

October 11, 2001

HSA-10/CC79

**John R. Rohde**  
**President**  
**Safety By Design Co., Inc.**  
**5401 Cornell Rd**  
**Lincoln, NE 68516**

**Dear Mr. Rohde:**

**In your June 26 letter to Mr. Frederick G. Wright, Jr., former Federal Highway Administration Program Manager for Safety, you provided information on a Trailer Attenuating Cushion (TAC) intended for use with trailer-mounted arrow boards or variable message signs, and requested formal acceptance of this device for use on the National Highway System (NHS) at NCHRP (National Cooperative Highway Research Program) Report 350 test level 3 (TL-3). To support your request, you also sent me a copy of the Midwest Roadside Safety Facility's June 20, 2002 report entitled "Safety Performance Evaluation of the BEAT Trailer-Mounted Attenuator" and a video tape of the crash tests conducted.**

**As you know, there is currently no AASHTO (American Association of State Highway and transportation Officials) -FHWA requirement that Category IV devices (such as trailer-mounted arrow boards and signs) used in work zones be crash tested. However, the 2002 AASHTO Roadside Design Guide recommends that these devices be crashworthy when placed in the roadway and the current Manual on Uniform Traffic Control Devices (MUTCD) recommends that they be placed on the shoulder of the roadway or beyond, and delineated and shielded when placed inside the designated clear zone. There is no NCHRP Report 350 test matrix for these types of devices. However, your decision to design and test an attenuator for these devices is commendable and the use of the Report 350 test matrix established for truck-mounted attenuators appears to be appropriate at this time.**

**Your TAC design is based on the bursting tube technology developed for the energy-absorbing terminal for box-beam guardrail. It incorporates three levels of energy absorption: (1) A bursting tube fabricated from 100 mm x 100 mm x 3.2 mm (4 in. x 4 in. x 1/8 in.) A500 Grade C steel with zinc rich paint on the interior that acts as a lubricant; (2) A stage 1 bursting tube of the same size but without lubricant; and (3) A 127 mm x 127 mm x 3.2 mm (5 in. x 5 in. x 1/8 in.) A500 Grade C steel tube nested outside of the stage 1 tube. As shown in Enclosure 1, the TAC is designed to be folded during transport and deployed (extended) when the trailer is placed in service. The overall length of the as-tested heavy trailer system, i.e., trailer frame plus attenuator, was 8384 mm (27 ft-6 in.) in the deployed position. In the folded condition, the tested unit was 5207 mm (17 ft-1 in.) long. The TAC is designed to be as wide as the trailer to which it is attached, which was 2092 mm (6 ft-10 in.) for the tested system.**

**The safety performance of the TAC was verified through full-scale crash testing of the design with a trailer weighing 1901 kg (4,200 lb). The two mandatory NCHRP Report 350 tests required for a truck-mounted attenuator were conducted: the 820-kg car and the 2000-kg pickup truck impacting head-on at 100 km/h (tests 3-50 and 3-51). You also ran a baseline**

test into an unshielded trailer for comparison purposes. In all three tests, the trailer was located on a smooth concrete surface. Both tests of the trailer with the TAC system passed all evaluation criteria, but the baseline test of a trailer without the TAC failed due to high occupant impact velocity (16.5 m/sec vs. 12 m/sec allowable) and an extensive crushing of the vehicle roof structure caused by the arrow board rotating downward onto the vehicle's roof. Summary sheets for these three tests are shown in Enclosure 2. In both tests with the TAC installed, the trailer came to rest approximately 50 meters from the initial impact point. Exact measurements are shown on the summary test sheet for each test.

Since the weight of variable message signs, flashing arrow boards and other trailers varies greatly, you have proposed four different TAC designs based on the weight of the trailer to which they are attached. The energy absorber lengths defined for each design were developed through a series of computer simulations supplemented by component and sub-assembly tests of the bursting tube system. The following table summarizes the four TAC systems designs:

Trailer Weight kg (lb)	Energy Absorber Length, mm (in.)			
	Stage 1		Stage 2	Total
	Lubricated	Unlubricated		
656 (1450)	762 (30)	584 (23)	229 (9)	1575 (62)
1019 (2250)	914 (36)	762 (30)	381 (15)	2057 (81)
1449 (3200)	914 (36)	1295 (51)	457 (18)	2667 (105)
1901 (4200)	1067 (42)	1372 (54)	610 (24)	3048 (120)

You also used computer simulation and engineering analysis to identify the risk of the trailer system pitching over onto impacting vehicles. Your results indicated that a front attenuator support tube placed between the trailer and the TAC is needed to assure that heavy sign systems do not drop onto the top of an impacting vehicle and identified relationships between the location of this support point and the trailer center-of-gravity height that would assure trailer stability, as shown in Figures 1 and 2 (Enclosures 3a and 3b). Trailers with center-of-gravity heights below the appropriate line are assured of remaining upright when subjected to impacts corresponding to NCHRP Report 350 TL-3 testing. Additionally, computer simulations of TAC impacts also indicated that some sign mast systems would require reinforcement to reduce damage to the trailer and eliminate the risk of signs dropping onto the hood or roof of an impacting vehicle. You recommend that sign masts be designed to withstand the trailer accelerations associated with the maximum impulsive loading from the TAC of 178 kN (40 kip). I assume that you will provide your clients with design details for specific trailers upon request.

**Based on the above, I conclude that your tested design meets NCHRP Report 350 evaluation criteria and may be used on the National Highway System (NHS) if such use is acceptable to the contracting agency. The alternative designs developed through computer simulation may also be used. Because the TAC is a proprietary design, the provisions of Title 23, Code of Federal Regulations, Section 635.411 apply to its use if it is specified by a highway agency. Finally, since the TAC is the first attenuator developed for a trailer, I strongly recommend that information be collected on its use and in-service performance to assess its overall effectiveness in reducing crash severities and trailer damage. Any data collected would be useful to help determine if the use of crash-tested Category IV work zone devices on the NHS should be made mandatory at some point in the future.**

**Sincerely yours,**

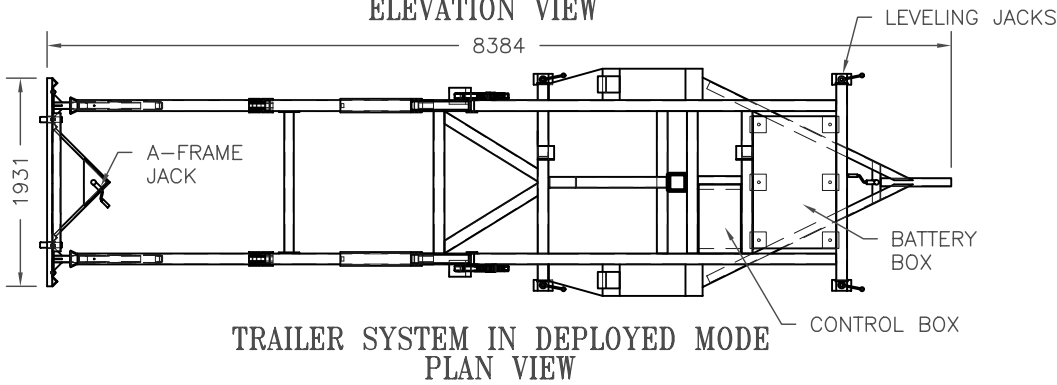
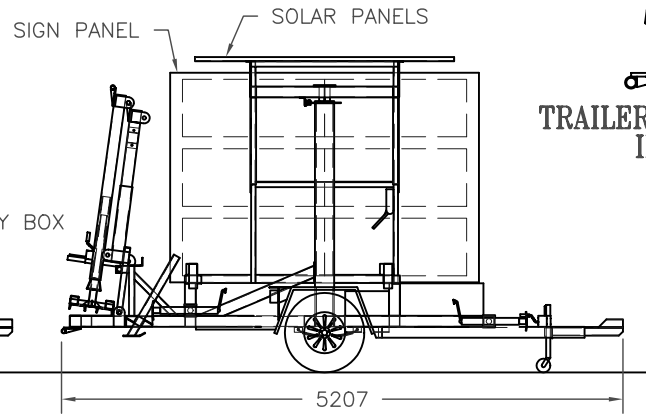
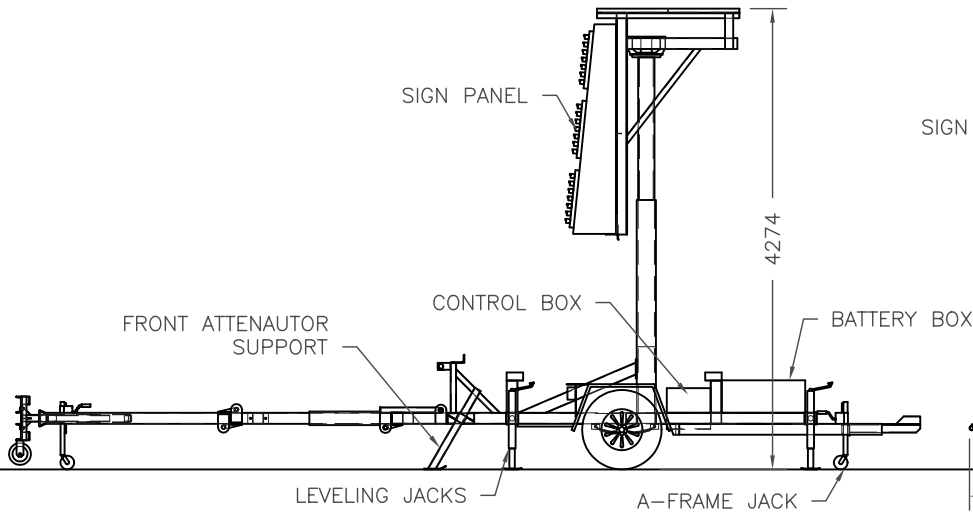
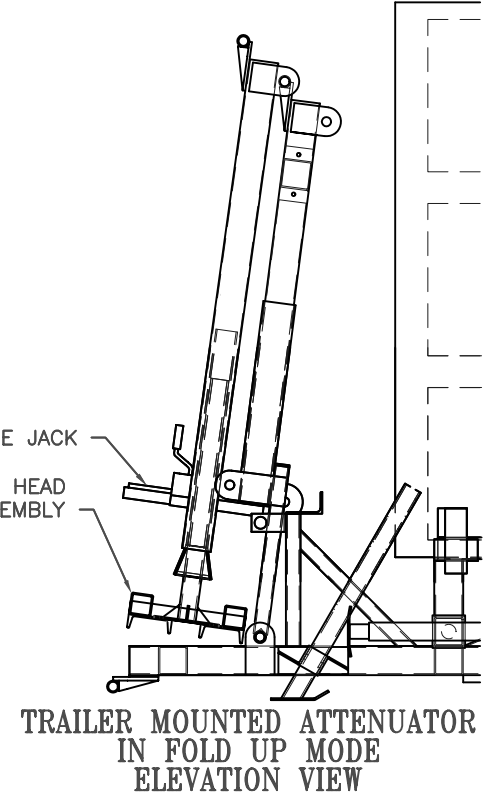
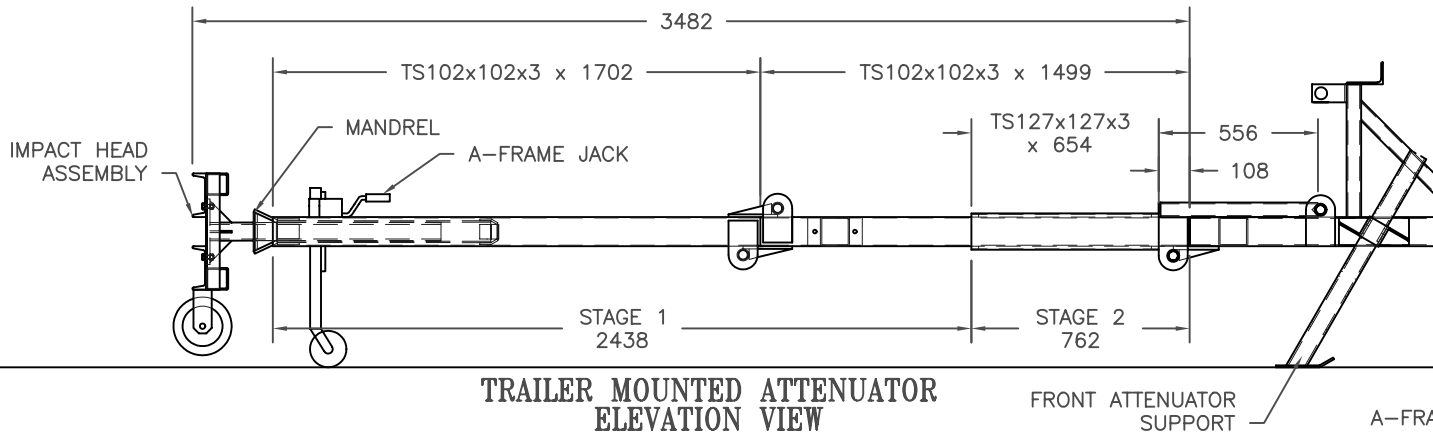
**(original signed by Richard D. Powers)**

***for:***



**Carol H. Jacoby, P.E.**

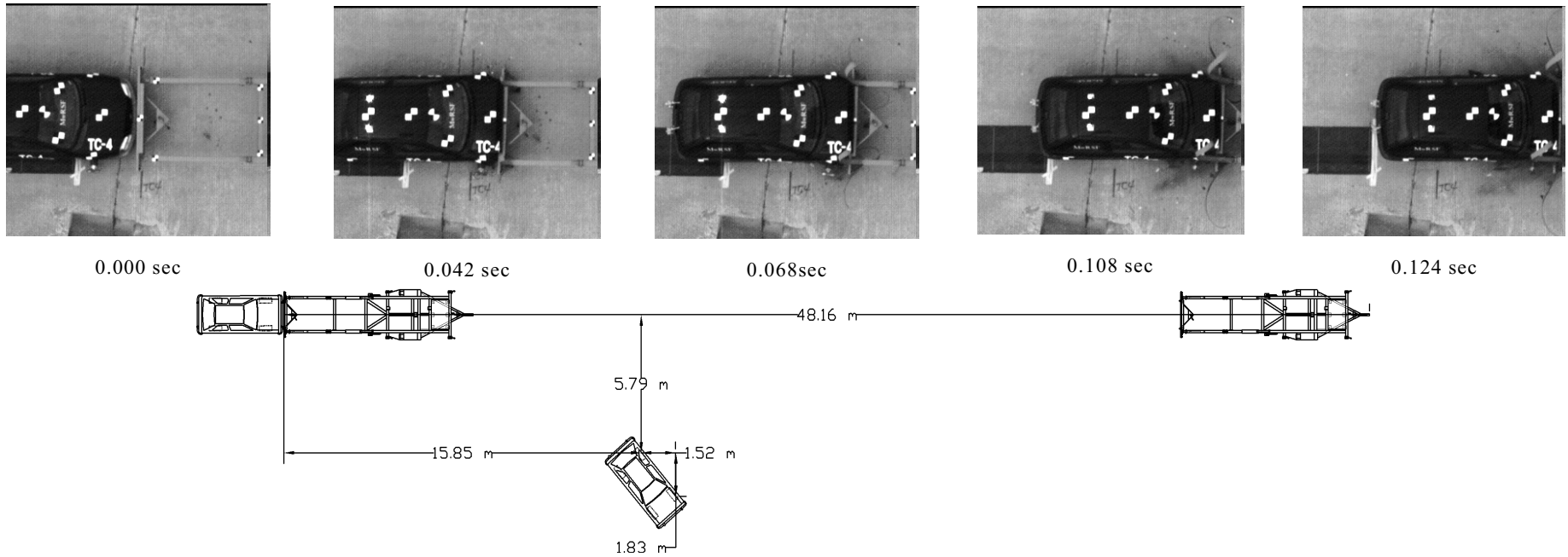
**Director, Office of Safety Design**

**3 Enclosures**



NOTE:  
ALL DIMENSIONS ARE IN MILLIMETERS (mm).

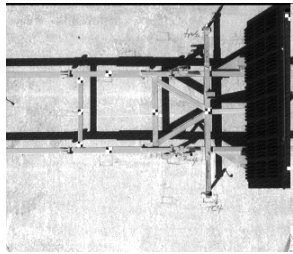
 Safety By Design Company	BEAT Trailer Mounted Attenuator System Drawing		Sheet: <b>S1</b>
	Drawing Name: TRAILER-M RO.DWG		Date: 04\15\02
Scale: NONE		By: SML	Rev: 



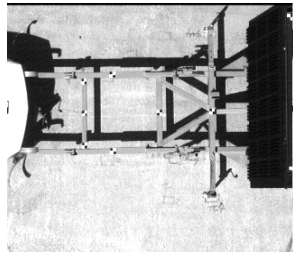
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- Date ..... 7/20/01
- Test Article
  - Type ..... BEAT Trailer-Mounted Attenuator
  - Key Elements ..... 1931-mm wide impact head  
Stage 1, 2, and 3 energy-absorbing tubes  
2,013-mm wide x 5,207-mm long x 4,274-mm high CMS trailer
  - Orientation ..... Head-on with centerline of CMS trailer
  - Anchorage ..... None (free-standing)
- Soil Type ..... On dry pavement
- Vehicle Model ..... 1995 Geo Metro, 2-door
  - Curb ..... 815 kg
  - Test Inertial ..... 833 kg
  - Gross Static ..... 908 kg
- Vehicle Speed
  - Impact ..... 105.6 km/hr
  - Exit ..... NA

- Vehicle Angle
  - Impact ..... 1.7 deg
  - Exit ..... NA
- Vehicle Stability ..... Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal ..... 12.63 g's < 20 g's
  - Lateral (not required) ..... NA
- Occupant Impact Velocity
  - Longitudinal ..... 10.32 m/s < 12 m/s
  - Lateral (not required) ..... NA
- Vehicle Damage ..... Minimal
  - TAD<sup>3</sup> ..... 12-FD-4
  - SAE<sup>4</sup> ..... 12FDEW2
- Vehicle Stopping Distance ..... 17.37 m downstream  
7.62 m right
- Test Article Damage ..... Moderate
- Test Final Position ..... 48.16 m downstream  
0.0 m right

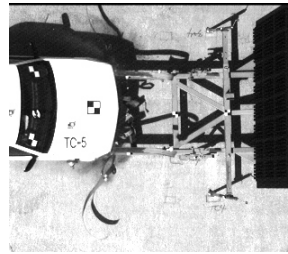
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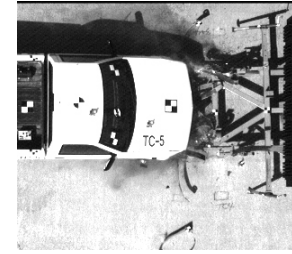
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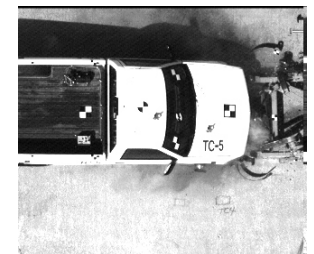
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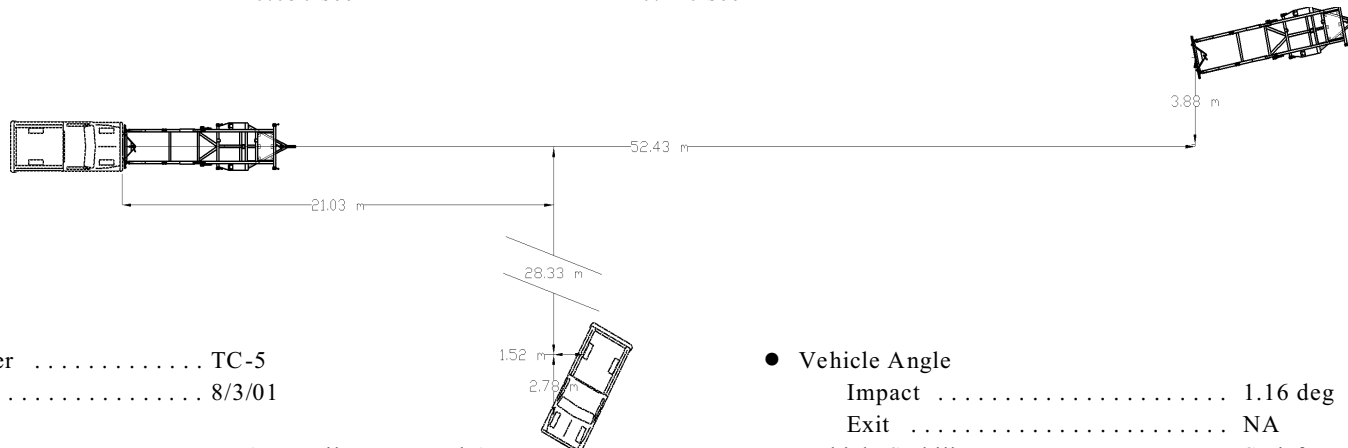
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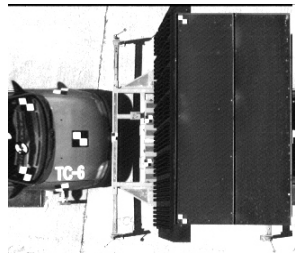
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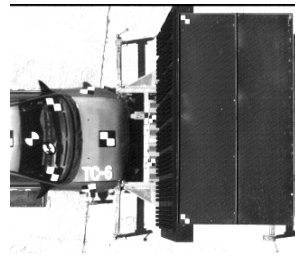
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- Date ..... 8/3/01
- Test Article
  - Type ..... BEAT Trailer-Mounted Attenuator
  - Key Elements ..... 1931-mm wide impact head  
Stage 1, 2, and 3 energy-absorbing tubes  
2,013-mm wide x5,207-mm long x 4,274-mm high CMS trailer
  - Orientation ..... Head-on with centerline of CMS trailer
  - Anchorage ..... None (free-standing)
- Soil Type ..... On dry pavement
- Vehicle Model ..... 1995 Chevy 2500 pickup truck
  - Curb ..... 2,041 kg
  - Test Inertial ..... 2,020 kg
  - Gross Static ..... 2,020 kg
- Vehicle Speed
  - Impact ..... 101.8 km/hr
  - Exit ..... NA

- Vehicle Angle
  - Impact ..... 1.16 deg
  - Exit ..... NA
- Vehicle Stability ..... Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal ..... 12.00 g's < 20 g's
  - Lateral (not required) ..... NA
- Occupant Impact Velocity
  - Longitudinal ..... 8.11 m/s < 12 m/s
  - Lateral (not required) ..... NA
- Vehicle Damage ..... Minimal
  - TAD<sup>3</sup> ..... 12-FD-3
  - SAE<sup>4</sup> ..... 12FDEW2
- Vehicle Stopping Distance ..... 21.03 m downstream  
28.33 m right
- Test Article Damage ..... Moderate
- Test Final Position ..... 52.43 m downstream  
3.88 m left

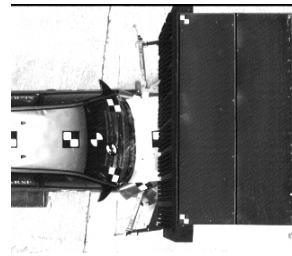
Summary of Test Results and Sequential Photographs, Test TC-5



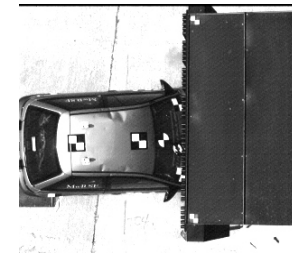
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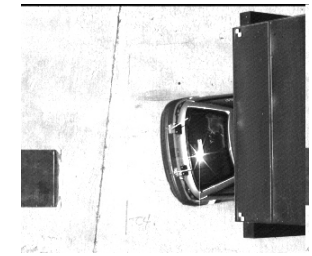
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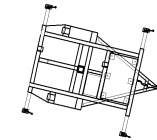
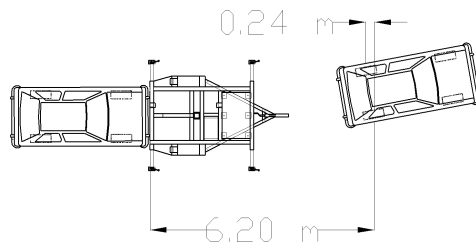
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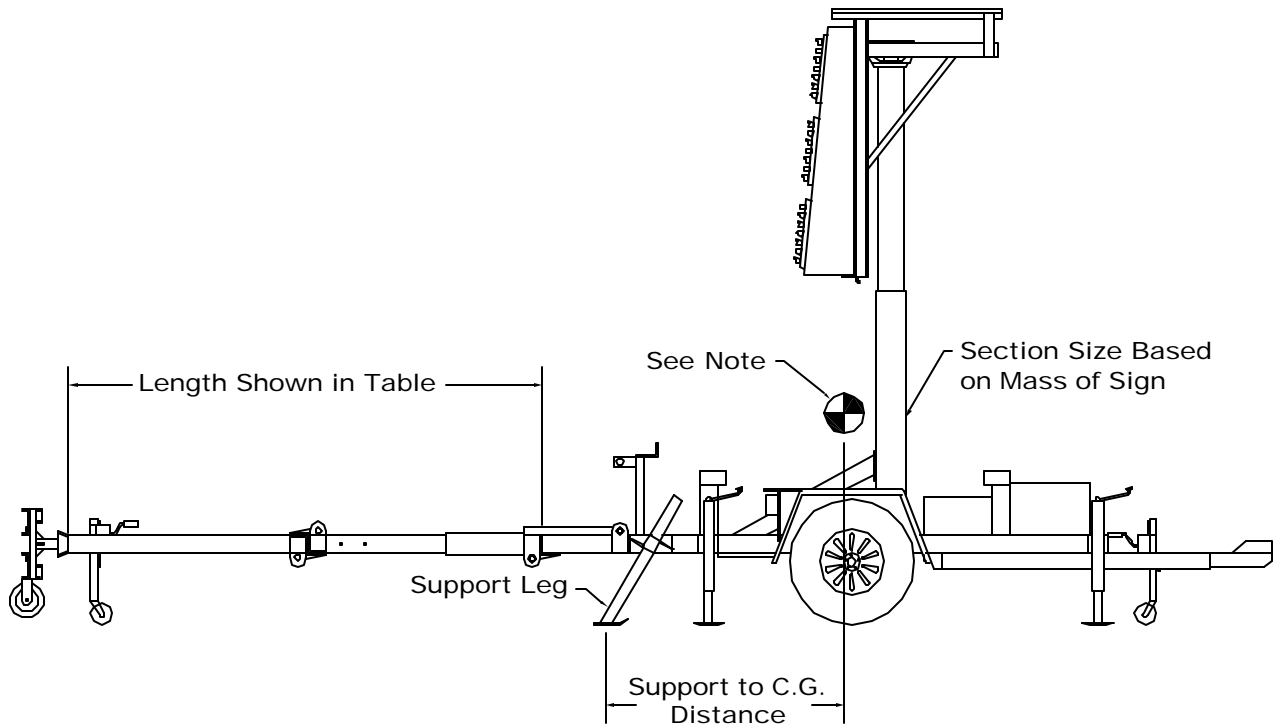


- Test Number ..... TC-6
- Date ..... 8/31/01
- Test Article
  - Type ..... CMS Trailer
  - Key Elements ..... 2,013-mm wide x3,836-mm long x 4,274-mm high sign trailer
  - Orientation ..... Head-on with centerline of CMS trailer
  - Anchorage ..... None (free-standing)
- Soil Type ..... On dry pavement
- Vehicle Model ..... 1995 Chevy Geo
  - Curb ..... 771 kg
  - Test Inertial ..... 841 kg
  - Gross Static ..... 917 kg
- Vehicle Speed
  - Impact ..... 98.9 km/hr
  - Exit ..... NA
- Vehicle Angle
  - Impact ..... 0.7 deg
  - Exit ..... NA

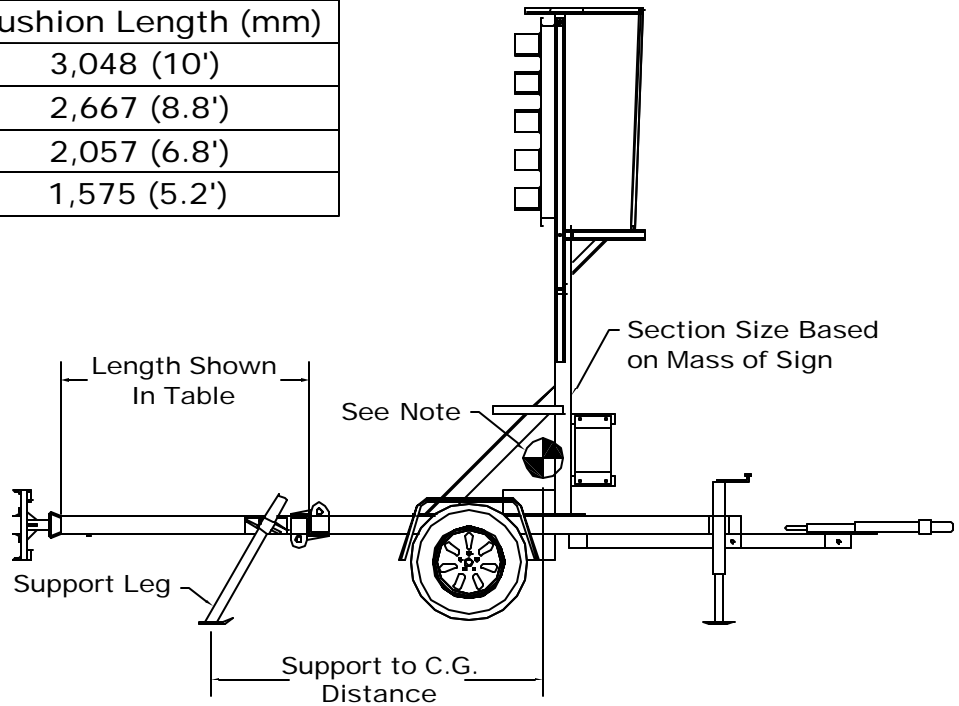
- Vehicle Stability ..... Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal ..... 10.64 g's < 20 g's
  - Lateral (not required) ..... -7.27/4.66 g's
- Occupant Impact Velocity
  - Longitudinal ..... 16.51 m/s < 12 m/s
  - Lateral (not required) ..... 1.40 m/s
- Vehicle Damage ..... Extensive
  - TAD<sup>3</sup> ..... 12-FD-5
  - SAE<sup>4</sup> ..... 12FDEW3
- Vehicle Stopping Distance ..... 6.20 m downstream  
0.77 m left
- Test Article Damage ..... Extensive
- Test Final Position ..... NA (Several large pieces in different locations)

Summary of Test Results and Sequential Photographs, Test TC-6

# Figure 1: Trailer Energy Attenuating Cushion (TAC)



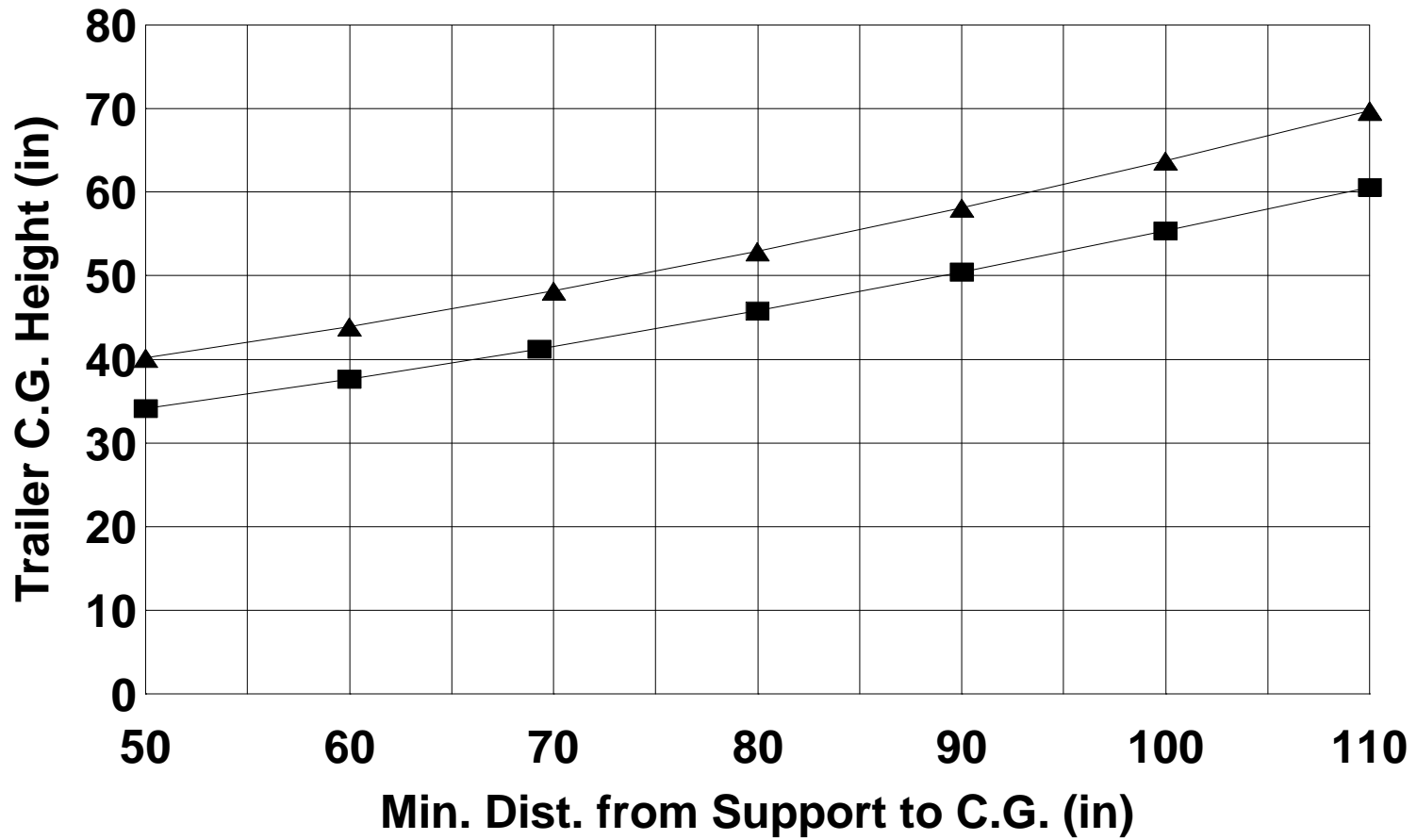
Trailer Weight (kg)	Cushion Length (mm)
1,450 to 1,901	3,048 (10')
1,020 to 1,449	2,667 (8.8')
657 to 1,019	2,057 (6.8')
Less than 656	1,575 (5.2')



Note: For each trailer configuration the height and horizontal location of the center-of-gravity must be within constraints.



**Figure 2. VMS Trailer Stability Chart**



▲ 635 kg trailer    ■ 1910 kg. trailer