Evaluation of Selected Crashworthiness Strategies for Passenger Trains

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Interest in high-speed passenger rail has increased recently. The potential for collisions at increased speeds has renewed concerns about the crashworthiness of passenger rail vehicles. Studies have been conducted to evaluate the effectiveness of alternative strategies for providing for the crashworthiness of the vehicle structures and interiors at increased collision speeds. Conventional practice has resulted in cars of essentially uniform longitudinal strength. This approach has been found to be effective for train-to-train collision speeds of up to 31 m/sec (70 mph). This uniform strength causes the structural crushing of the train to proceed uniformly through both the unoccupied and occupied areas of the train. The crash energy management approach results in varying longitudinal strength, with high strength in the occupied areas and lower strength in the unoccupied areas. This approach attempts to distribute the structural crushing throughout the train to the unoccupied areas to preserve the occupant volumes and to limit the decelerations of the cars. The crash energy management approach has been found to offer significant benefits for higher-speed collisions. The interior crashworthiness analysis evaluated the influence of interior configuration and occupant restraint on fatalities resulting from occupant motions during a collision. For a sufficiently gentle train deceleration, compartmentalization (a strategy for providing a "friendly" interior) can provide sufficient occupant protection to keep accepted injury criteria below the threshold values applied by the automotive industry. The use of seat belts and shoulder restraints reduces the likelihood of fatalities due to deceleration to near-certain survival for even the most severe collision conditions considered.

Interest in high-speed passenger rail, with speeds in excess of 56 m/sec (125 mph), has increased recently. The potential for collisions at increased speeds and collisions involving passenger vehicles and vehicles with substantially different structures has renewed concerns about the crashworthiness of passenger rail vehicles. Studies have been conducted to evaluate the effectiveness of alternative strategies for providing for the crashworthiness of the vehicle structures and interiors at increased collision speeds. This paper describes comparisons of strategies for ensuring the structural crashworthiness of passenger vehicles and describes comparisons of strategies for ensuring interior crashworthiness for the protection of occupants of the train during collisions.

BACKGROUND

Trains may collide with objects that are relatively small, such as an animal on the tracks, highway vehicles, maintenance-of-way equipment, or another train. Most of these collisions can only occur in the normal running direction of the train; however, impacts into the side of the train can occur at grade crossings. Derailment can lead to the train rolling over, inducing high loads into the sides of the cars and roof. Longitudinal collisions can occur at any speed up to the operating speed of the train. Highway vehicle collisions into the side of the train can occur at lower speeds.

In addition to the primary collision between the train and the impacted object, there is also a secondary collision between the occupants and the interior. Causes of fatalities associated with the primary collision include crushing of the occupant compartment, in which the occupants themselves are crushed, local penetration into the occupant compartment, in which an object intrudes into the occupant compartment and directly strikes an occupant, and occupant ejection from the occupant compartment, in which an occupant is thrown from the train and strikes some element on the wayside. Causes of fatalities associated with secondary collisions include excessive deceleration of the head or chest of the occupant and excessive forces imparted to the body, such as axial neck loads.

In designing for crashworthiness the first objective is to preserve a minimum occupant volume for the occupants to ride out the collision. Preserving the occupant volume is accomplished with structural strength; that is, if the occupant compartment is sufficiently strong, then there will be sufficient space for the occupants to ride out the collision. The second objective is to limit the forces and decelerations imparted to the occupants to acceptable levels of human tolerance. Limiting the decelerations and forces is accomplished through a combination of structural crashworthiness measures: allowing portions of the vehicle to be crushed in a predetermined manner, thereby limiting the decelerations of the vehicle; using interior crashworthiness measures, including occupant restraints, such as seat belts and shoulder harnesses; and applying strategies such as compartmentalization.

To evaluate the performance of a train in a particular collision, the collision mechanics of the train must be estimated or determined, the likelihood of car-to-car override and lateral buckling of the train needs to be known, and the forces acting between cars and the crushing behavior of the cars must be developed. Once the behavior of the train has been determined, the interior performance can be evaluated. A detailed review of transportation crashworthiness practice and research and its applicability to passenger rail transportation is presented elsewhere (*1*).

STRUCTURAL CRASHWORTHINESS

Conventional practice has resulted in cars of uniform longitudinal strength. The crash energy management approach results in varying longitudinal strength throughout the train, with high strength in the occupied areas and lower strength in the unoccupied areas. This approach attempts to distribute the structural crushing through-

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out the train to the unoccupied areas to preserve the occupant volumes and to limit the decelerations of the cars. This initial analysis compares the structural crashworthiness of passenger vehicles designed according to conventional practice and passenger vehicles designed to allow the ends of the cars to crush. This strategy has received much attention in recent years in Japan (*2*), France (*3*), and England (4–6).

Analysis Approach

The collision scenario used to make the comparison between the two structural crashworthiness strategies is a head-on collision of two identical trains, one moving at speed and the other standing. To do the analysis and to provide a basis for comparison, it is assumed that the collision mechanics of the train allow the trains to stay in-line and to remain upright.

The model used in the analysis consists of lumped masses connected by nonlinear force/crush characteristics. The comparison between the two strategies is accomplished by developing the nonlinear force/crush characteristics for the cars and applying the model to determine the occupant volume lost and the secondary impact velocities for a range of collision speeds. The train modeled for the structural crashworthiness analysis is made up of a power car, six coach cars, and another power car, with the power cars each weighing 890 kN (200 kips) and the coaches each weighing 534 kN (120 kips).

Conventional Design

Figure 1 shows the car-to-car force/crush characteristic used for the train of conventional design. This characteristic is based on the force/crush characteristic developed for the Silverliner car (*7*), modified to allow for a shear-back coupler design and a more gradual crushing of the end structure. The maximum strength developed is the force required to cause gross yielding of the structure.

Crash Energy Management Design

The crash energy management design force/crush characteristics were developed by determining the decelerations for each of the cars required to produce acceptable conditions for the occupants and then determining the forces required between cars to produce those decelerations. These forces and decelerations were adjusted within constraints for the forces and the crush distances of the car structures. The forces were constrained to be between 7.1 MN (1.6 million lbs), presuming that greater strength would incur excessive vehicle weight, and 1.8 MN (400,000 lbs), presuming that less strength would impair the vehicle's ability to support service loads. Constraints placed on crush distances include 1.2 m (4 ft) of available crush distance ahead of the operator's cab in the front of each power car, 7.77 m (25.5 ft) of available crush distance at each end of all of the coach cars. Additional constraints include symmetry, that is, the train must be able to withstand collisions in both directions, and a minimum number of crush characteristics, such that only one coach car structural design and one power car structural design are required. Figure 2 shows the force/crush characteristic between the standing and moving power cars, between the power car and the first coach, and between the remaining coaches.

Analysis Results and Comparison

The scenario considered is a moving train colliding with a standing train. Both designs were analyzed for their performance in this scenario for a range of closing speeds. The basis for comparison is the

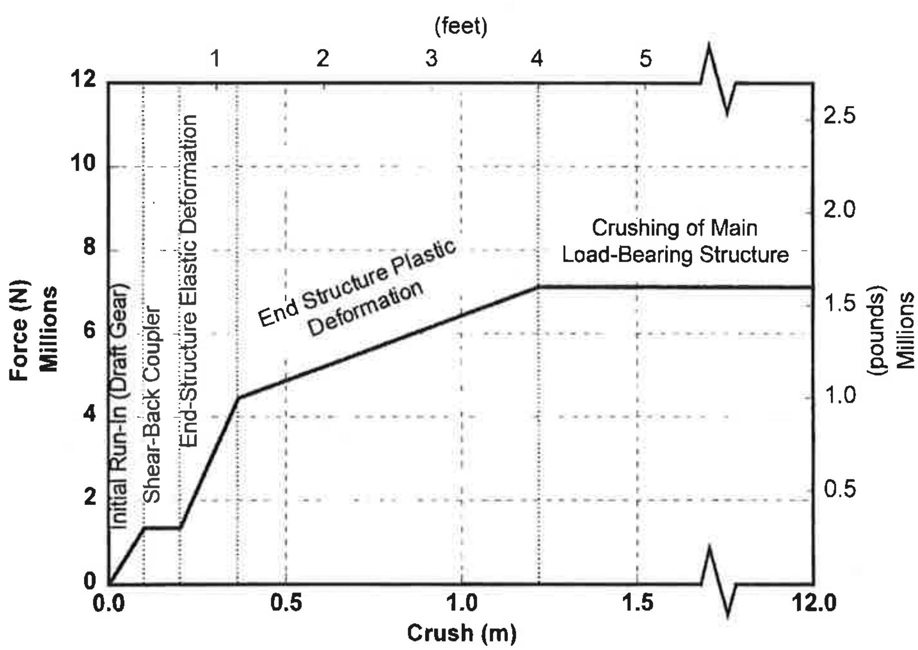

FIGURE 1 Conventional design crush characteristic for power car to power car, power car to coach car, and coach to coach car.

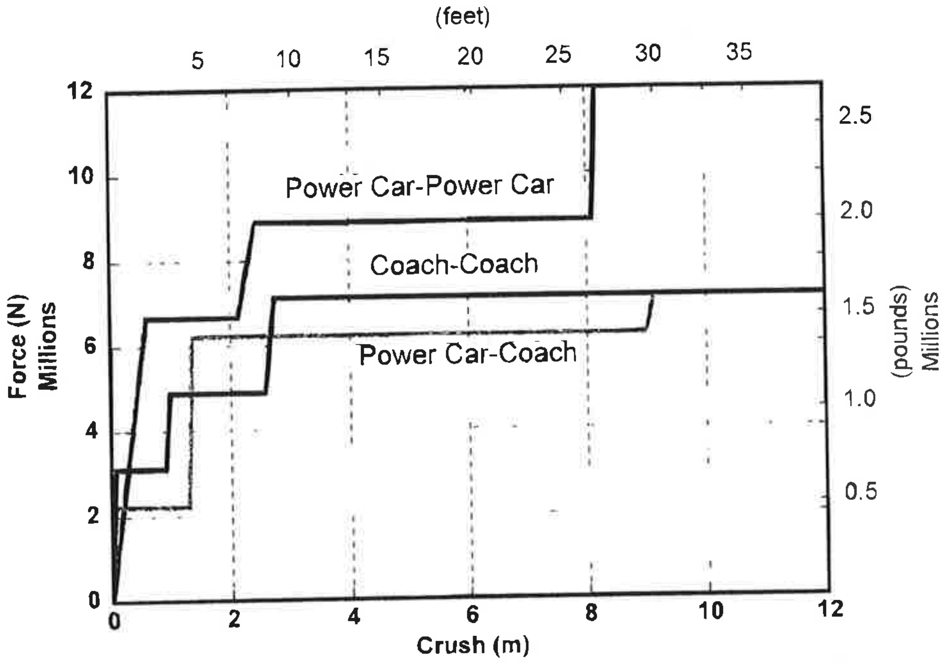

FIGURE 2 Crash energy management design force/crush characteristics.

loss of occupant volume and the deceleration imparted to the occupants during the secondary impact between the occupant and the seat back ahead of the occupant.

Occupant Volume

Figure 3(*a*) illustrates the occupant volume lost in each of the cars for the conventional design train for four closing speeds ranging from 16 m/sec (35 mph) to 63 m/sec (140 mph). Most of the occupant volume lost is in the first coach car. The figure shows that the crushing of the train starts at the front and proceeds toward the rear of the train. Figure 3(*b*) illustrates the occupant volume lost in each of the cars for the constrained crash energy management design train for four closing speeds ranging from 16 m/sec (35 mph) to 63 m/sec (140 mph). The figure shows that this design approach is successful in distributing the crush throughout the train. The figures show that for closing speeds up to about 31 m/sec (70 mph), the conventional design preserves all of the passenger volume, whereas the constrained crash energy management design preserves most of the passenger volumes up to 49 m/sec (110 mph). The additional occupant volume lost for closing speeds above 31 m/sec (70 mph) is much greater for the conventional design than for the constrained crash energy management design.

Occupant Deceleration

When sufficient volume is preserved for the occupant to ride out the collision, the occupant can still be injured by excessive deceleration or forces. For an unrestrained occupant these forces and decelerations principally come about when the occupant strikes the interior. How hard the occupant strikes the interior depends on the deceleration of the train itself during the collision and the friendliness of the interior. To provide a basis for comparison between the decelerations generated by the conventional design and by the constrained crash energy management design, a simplified model of an occupant is used to calculate the decelerations of the occupant's head, and these decelerations are then compared with accepted injury criteria.

The occupant model is based on the assumption that the occupant goes into free flight at the start of the collision and subsequently strikes the interior. The occupant is assumed to strike the seat back ahead of him or her. The seat back has some amount of padding and flexibility. Given the seat back force/deflection characteristic and the nominal mass of the head, the deceleration of the head can be calculated from the velocity with which the head impacts the seat back. The head deceleration can then be evaluated on the basis of generally accepted injury criteria. The deceleration time history of the head can be used to calculate the head injury criteria (HIC) (*8*), injury criteria widely applied in the automotive and aircraft industries to evaluate test and analysis data. The seat back force/deflection characteristic used in the analysis is the softest characteristic described in the NHTSA standard *School Bus Seating and Crash Protection* (*9*).

Figure 4 shows plots of occupant velocity relative to that of the vehicle as a function of displacement relative to that of the vehicle for both the constrained crash energy management design and conventional design at 45 m/sec (100 mph). The distance from the occupant's nose to the seat back ahead of him or her is assumed to be 0.76 m (2.5 ft), the seat pitch (longitudinal distance between two seats one row apart) is assumed to be 1.1 m (42 in.), the occupant's head is assumed to be 0.20 m (8 in.) deep, and the padding on the seat is assumed to be 0.10 m (4 in.) thick.

Table 1 lists the range of HIC values expected on the moving train for several collision speeds for both the crash energy management and conventional design trains. The crash energy management design results in substantially lower HIC values. This is a result of

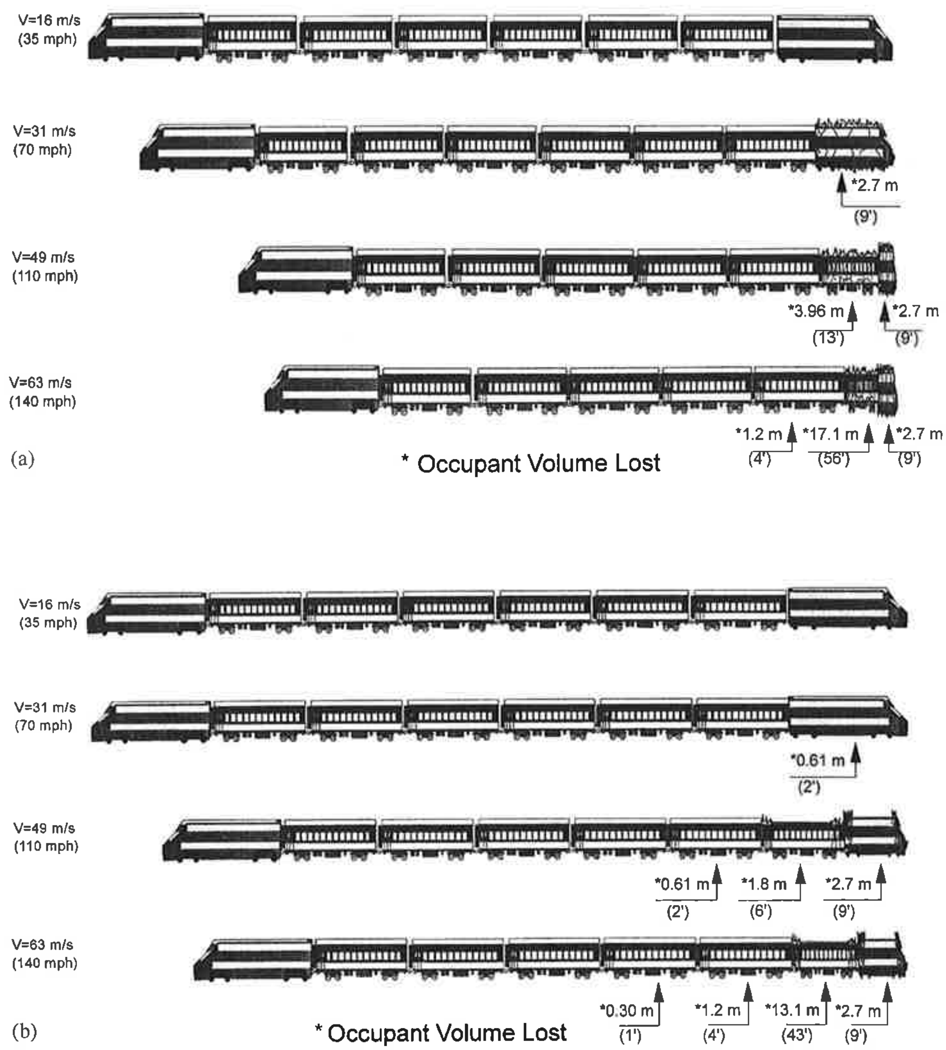

FIGURE 3 **Occupant volume loss for a range of closing speeds: (*a*) conventional design; (*b*) constrained crash energy design.**

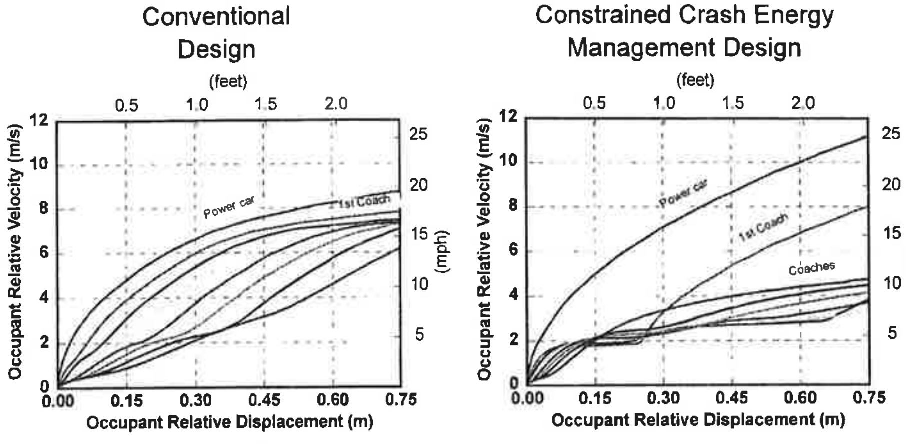

FIGURE 4 **Occupant relative displacement versus occupant relative velocity.**

TABLE 1 HIC Values, Conventional and Crash Energy Management Designs

Primary Collision Speed (m/s)*		HIC					
		Coaches					
		1	2	3	4	5	6
Conventional Design	63	230-480	190-430	180-400	180-400	160-360	120-250
	49	230-480	190-430	180-400	180-400	160-360	120-250
	31	230-480	190-430	180-400	180-400	160-360	120-250
	16	200-440	180-400	180-400	180-400	170-375	160-350
Crash Energy Management Design	63	240-490	40-80	20-50	30-70	50-110	60-140
	49	235-485	40-80	20-50	30-70	50-110	60-140
	31	230-480	30-70	20-50	30-70	50-110	60-140
	16	160-350	10-40	10-40	30-70	40-120	50-130

* 1 m/s = 2.2 mi/h

the lower secondary collision velocities for most of the cars in the consist.

Structural Crashworthiness Analysis Conclusions

For train-to-train collisions at closing speeds above 31 m/sec (70 mph) the constrained crash energy management design is more effective than the conventional approach in preserving occupant volume. For closing speeds below 31 m/sec (70 mph) both strategies are equally effective in preserving occupant volume. The constrained crash energy management design does result in gentler secondary impacts than the conventional design for train-to-train collisions at all speeds analyzed.

INTERIOR CRASHWORTHINESS

The objective of the interior analysis was to evaluate the influence of interior configuration, seat belts, and seat belts with shoulder harnesses on fatalities resulting from occupant motions during a collision. Three different interior configurations were analyzed: forward-facing consecutive rows of seats, facing rows of seats, and facing rows of seats with a table. Interiors with both the forward-facing consecutive rows of seats and facing rows of seats were evaluated with the occupant unrestrained, the occupant restrained with a seat belt alone, and the occupant restrained with a seat belt and a shoulder harness.

As part of this analysis the effectiveness of compartmentalization as a means of achieving occupant protection was evaluated. Compartmentalization is a strategy for providing a "friendly" interior for the occupants to survive the secondary collision. By providing a sufficient amount of cushion and flexibility in the surface of impact (e.g., the seat back), the impact force experienced by the occupant can be reduced to a survivable level. NHTSA concluded that this strategy justifies the absence of seat belts in school buses (*10*.)

Collision Conditions

The train modeled for the interior crashworthiness analysis is made up of a power car, five coach cars, and a cab car. This train model was used in exercises for a range of collision conditions, and the results that describe the decelerations of the cars in the train during the collision were used in evaluating train interior performance. The three different interior configurations were evaluated for their performances with respect to secondary impacts by using six different crash pulses. These collision conditions are listed in Table 2.

Analysis Approach

The analysis was performed by using MADYMO, a computer simulation program developed for evaluating the performance of automobile interiors during frontal automobile collisions (*11*). The computer program produces a detailed representation of the kinematics and dynamics of the human body. Program outputs include a number of criteria for evaluating occupant fatalities. For this evaluation, the HIC, chest deceleration, and axial neck load were used to evaluate the performance of the interior.

TABLE 2 Train Collision Conditions for Interior Analysis

Constrained Crash Energy Management Design	Conventional US Design
First Coach Power Car to Power Car Collision 63 m/s* Impact Speed	**First Coach** Power Car to Power Car Collision 63 m/s Impact Speed
Cab Car (Last Car) Power Car to Power Car Collision 63 m/s Impact Speed	**Cab Car** (Last Car) Power Car to Power Car Collision 63 m/s Impact Speed
Cab Car (Leading Car) Cab Car to Power Car Collision 31 m/s Impact Speed	**Cab Car** (Leading Car) Cab Car to Power Car Collision 31 m/s Impact Speed

* 1 m/s = 2.2 mi/h

Computer simulations were made of each of the interior configurations for each of the crash pulses. A total of 42 computer simulations were made. The occupant modeled for each of these simulations was the 50th percentile male (the U.S. male whose physical features are the median, for example, half of the male population is taller and half is shorter and half of the male population is heavier and half is lighter). The results of the analyses described in this paper are for the nominal male and may be different for occupants of a different size or age. The initial position of the occupant may also have an influence on these results, as may the conscious response of the occupant to the collision. The model implemented in MADYMO is based on the assumption that the occupant is passive during the collision. It should also be noted that the principal cause of fatalities is expected to be loss of occupant volume, which may account for approximately 75 percent of the fatalities during a collision (*12*).

Injury Criteria

HIC is a function of the relative acceleration of the head during impact. It can be used to predict the probability of a fatality resulting from head injury (*13*). As required in the NHTSA standard (49 C.F.R. 571.208) the HIC value shall not exceed 1,000 for a vehicle impacting a fixed collision barrier at 13 m/sec (30 mph). This corresponds to a predicted fatality rate of approximately 18 percent for the 50th percentile male.

In addition to HIC chest deceleration and neck load were also evaluated as part of the interior crashworthiness analysis. Chest deceleration is also used by NHTSA and FAA to evaluate crashworthiness performance, with the commonly accepted maximum value of 588 m/Sec^2 (60 *g*'s). This deceleration corresponds approximately to a 22 percent fatality rate for the 50th percentile male. The compressive and tensile neck load limits used in the analysis were proposed as regulations by NHTSA, but they were not implemented (*14*).

Results

Seated Rows

Figure 5 shows the computer-simulated motions of an occupant for an unrestrained, a belted, and a belted and harnessed occupant in the interior with forward-facing consecutive rows of seats. In the interest of reducing the computations required to generate the graphical output, these results are generated from just the kinematics of the human-body and do not show the deformations of the body components, such as the head, neck, or chest, or the deformations of the seat. As a consequence, the seat back appears to intrude into the occupant's head in the figure for the unrestrained occupant. In the simulation itself this intrusion is not allowed to occur; it is an artifact of the simplified graphical output.

The results of the analysis show that the motions of the occupant during a collision are insensitive to the crash pulse. These motions depend principally on the interior configuration and the occupant's restraint or lack of restraint. The instantaneous velocity of the occupant at any given time during his or her motion is sensitive to the crash pulse. The mode of injury depends on the interior and the type of occupant restraint, but whether or not the forces or decelerations imparted to the occupant are sufficient to cause injury depends on the crash pulse and the force/deflection characteristic of the impacted surface.

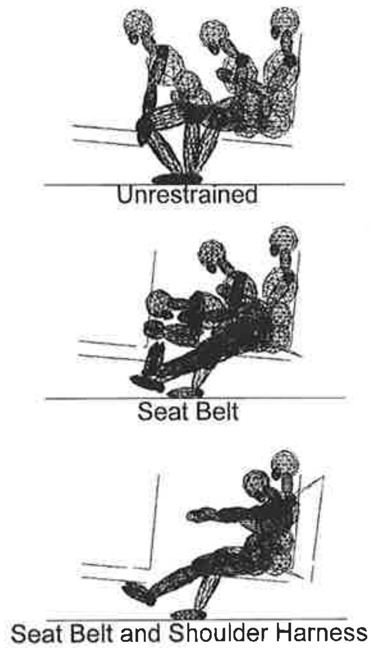

FIGURE 5 Occupant motion, seated in rows, interior.

Table 3 lists the values for the selected injury criteria and the associated probabilities of fatal injury for occupants who are unrestrained, belted, and belted with a shoulder harness in the row seat interior. The data in Table 3 indicate that the most severe crash pulse for this interior is for the cab car when it is leading during the collision. Table 3 also shows that the nominal occupant is expected to survive the deceleration in all of the collision scenarios evaluated if he or she is restrained with seat and shoulder belts.

Facing Seats

Figure 6 shows the computer-simulated motions for an occupant who is unrestrained, belted, and belted with a shoulder harness in the interior with facing rows of seats. For this analysis only the forward-facing seat is occupied. The occupant travels a substantial distance before impacting the seat back of the facing seat. This distance allows the occupant to build up speed relative to the interior, resulting in a severe impact.

Table 4 lists the values for the selected injury criteria and the associated probabilities of fatal injury for occupants who are unrestrained, belted, and belted with a shoulder harness in the facing seat interior. This interior was the worst-performing interior evaluated. There is certain fatality in this interior configuration for all crash pulses considered for an unrestrained 50th percentile male occupant facing forward with the assumed initial position. The outcome of the secondary collision is likely to be influenced by the occupant's size and initial position, as well as the occupant's response to the collision. These results are not sufficient to justify the conclusion that all passengers with sufficient occupant volume to survive are killed by the secondary collision. The most severe crash pulse for this interior is for the cab car when it is leading during the collision,

TABLE 3 Injury Criteria and Fatality Rates for Secondary Collisions, Seated in Rows

Crash Pulse		HIC			Chest Accel. (m/s^2)*			Neck Load (N)**		
		Belted	Harness	Unbelted	Belted	Harness	Unbelted	Belted	Harness	Unbelted
Conventional Design	1st Coach 63 m/s Power Car to Power Car	45 (0%)	21 (0%)	167 (0%)	117 (0%)	88 (0%)	235 (2%)	-1290 (0%)	310 (0%)	-1720 (0%)
	Cab Car 63 m/s Power Car to Power Car	18 (0%)	13 (0%)	196 (0%)	107 (0%)	98.1 (0%)	353 (4%)	627 (0%)	310 (0%)	-2350 (0%)
	Cab Car 31 m/s Cab Car to Power Car	74 (0%)	42 (0%)	662 (4%)	186 (0%)	167 (0%)	520 (16%)	-2540 (0%)	761 (0%)	-1710 (0%)
Crash Energy Management Design	1st Coach 63 m/s Power Car to Power Car	75 (0%)	15 (0%)	221 (0%)	196 (0%)	98.1 (0%)	373 (4%)	-2380 (0%)	310 (0%)	-2380 (0%)
	Cab Car 63 m/s Power Car to Power Car	0 (0%)	0 (0%)	13 (0%)	20 (0%)	20 (0%)	69 (0%)	76 (0%)	-71 (0%)	-1020 (0%)
	Cab Car 31 m/s Cab Car to Power Car	170 (0%)	22 (0%)	587 (2%)	265 (2%)	127 (0%)	481 (13%)	3050 (0%)	380 (0%)	-1490 (0%)

* 1 m/s^2 = 0.10 G's
** 1 N = 0.22 lbf

similar to the result for the interior with rows of seats all facing the same direction. For this crash pulse there is a substantial probability of fatality even for occupants with lap belts alone. Table 4 also shows that the nominal occupant is expected to survive the deceleration for all the crash pulses used in the evaluation if the occupant is restrained with a lap belt combined with a shoulder belt.

Seats and Table

Figure 7 shows occupant motions for an unrestrained forward-facing occupant. The table itself acts a restraint, with a relatively short distance between the occupant and table, which does not allow the occupant to build up much speed before impacting the table. One concern is how the forces between that table and the occupant are distributed. There is the potential of severe internal abdominal injuries if the forces are too concentrated, that is, if the table edge acts as a knife edge.

Table 5 lists the values for the selected injury criteria and the associated probabilities of fatality for a forward-facing occupant in the interior with seats and table. The probability of fatality from deceleration is less than 10 percent for all of the crash pulses considered except the crash pulse for the conventional design train with the cab car leading, in which the likelihood of fatality is near certain.

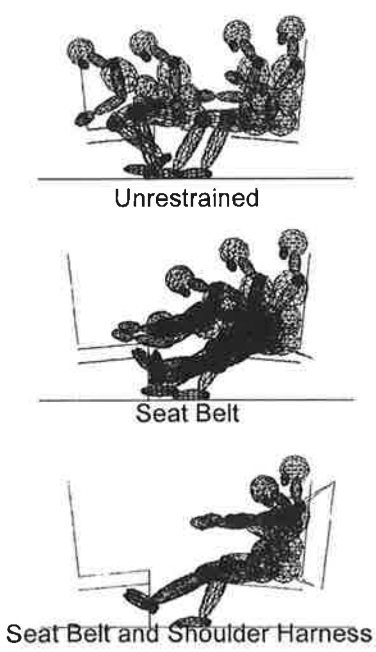

FIGURE 6 Occupant motion, facing seats, interior.

Interior Crashworthiness Analysis Conclusions

The results of the analysis indicate that seat belts and seat belts with shoulder harnesses are an effective means of providing occupant protection for a wide range of collision conditions. Seat belts with shoulder harnesses provide sufficient occupant protection to ensure near certain survival for all of the collision conditions analyzed. The results of the analysis suggest that under some conditions occupants may potentially suffer greater injury with lap belts than without, as a result of the occupant's head impacting the top of the seat back ahead of him or her. These conditions include seats in rows that are more closely spaced than the spacing considered in the analysis. The analysis results also indicate that compartmentalization can be an effective means of providing occupant protection for a limited range of collision conditions. This strategy provides a level of protection at least as great as that required for automobiles and aircraft for all of the conditions analyzed except when the cab car is leading during the collision and for facing seats.

CONCLUSIONS

For the conditions considered in the present study both the crash energy management design and the conventional design preserve

TABLE 4 Injury Criteria and Fatality Rates for Secondary Collisions, Facing Seats

Crash Pulse		HIC			Chest Accel. (m/s²)*			Neck Load (N)**		
		Belted	Harness	Unbelted	Belted	Harness	Unbelted	Belted	Harness	Unbelted
Conventional Design	1st Coach 63 m/s Power Car to Power Car	34 (0%)	21 (0%)	490 (3%)	108 (0%)	88 (0%)	245 (1%)	782 (0%)	310 (0%)	-6140 (100%)
	Cab Car 63 m/s Power Car to Power Car	18 (0%)	13 (0%)	1019 (18%)	98.1 (0%)	98.1 (0%)	324 (3%)	605 (0%)	310 (0%)	-11410 (100%)
	Cab Car 31 m/s Cab Car to Power Car	1668 (75%)	42 (0%)	3263 (100%)	255 (2%)	167 (0%)	432 (8%)	-2860 (0%)	761 (0%)	-5262 (100%)
Crash Energy Management Design	1st Coach 63 m/s Power Car to Power Car	502 (3%)	17 (0%)	4044 (100%)	216 (0%)	98.1 (0%)	628 (35%)	-1530 (0%)	310 (0%)	-23280 (100%)
	Cab Car 63 m/s Power Car to Power Car	0 (0%)	0 (0%)	151 (0%)	20 (0%)	20 (0%)	265 (2%)	76 (0%)	-71 (0%)	-9043 (100%)
	Cab Car 31 m/s Cab Car to Power Car	1247 (38%)	26 (0%)	1616 (68%)	196 (0)%	118 (0)%	304 (3%)	1650 (0%)	410 (0%)	-5974 (100%)

* 1 m/s² = 0.10 G's
** 1 N = 0.22 lbf

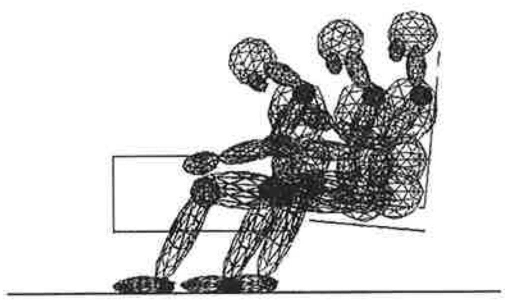

FIGURE 7 Occupant motion, seats and table.

sufficient volume for the occupants to survive in train-to-train collisions below 31 m/sec (70 mph). For collisions above 31 m/sec (70 mph) the crash energy management approach is significantly more effective than the conventional approach in preserving occupant volume. For the full range of collision speeds the crash energy management design provides a significantly gentler initial deceleration than the conventional design.

For a sufficiently gentle initial train deceleration, compartmentalization provides sufficient occupant protection to keep accepted injury criteria below the threshold values used by the automotive and aircraft industries in evaluating interior crashworthiness performance. The use of seat belts and shoulder restraints reduces the likelihood of fatalities due to secondary collision to near-certain survival for all of the occupants not killed because of the loss of occupant volume for all collisions considered.

The crash energy management design presented in this paper was designed against a particular collision scenario and should not be considered a universal or global optimum. The optimum force/crush characteristics will depend on the details of the collisions that must be survived. If a range of collisions must be survived (i.e., collisions with freight trains, with maintenance-of-way equipment, with highway vehicles, etc.) a number of force/crush characteristics should be evaluated against this range of collisions to determine the optimum for a particular application.

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TABLE 5 Injury Criteria and Fatality Rates for Secondary Collisions, Seats and Tables

Crash Pulse		HIC	Chest G's	Neck Load (pounds)
Conventional Design	1st Coach 140 mph head to head	311 (0%)	42 (7%)	602 (0%)
	Cab Car 140 mph head to head	186 (0%)	33 (3%)	456 (0%)
	Cab Car 70 mph tail to head	702 (7%)	51 (14%)	787 (100%)
Crash Energy Management Design	1st Coach 140 mph head to head	110 (0%)	24 (1%)	288 (0%)
	Cab Car 140 mph head to head	16 (0%)	16 (0%)	163 (0%)
	Cab Car 70 mph tail to head	415 (2%)	40 (5%)	601 (0%)

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