb.). The truck shall feature a dual rear axle arrangement and a stiff suspension that is intended to subject the TMA to considerably more stress loading than typical field use would impart. The combination truck and TMA weight shall be recorded. A record of the TMA's travel position and odometer mileage as well as the general roadway conditions shall be required. The TMA shall be regularly inspected and a record kept of any changes in system appearance. Any items showing signs of damage or loosening shall be noted and addressed. Replacement parts are to be listed. Recommended design changes shall be noted in the report. The SST TMA system shall incorporate the modifications and shall retain performance characteristics conforming to NCHRP Report 350 and this specification.

C. Speed Bump Test:

The SST TMA shall be subject to a speed bump test to determine durability of the TMA. It shall consist of mounting the TMA to a truck and running it over two 1 ½" speed bumps anchored 50 feet apart. The speed of the truck is determined by running over the bumps with the SST TMA. Start at 5 MPH and increase speed by 5 MPH up to 25 MPH. The highest shock load is to be used for the tests. Drive the truck at this speed over the bumps 100 times. After every 20 times, check the TMA for damage and record. Any items showing signs of damage or loosening shall be noted and addressed. Replacement parts are to be listed. Recommended design changes shall be noted in the report. The SST TMA system shall incorporate the modifications and shall retain performance characteristics conforming to NCHRP Report 350 and this specification.

VII. ENVIRONMENTAL TESTING:

The cartridges of the SST TMA are the same cartridges used on the Safe-Stop 180 TMA[®]. Therefore, they shall perform successfully under the same moisture, corrosion and vibration tests:

A. Moisture Test:

1. The complete TMA cartridges shall be weighed prior to and after the moisture test, utilizing a certified scale. These TMA cartridge weights shall be a part of the test data submitted with the bid. The cartridges shall be placed in the normal horizontal operating position and subjected to precipitation equivalent to 150 mm (6 inches) of water per hour. Water shall be delivered from nozzles with spray cones mounted so that the required precipitation is evenly distributed over the entire area of the cartridge top, sides, and ends.
2. After a period of 24 hours, the cartridges shall be placed on their top sides and the same precipitation rate continued on the bottom side for 24 hours. The water shall be turned off, the cartridges returned to the normal operating position, and the cartridges will be allowed to drain for one hour before being weighed. The weight after the test shall be the same as the initial mass \pm 2.3 kg (5 lb.). The cartridges will then be examined. The complete outer covering of the TMA cartridges shall be removed, the energy absorbing cells shall be examined and photographs of the energy absorbing cells shall be submitted with the moisture test data.
3. The cells shall be free of moisture and retain 100% of their energy absorbing qualities. The results of the examination of the energy absorbing cells for moisture retention shall be submitted on or before the scheduled bid opening.
4. Attenuator cells showing excessive retention of moisture or any damage whatsoever will constitute failure of the device.

B. Corrosion Test:

1. A sample of attenuator energy absorbing material shall be subjected to a salt spray (fog) test in accordance with ASTM B117-73, Method of Salt Spray (fog) Testing, for a period of 50 hours and consisting of two (2) periods. Each period shall consist of 24 hours exposure and one (1) hour drying time.

2. The sample of the structure shall consist of a section with a minimum dimension of 1050 cubic cm (4 cubic inches), and must include any adjacent bonding material. Photographs of the sample structure will be made prior to and after removal from the TMA cartridge assembly. Also, photographs will be made of this same sample prior to and after the corrosion test. All photographs listed above shall be submitted with the corrosion test results.

3. Immediately after the device has been subjected to the corrosion test, there shall be no evidence of corrosion that would affect the energy absorbing qualities of the sample.

C. Vibration Test:

The standard TMA cartridge shall be subject to two 40 hour vibration tests. The vibration test fixture will be free of springs or dampeners, and shall have a vertical pivot point that is located $3.53 \pm .23$ m (139 ± 9 inches) from the TMA cartridge and capable of inducing the required frequency and excursion into the attenuator through a mechanically positive system. Photos of the TMA cartridges mounted to the test fixture in the horizontal operating position for cartridges A and B, and cartridge B horizontal and cartridge A flipped 180° position must be submitted with the bid.

The frequency of the vibration will be 5 Hz to 8 Hz for a period of 40 hours in each test position (80 hours total). Excursion is to be 15.25 ± 1.25 mm ($.60 \pm .05$ inches), measured peak to peak vertically at the location where the attenuator is attached to the back support. Measurements prior to, at 20 hours, and on completion of the vibration tests will be recorded with the TMA cartridge mounted in the normal operating position, and mounted with cartridge A in the 180° position. A variance of 13 mm (.50 inches) of any component dimension, damage to the energy absorbing cells that would affect their performance, or damage to the back support, or exterior skin will constitute failure of the device. Extra tie-downs, dampeners, supports, etc. will not be allowed unless they are included in the production model. Vibration data forms and vibration test time log forms are to be used for recording the data required and shall be submitted with the bid. Certified TMA assembly weights shall be recorded prior to and after each vibration test and submitted.

- a. Test No. 1: The TMA cartridges shall be mounted to the vibration apparatus in the normal horizontal operation position. The indicated measurements shall be recorded prior to, at 20 hours, and on completion of this vibration test and recorded on vibration data forms.
- b. Test No. 2 The TMA cartridges shall be mounted to the vibration apparatus in an elevated position 180° to the horizontal. The indicated measurements shall be recorded prior to, at 20 hours, and on completion of this vibration test and recorded on vibration data forms.