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FIBCO "MOD II" PORTABLE TRUCK BARRIER

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TESTING AND RESEARCH DIVISION
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FIBCO "MOD II" PORTABLE TRUCK BARRIER

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Research Project 76 NM-507
Research Report No. R-1069

Lansing, December 1977

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Truck-mounted impact attenuators have been suggested for use on slow-moving or stationary highway maintenance trucks on high-speed roads to prevent injury to the occupant of the striking vehicle, road workers, and the driver of the maintenance truck. The 'Mod II' truck-mounted impact attenuator has been submitted for evaluation by Fibco, Inc. of Boston, Massachusetts, as a safety improvement for highway worker and passenger vehicle protection.

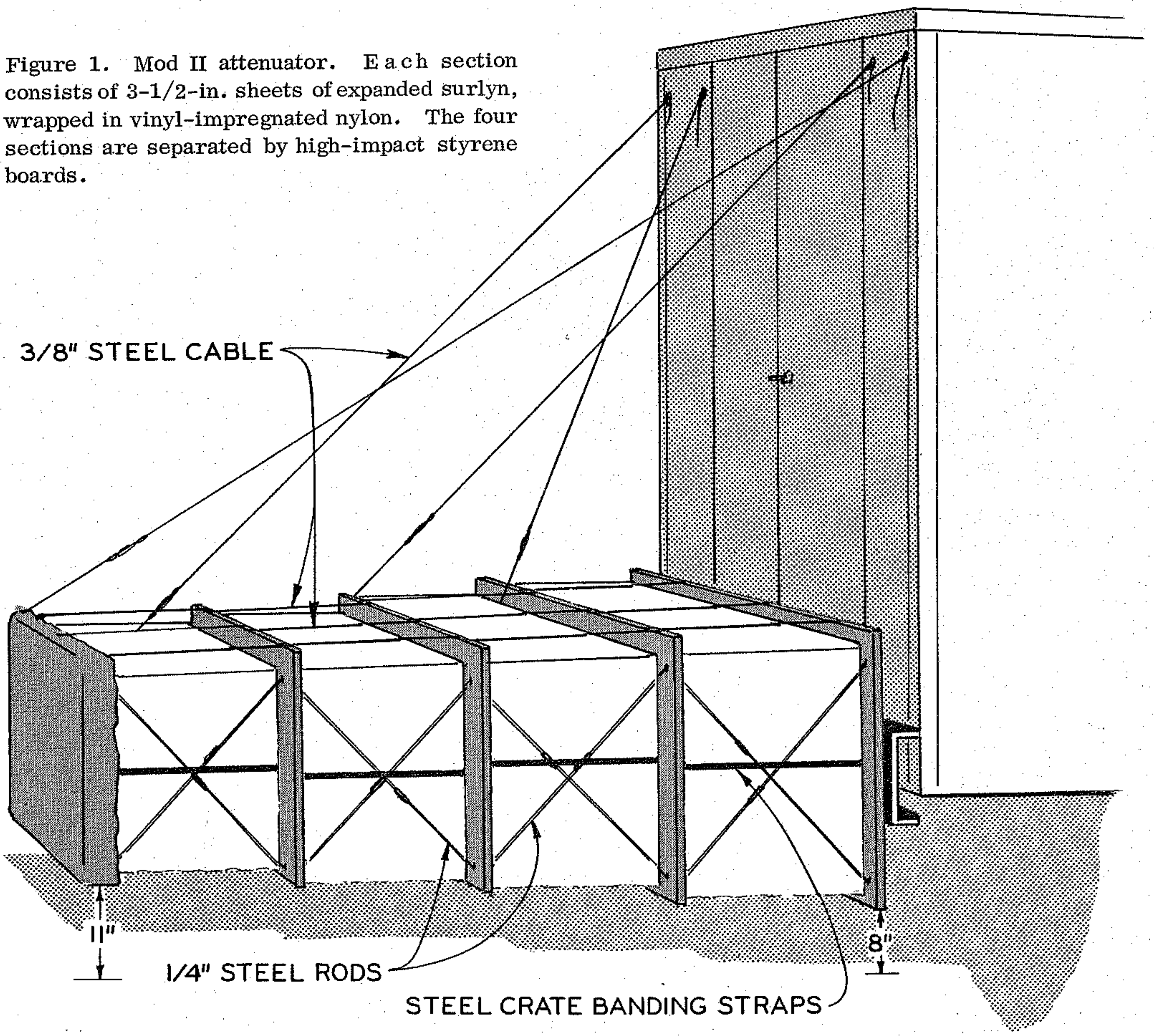
The Mod II impact attenuator contains four bays, each containing six sheets of expanded surlyn material packaged in a weatherproof vinyl wrap and sandwiched between rigid expanded styrene composite boards. Each succeeding bay is made slightly smaller than the one forward of it, giving a slight pyramidal shape to the barrier. The entire device has an overall length of 7 ft 8 in., and a road clearance of 11 in. The Mod II attenuator is shown schematically in Figure 1.

The Federal Highway Administration report, "Crash Cushion Selection Criteria and Design," (FHWA Notice N 5040.16) was used as a checklist for the basic design specifications of the Mod II attenuator. These design specifications for mobile impact attenuators fall into five main categories: 1) maximum allowable deceleration, 2) redirection or fendering capability, 3) initial cost, 4) restitution maintenance, and 5) flying debris.

Of the above categories, the maximum allowable deceleration for the striking vehicle is the most important. Table A in the above report suggested that the maximum limit of average vehicle deceleration in vehicle-structure impacts be 12 g. The authors of the table, Cornell Aeronautical Laboratory, suggest that the average be calculated for a period not exceeding 200 milliseconds (msec).

It should also be noted that the deceleration averages in this table are for the center of gravity of the crash vehicle and that "The decelerations experienced by the (unrestrained) vehicle occupants are likely to be in the range of 50 to 200 g--very likely to produce injury and, at the upper level, fatality." In the early period of crash cushion development, without experience upon which a judgement could be made about what was economically achievable, it was decided to adopt the 12 g maximum shown in this table for lap-belted occupants as the design maximum deceleration for crash cushions. In addition, average g forces during crash testing, which the authors of Table A suggested be based on the highest 200 msec, are

Figure 1. Mod II attenuator. Each section consists of 3-1/2-in. sheets of expanded surlyn, wrapped in vinyl-impregnated nylon. The four sections are separated by high-impact styrene boards.



today being based on the highest 50 msec average. However, in design calculations for crash cushions, time is indeterminate and deceleration is calculated on the basis of resisting force and stopping distance.

TABLE 1
REQUIRED LENGTHS OF
CRASH BARRIER
(Impacting vehicle speed of 50 mph)

	Vehicle Weight, lb	Required Resisting Force, lb	Crush Distance, ft
10,000 lb Sign Truck	2,000	24,000	5.80
	2,500	30,000	6.81
	3,000	36,000	7.65
	3,500	42,000	8.20
	4,000	48,000	8.69
	4,500	54,000	9.10
28,000 lb Sign Truck	2,000	24,000	6.49
	2,500	30,000	7.78
	3,000	36,000	8.90
	3,500	42,000	9.73
	4,000	48,000	10.49
	4,500	54,000	11.05
Mass = ∞ lb (Immovable)	2,000	24,000	6.95
	2,500	30,000	8.48
	3,000	36,000	9.80
	3,500	42,000	10.84
	4,000	48,000	11.77
	4,500	54,000	12.59

Basic design equations can be used to determine the necessary length of a crash barrier. The equations used here were taken from "Impact Design of Crash Cushions for Non-Stationary Barriers," an Ontario Ministry of Transportation and Communication Report (No. RR 505, January 1977). Given the 12 g maximum deceleration, the following equations were used to compare to the Mod II crash test and the results are given in Table 1.

Definition of terms:

F_1 = Limiting crushing force

m_1 = Mass of smallest car to be protected (2,000 lb)

a_{max} = Tolerable average deceleration (-12 g)

S_1 = Necessary crush length

V = Impact velocity (50 mph, 73.3 ft/sec)

M = Mass of sign truck (10,000 lb, 28,000 lb, infinite)

$$S_1 = \frac{M}{m_1 + M} \frac{V^2}{2a_{max}}$$

For 10,000 lb truck

$$S_1 = \frac{10,000}{2,000 + 10,000} \frac{(73.3)^2}{2(12 \times 32.2)} = 5.80 \text{ ft}$$

For 28,000 lb truck

$$S_1 = \frac{28,000}{2,000 + 28,000} \frac{(73.3)^2}{2(12 \times 32.2)} = 6.49 \text{ ft}$$

For ∞ lb truck (immovable)

$$S_1 = \frac{(73.3)^2}{2(12 \times 32.2)} = 6.95 \text{ ft}$$

For larger cars to be protected, m greater than m_1 and for the same a_{max};

$$F = m\, a_{max} \text{ greater than } m_1\, a_{max}$$

If the material is just strong enough to sustain this new force F, then the crushing distance X, where X is greater than S_1, can be calculated for any mass m by:

$$X = \frac{V^2}{2a_{max}} \left[\ln \left(\frac{M}{m_1}\right) - \ln \frac{m + M}{m_1 + M} + \frac{M}{m + M} \right]$$

For an immovable struck vehicle, (mass (M) = ∞), the above equation reduces to:

$$X = \frac{V^2}{2a_{max}} \left[1 + \ln \left(\frac{M}{m_1}\right) \right]$$

As can be observed from Table 1, the crash barrier is of maximum required length when the barrier is affixed to an immovable object (mass of truck equals infinity). For a built-in factor of safety, this length probably should be required for any truck-mounted attenuator. A maximum crush distance of 12.59 ft was calculated, overall length would increase accordingly.

It is probable that a crash cushion will be struck on the side. Theoretically, the cushion must prevent the vehicle from coming in direct contact with the barrier-mounted truck. The system could, however, cause the vehicle to proceed along in the roadway, thereby creating a possibility that the errant vehicle will become a hazard to following traffic, or the work crew. The Mod II barrier evidently was not tested under side impact conditions, so its fendering capability cannot be determined from the information supplied.

During the time between the impact of a crash cushion and when it is restored by maintenance crews, normal traffic continues to pass the sign truck. The probability that a collision will take place during this time is the same as before it was hit, so it is important to promptly restore the crash cushion to its original configuration. After the Mod II barrier had been struck by a 4,100-lb vehicle at 47 mph, the sales literature stated that all four bays of surlyn material could be re-used, but three of the five composite boards needed replacement. No estimate of restoration time or cost was available.

The original cost of the Mod II crash cushion is $5,000. In addition, the labor costs for three men needed for installation must be included. The necessary amount of installation time is not specified in the sales literature.

If parts of a crash cushion come loose or tear off during the impact, they can possibly endanger following traffic. Test results in the sales literature indicate that the Mod II barrier does not emit debris and all parts of the unit remain together.

The sales literature indicated that the barrier material is re-usable, so repetitive loading tests were conducted in the Laboratory to observe the possible change in crushing load of the surlyn material. If a reduction in crushing load could be observed, this would indicate that the crash cushion had weakened under the original impact and additional length must be added to the cushion to compensate. (However, the supplier's literature indicated that buckling of the stacked modules occurred when a longer assembly was used.)

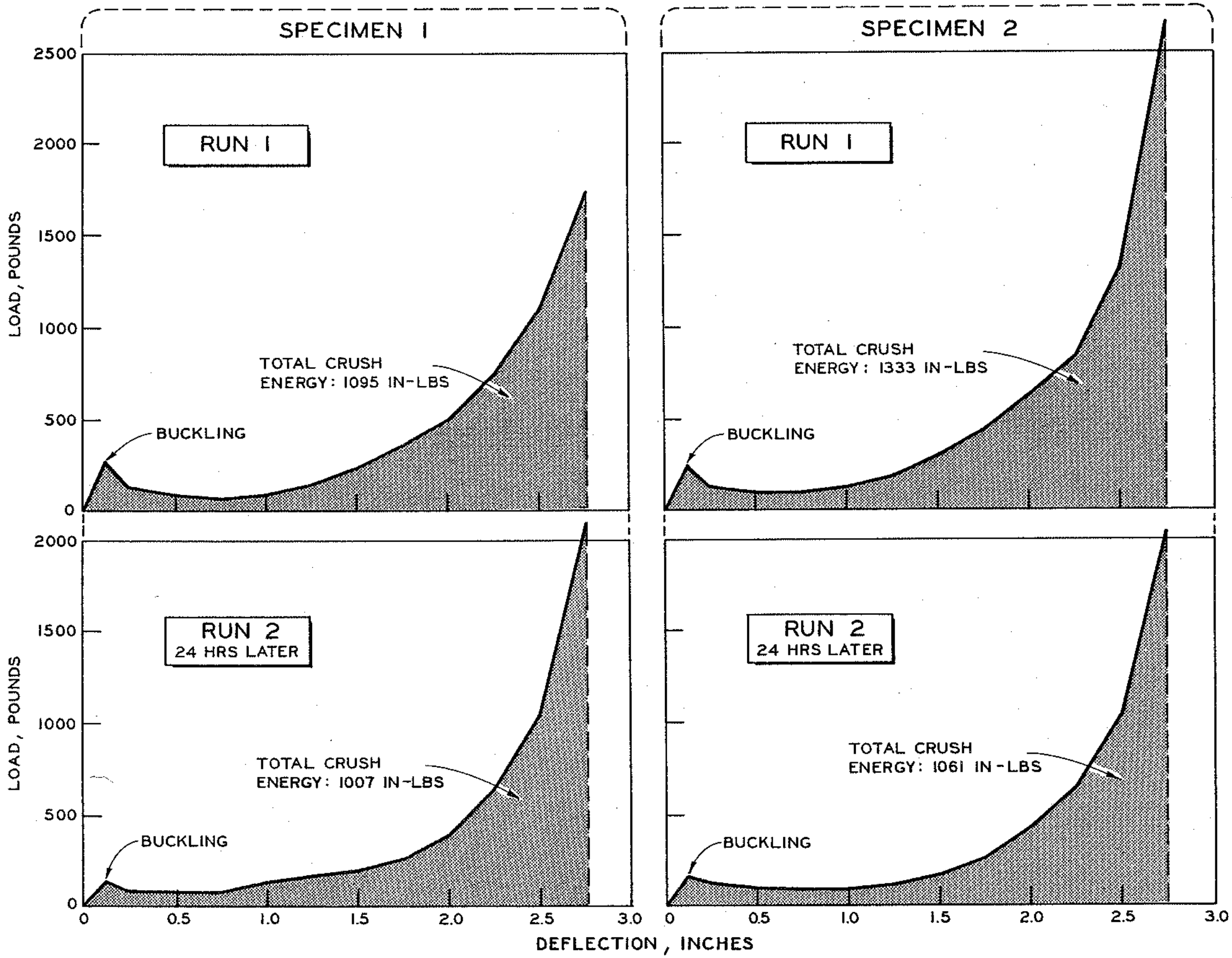


Figure 2. Results of applying a repetitive static load to 6 by 6 by 3-1/2 inch surlyn samples.

A repetitive static load was applied to 6 by 6-in. samples of surlyn by the MTS Electrohydraulic testing machine to determine whether a weakening of the material occurred with repeated load applications. Four runs were conducted on each sample, allowing five-minute intervals between runs for recovery of the sample dimensions. In addition, static loads were applied to two samples 24 hours later to determine the new crushing load, if different from the original.

Our test results (Fig. 2) indicate that the surlyn material suffered a 20 to 35 percent reduction in peak buckling load and in addition, 8 to 20 percent loss in ability to absorb energy (area under the curve, Fig. 2). This weakening could cause hazards if re-used. As can be observed from Runs No. 1 and No. 2 in Figure 2, the amount of crushing strength lost is not consistent and difficulty should be expected when attempting to calculate a 'ballpark' figure for such a loss.

A static vs. dynamic loading comparison of the surlyn material indicates that crushing load increases with increased loading rates. Our tests conducted at approximately a 15 mph impact resulted in crushing loads more than twice the magnitude of our static tests. This may be partially due to entrapment of air pockets in the surlyn's honeycomb design. It can be interpreted that at higher impacting velocities, greater loads will be needed to crush the surlyn. Since vehicle weight and crushing load (dependent on impact velocity), are the varying factors influencing g force, it seems reasonable to assume that lighter vehicle weights and higher impacting velocities could increase the g force to intolerable levels.

The test report supplied by Fibco, Inc. did not include any data for impacts of cars in the 2,000-lb range. The deceleration forces for the smaller vehicles may be significantly higher than 12 g and with no data to support the contrary, a 12 g maximum for a 2,000-lb vehicle cannot be assumed. It is also unfortunate that side impacts were not conducted to evaluate the fendering capability of the crash cushion. The very light weight, and method of assembly, would not seem to provide good performance in this respect. In addition, no secondary impact data were supplied to support the re-usability of the cushion used in the Mod II test, yet it is stated in the sales information that the barrier can be re-used by merely replacing a few of the composite boards. Our test results indicate the contrary to this statement and it was noted during testing that after one impact, the surlyn material developed a crease at mid-thickness that weakened its resistance to crushing under another application of load.

The length of the Mod II cushion is also questionable. The cushion used in the test was 7 ft 8 in. and was attached to a 10,000-lb truck. The impacting car weighed 4,000 lb and traveled at 47 mph. It was previously calculated that the crush length when attached to a 28,000-lb truck should be more than 10 ft. Obviously, only a part of the material thickness can be used to deform at reasonable loads, so total installed length must be increased accordingly. It should be reasonable to assume that heavier and faster vehicles may impact the barrier when attached to a much heavier truck than that used in the manufacturer's tests.

It is interesting to derive from Figure 2, the calculated decelerations of a relatively low velocity impact vehicle at half of the barrier's available crush length. At 1-3/4 in. deflection (per 3-1/2-in. plank, Fig. 2), the surlyn crash cushion has crushed approximately 3 ft 6 in. of the total 7 ft 8 in. The vehicle deceleration caused by the front section of the barrier at this crush distance is:

$$\frac{1,782 \text{ sq in. x } 10 \text{ lb/sq in.}}{4,100 \text{ lb}} = 4.4 \text{ g}$$

and the deceleration caused by rear section is:

$$\frac{2,500 \text{ sq in. x } 10 \text{ lb/sq in.}}{4,100 \text{ lb}} = 6.1 \text{ g}$$

Calculated decelerations for all four test runs at 1-3/4 in. and 2-3/4 in. are contained in Table 2.

Notice that with more than half the usable deflection already gone, decelerations are relatively low, but the cushion will soon begin to 'bottom out,' causing considerably high resistance to vehicle penetration, and decelerations suddenly will increase sharply (Table 2).

The main point here is that a crash cushion should have predictable crush strength, and, ideally, be relatively constant in strength over much of the total crush distance, and not vary in crush strength with speed of crush.

The test conducted in the Laboratory simulated impact with an immovable object, while the crash data supplied in the sales literature involved a 10,000-lb sign truck which was set into motion at impact. The motion of the sign truck can account for the lower g levels experienced in the crash test by absorbing some of the impact energy by rolling, but cannot be assumed legitimate for varied vehicle weights or speeds, or sign truck masses.

TABLE 2
CALCULATED DECELERATIONS FOR A 4,100-lb CAR

Sample No.	Run No.	Deflection Per Panel, in.	Load lb/sq in.	g Due to Front Section	g Due to Rear Section
1	1	1-3/4	10.00	4.40	6.10
		2-3/4	48.61	21.26	29.82
1	2	1-3/4	6.94	3.00	4.23
		2-3/4	58.33	27.66	38.96
2	1	1-3/4	11.94	3.61	5.08
		2-3/4	73.61	31.86	44.88
2	2	1-3/4	6.94	3.00	4.23
		2-3/4	56.94	24.65	34.60

The cost of the Mod II attenuator is approximately $5,000, compared to the Texas Barrel crash cushion whose cost is around $1,800. The savings in cost, plus evidence of past performances, favor the consideration of the Texas Barrel cushion.

The lack of data concerning angular impacts and lightweight vehicle impacts, plus theoretical data indicating necessary additional cushion length for higher speed and heavier vehicles, and laboratory results indicating that the surlyn material has different properties when re-used, and crushing strengths variable with impact speed, all suggest that the Mod II truck-mounted attenuator should not be used, and, therefore, we cannot recommend it. Possibly this material could be made into a satisfactory device, but more developmental work is required. In addition, it is recommended that the Texas Barrel cushion, due to its service record and lower cost, be considered an alternative.