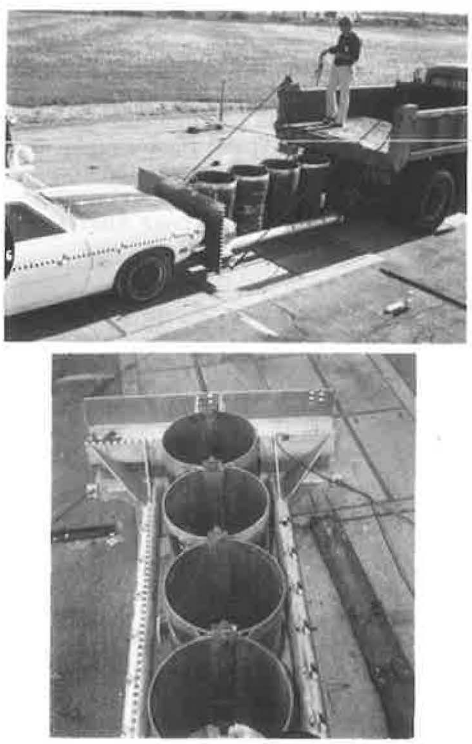
Abridgment

Experimental Evaluation of a Portable Energy-Absorbing System for Highway Service Vehicles

John F. Carney III, University of Connecticut, Storrs

This paper is concerned with the crash testing of a new portable energy-absorbing system attached to the rear of a highway service vehicle. The study objective was to design a system to provide protection for both the motoring public and the service personnel engaged in maintenance operations on our highways. Four full-scale crash tests were conducted to evaluate the performance of the system with respect to structural adequacy, impact severity, and vehicle trajectory. The details of the energy-absorbing systems design are presented in Carney and Sazinski (1). They show that the device must absorb 319 107 J (235 330 ft•lb) of energy and possess a collapsing stroke of 2.23 m (7.31 ft). Four 0.6-m (2-ft) diameter pipes connected in series are used as the unit energy-absorbing components. Because of vertical stability considerations, the depth of the pipe system was set at 0.86 m (34 in). Then a polymodular design was carried out. In the polymodular design, the wall thicknesses of the two pipes nearest the rear of the service vehicle were taken as 9.525 mm (0.375 in). The third pipe in the series was given a thickness of 6.756 mm (0.266 in). The fourth pipe, the one nearest the impact point, has a thickness of 6.756 mm (0.266 in) and 0.508-m (1.67-ft) long vertical slits, 180° apart, in its sides. With this setup, the pipe system exhibits increasing stiffness as the collapse length increases. Carney and Sazinski (1) show that this system can, when fully collapsed, just absorb the 319 107 J (235 330 ft•lb) of energy to be dissipated.

Figure 1. Two views of the portable energy-absorbing system.



The system has been designed to possess the following two characteristics:

1. It is capable of absorbing most of the energy dissipated in a high-speed collision between an automobile and the highway service vehicle.
2. It absorbs this energy in such a way that the accelerations and acceleration rates to which the automobile and service vehicle are subjected are within the guidelines specified by the Federal Highway Administration.

The energy-absorbing system involves three components: (a) the service vehicle guidance frame, (b) the energy-absorbing pipes, and (c) the impacting plate assembly. The unit, as mounted on the service vehicle, is shown in Figure 1 (top). The impacting plate assembly shown in Figure 1 (bottom) is constructed of 6061-T6 aluminum. The remaining components of the energy-absorbing system are made of steel. It is interesting to note that the round aluminum tubing in the impacting plate assembly slides inside the structural tubing on collapse of the system.

FULL-SCALE CRASH-TESTING PROGRAM

The crash-testing phase of the research was carried out under a subcontract by Calspan Corporation of Buffalo, New York. The testing program followed as closely as possible the procedures spelled out in Bronstad and Michie (2). Four full-scale crash tests were conducted to evaluate the performance of the energy-absorbing system under different impact conditions.

Test vehicle 1 was a 1971 Ford Maverick, weighing 10.05 kN (2260 lb), which impacted the 62.27-kN (14 000-lb) service truck equipped with the portable energy-absorbing system. The impact velocity was 73.69 km/h (45.8 mph). The impact angle was 0°, and impact occurred at the centerline of the truck.

Test vehicle 2 was a 1970 Pontiac, weighing 19.93 kN (4480 lb). The impact velocity was 74.90 km/h (46.55 mph). The impact angle was 0°, and impact occurred at the centerline of the truck.

Test vehicle 3 was a 1973 Plymouth, weighing 19.93 kN (4480 lb). The impact velocity was 73.18 km/h (45.48 mph). The impact angle was 0°, and impact occurred at a 0.762-m (2.5-ft) offset from the centerline of the truck.

Test vehicle 4 was a 1973 Plymouth, weighing 19.88 kN (4470 lb). The impact velocity was 7366 km/h (45.78 mph). The impact angle was 10°, and impact occurred at a 0.762-m (2.5-ft) offset from the centerline of the truck.

During the testing program, the four automobiles and the service truck were instrumented with accelerometer

Figure 2. Crash test 1.

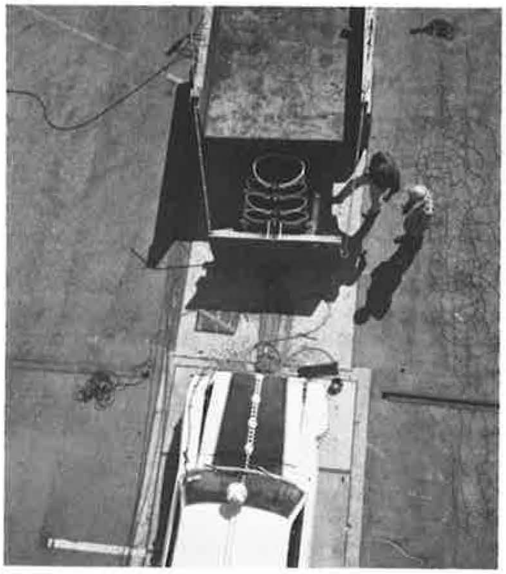
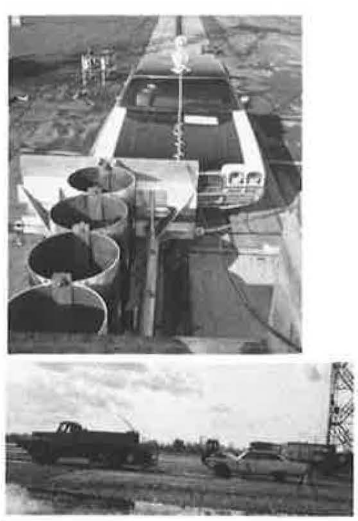


Figure 3. Crash test 2.

Figure 4. Crash test 3.



packages. The test results demonstrate the effectiveness of the energy-absorbing system. The four automobiles sustained—in view of their impact velocities—minimal damage; the service vehicle was undamaged by the four crashes. The same energy-absorbing system was employed for all four tests; the four collapsing pipes were the only system component to be replaced after each crash. Figures 2-5 show the results of the crashes on the impacting automobiles and the energy-absorbing unit.

The results of test 1 are presented in Figure 2, which shows the energy-absorbing system and the 1971 Ford Maverick after the collision. In this test, the average deceleration of the automobile was 9.8 *g*.

Figure 3 shows the results of test 2. The average deceleration of the automobile was 8.5 *g* in this crash test.

The collision mode and the postimpact configuration of test 3 are presented in Figure 4. In this test, the automobile's average deceleration was 7.7 *g*.

Figure 5. Crash test 4.

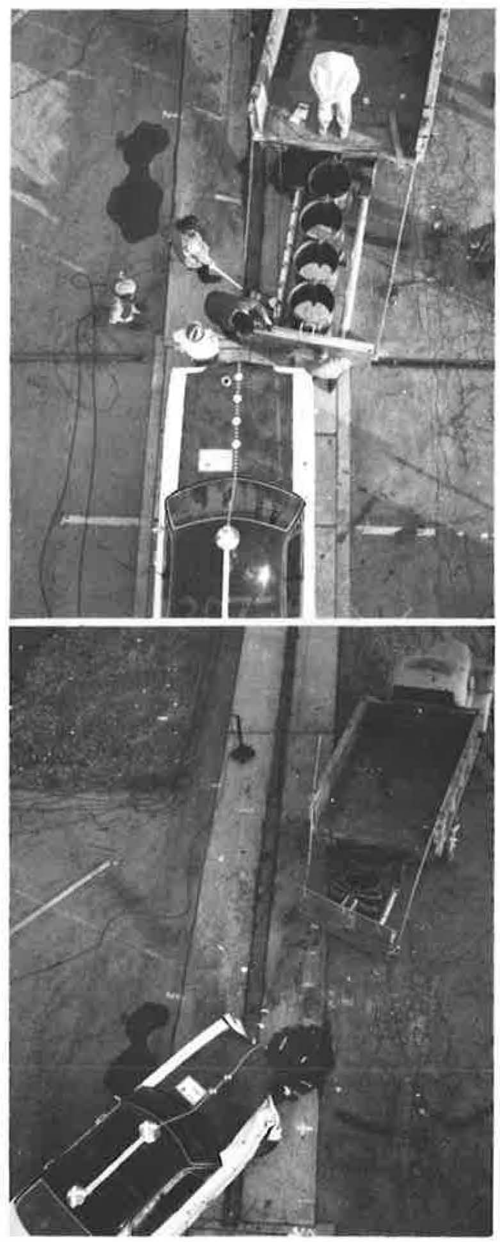


Figure 5 shows the collision mode and postimpact configuration of test 4. The average deceleration of the automobile was 7.8 *g* in this test.

The deceleration levels in the three "heavy" automobile crash tests were well within the guidelines set forth in Bronstad and Michie (2). In the 10.05-kN (2260-lb) automobile crash test, although the average deceleration was less than the limiting value of 12 *g* (2), there was an initial 80-*g* acceleration "spike" of approximately 10 ms duration after which the decelerations dropped to and remained at acceptable levels. This lightweight vehicle "spike" is caused by a 1.913-kN (430-lb) aluminum impacting plate assembly and can be reduced by decreasing the weight of this component, which must be moved to permit the collapse of the energy-absorbing system. Work in this area is continuing at the University of Connecticut.

SUMMARY AND CONCLUSIONS

A portable energy-absorbing system that is attached to the rear of a standard 62.27-kN (14 000-lb) highway service vehicle has been designed and constructed. Four full-scale crash tests were conducted to evaluate the system with respect to structural adequacy, impact severity, and vehicle trajectory.

The performance of the system has been demonstrated. Three of these units are now being used on department of transportation maintenance operations in Connecticut to provide protection for both the motoring public and service personnel engaged in maintenance operations. It offers effective protection for the equipment used in these maintenance and repair projects. Of particular value is its implementation during the highway line-striping operations. In addition, the energy-absorbing system provides immediate temporary protection during short-term repair or clean-up operations, i.e., the repairing of a Fitch sand-filled barrel installation.

The energy-absorbing system possesses the following favorable characteristics:

1. It absorbs most of the energy dissipated in a high-speed collision between an automobile and the highway service vehicle; it absorbs this energy in such a way that the accelerations and acceleration rates to which the automobile and service vehicle are subjected are within the guidelines specified by the Federal Highway Administration.
2. It is inexpensive to build. The total assembly can be constructed for less than $2000. This figure compares favorably with the $5500 cost of the hydro-cell unit that has been used during lane-striping operations in Connecticut.
3. It is very inexpensive to repair. Under most crash conditions, all that is required is to insert new 0.6-m (2-ft) diameter pipes into the system. These pipes are bolted together and cost about $100 each. The aluminum impacting plate and the steel frame under the dump truck body will not usually require repairs. In the case of a low-speed collision, the steel pipes can be jacked back to their original shape and reused.
4. There is no tendency for the impacting automobile to nose-dive under the energy-absorbing unit or catapult over the unit, and the system exhibits essentially no rebound characteristics.
5. In the event of an eccentric impact, the intrusion of the impacting automobile into the adjacent traffic lane is minimal.
6. The 62.27-kN (14 000-lb) service vehicle can be expected to suffer no damage during the crash, and adjacent lane intrusion by the truck is not a problem. The same 62.27-kN (14 000-lb) service vehicle was used for all four crash tests and suffered no damage.
7. It is compact and designed for use on curved and hilly roads.

ACKNOWLEDGMENT

This work was accomplished in cooperation with the Connecticut Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. The contents of this report reflect my views, and I am responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of Connecticut or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

REFERENCES

1. J. F. Carney III and R. J. Sazinski. A Portable Energy Absorbing System for Highway Service Vehicles. Transportation Engineering Journal, Vol. 104, No. TE4, July 1978.
2. M. E. Bronstad and J. D. Michie. Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances. NCHRP, Rept. 153, 1974.